European Commission

JRC TECHNICAL REPORTS

Identifying Sources of Marine Litter

MSFD GES
TG Marine Litter
- Thematic Report

Joana Mira Veiga, David Fleet, Susan Kinsey, Per Nilsson, Thomais Vlachogianni, Stefanie Werner, François Galgani, Richard C. Thompson, Jeroen Dagevos, Jesús Gago, Paula Sobral and Richard Cronin

2016

Joint Research Centre

EUR 28309 EN

Contact information
Name: Georg Hanke
Address: Joint Research Centre (JRC), Via Enrico Fermi 2749, I-21027 Ispra (VA), Italy
E-mail: georg.hanke@jrc.ec.europa.eu
Tel.: +39 0332 785586

JRC Science Hub
https://ec.europa.eu/jrc

JRC104038

EUR 28309 EN

PDF	ISBN 978-92-79-64522-8	ISSN 1831-9424	doi:10.2788/018068
Print	ISBN 978-92-79-64521-1	ISSN 1018-5593	doi:10.2788/956934

Luxembourg: Publications Office of the European Union, 2016

How to cite: Veiga, J.M., Fleet, D., Kinsey, S., Nilsson, P., Vlachogianni, T., Werner, S., Galgani, F., Thompson, R.C., Dagevos, J., Gago, J., Sobral, P. and Cronin, R.; 2016; *Identifying Sources of Marine Litter*. *MSFD GES TG Marine Litter Thematic Report;* JRC Technical Report; EUR 28309; doi:10.2788/018068

Table of contents

Foreword

The Marine Directors of the European Union (EU), Acceding Countries, Candidate Countries and EFTA Countries have jointly developed a common strategy for supporting the implementation of the Directive 2008/56/EC, the Marine Strategy Framework Directive (MSFD). The main aim of this strategy is to allow a coherent and harmonious implementation of the Directive. Focus is on methodological questions related to a common understanding of the technical and scientific implications of the Marine Strategy Framework Directive. In particular, one of the objectives of the strategy is the development of non-legally binding and practical documents, such as this report, on various technical issues of the Directive.

The MSFD Technical Group on Marine Litter acts through a mandate by the European Marine Directors. It is led by DG ENV and chaired by IFREMER, the EC Joint Research Centre (JRC) and the German Environment Agency. TG Marine Litter Members include EU Member State delegates, Regional Sea Conventions, additional stakeholders and invited technical experts. The TG Marine Litter provides advice to the MSFD implementation process, it reviews scientific developments and prepares technical guidance and information documents.

This present technical report is part of a series of thematic reports issued by the TG ML providing guidance on specific topics: ***Identifying Sources of Marine Litter,*** *Riverine Litter Monitoring – Options and Recommendations* and *Harm caused by Marine Litter*. These thematic reports are targeted to those experts who are directly or indirectly implementing the MSFD in the marine regions.

This report should further support EU Member States in the implementation of monitoring programmes and plan of measures to act upon marine litter.

The members of the Marine Strategy Coordination Group will assess and decide upon the necessity for reviewing this document in the light of scientific and technical progress and experiences gained in implementing the Marine Strategy Framework Directive.

Acknowledgements

The authors would like to thank all the members of the Technical Group on Marine Litter (TGML) that provided valuable comments during the general meetings, throughout the development of this report. In particular, we acknowledge the contributions from Annemie Volckaert, Lex Oosterbaan, Sandra Moutinho, Tatiana Hema, Ania Budziak, Georg Hanke and Gijsbert Tweehuysen.

The technical support done by the Coastal and Marine Union (EUCC) for the final formatting of the report is also acknowledged.

Finally, we thank the artist Fran Crowe (www.flyintheface.com) for kindly providing the picture used on the cover of this report.

Abstract

Marine litter is a global problem causing harm to marine wildlife, coastal communities and maritime activities. It also embodies an emerging concern for human health and safety. The reduction of marine litter pollution poses a complex challenge for humankind, requiring adjustments in human behaviour as well as in the different phases of the life-cycle of products and across multiple economic sectors.

The Marine Strategy Framework Directive (MSFD) requires European Member States to monitor marine litter and implement programmes of measures to reduce its occurrence. A crucial step in monitoring and effectively addressing marine litter is the identification of the origin and the pathways that lead to litter entering the marine environment. A given site or region can be subject to litter pollution from a number of sources, which can be local, regional or even distant, as litter can be transported to a specific area by ocean currents and wind drift. For this reason, pinpointing the origin of the different items that make up marine litter is a difficult task and will always have an inherent degree of associated uncertainty. Plastic food packaging recorded in the marine environment, for example, can consist of a diverse selection of items, which can be generated from a number of sources, which in turn can be sea-based or land-based and originate from near or distant regions.

A wide variety of methods have been used over the years to determine the sources of marine litter, from simple counts of items believed to originate from a given source to more complex statistical methods. This report provides a brief overview of the main methods used and outlines one of the most promising approaches for determining sources – a *Matrix Score Technique* based on likelihoods, which considers the possibility that specific items originate from more than one source. Furthermore, it presents a series of other parameters that can be used to analyse data-sets, with regard to the use, origin and risk of items recorded in the marine or coastal environments. These can further support decision-making when considering preventive measures. Finally, recommendations to help the process of identification of sources are given, from the early stage of data collection and site characterization to bringing in the knowledge of local stakeholders to better determine where litter is coming from and what needs to be done to prevent it.

1. Introduction

Marine litter (hereafter ML) represents all synthetic or processed items or fragments that have been discarded or lost either directly into the coastal and marine environments or somehow transported from land to the sea, e.g. by rivers or effluents, wind and land run-off. It is generally recognised that the majority of ML originates from land-based activities and uses, although sea-based sources are important in some regions. ML is therefore a consequence of how societies and individuals produce and deal with waste.

In order to help identify the drivers and deficiencies in the production, consumption and waste management systems that generate ML, it is crucial to understand where, by whom and why litter is released from these systems and how it enters the marine environment. This process is necessary in order to establish appropriate operational targets and to design, implement and monitor effective management and mitigation measures within the MSFD.

The importance of identifying sources is reflected in the Commission Decision (2010/477/EU) on Criteria and Methodological Standards for Descriptor 10 Marine Litter. Sources of litter are referred to in relation to two of the specifications and standardised methods for monitoring and assessment, as follows:

1. *For D10C1: litter shall be monitored on the coastline and may additionally be monitored in the surface layer of the water column and on the seabed.* ***Information on the source and pathway of the litter shall be collected, where feasible****;*
2. *For D10C2: micro-litter shall be monitored in the surface layer of the water column and in the seabed sediment and may additionally be monitored on the coastline.* ***Micro-litter shall be monitored in a manner that can be related to point-sources for inputs*** *(such as harbours, marinas, waste-water treatment plants, storm-water effluents),* ***where feasible****.*

The analysis of sources involves several challenges which make the task rather complex, and give the results an inherent degree of associated uncertainty. ML is not only composed of a large fraction of unidentifiable items (e.g. small plastic fragments originating from the disintegration of larger items) but also of single items, which can originate from a number of different sources(e.g. plastic bottles can originate from diverse activities like coastal tourism, recreational boats, shipping, etc.). In addition the geographic origin of the litter recorded (e.g. on a given beach) is often not clear. Because of its persistent nature, ML can be transported across long distances and remain in the marine environment for an undetermined length of time often making its geographic, sectorial and temporal origin difficult to assess. When attempting to ascribe ML to a source, it is therefore important to approach the problem holistically and make use of a broad spectrum of information that goes beyond what the items *per se* are able to indicate. This is an emerging area of research and it is expected that improved understanding of litter transport dynamics and fate of ML in the different coastal and marine environments will shed further light on the topic in the near future.

This document addresses the following key questions:

- Why it is important to identify the sources and pathways of ML and what are the challenges and difficulties in tracking ML back to its origin;
- Which methodologies are available to link ML items to sources;
- Which is currently the best available approach and what are the key aspects to consider with regard to data collection and allocation to sources;
- What other parameters can provide further insight into the problem of sourcing ML and which can help to define priorities and strategies to tackle it;

In this report, we discuss available methodologies that attempt to link ML to its origin and provide recommendations on how to better assess the magnitude of the contribution of different sources and pathways of entry of ML. We also consider the use of other parameters that can help in assessing whether measures implemented are successful or not.

2. The challenges of identifying sources and pathways

Litter enters the ocean from diverse point and diffuse sources, which can be both land- and ocean-based. It can also be transported over long distances before being deposited onto shorelines or settling on the bottom of the oceans and seas.

Source identification can be very difficult, especially when the litter item has remained in the marine environment for a long period. Certain items, in particular fragments resulting from the disintegration of larger items, can be very hard or even impossible to identify in terms of their initial purpose and possible origin.

2.1 Where is marine litter generated and how does it enter the marine environment

2.1.1 Sources, Geographical Origin, Pathways and Transport Mechanisms

Products or items become "litter" when they are improperly discarded, abandoned or lost in public spaces and the natural environment, during any stage of their production-use-disposal-treatment lifecycle. It is common to define as the "source" of ML the economic sector (e.g. fisheries, shipping, coastal tourism, waste collection, landfills) that is responsible for the initial release of litter. However, this simple idea of source doesn't tell us much about why and how a given item ends up in the sea. In order to implement measures to combat ML pollution effectively, we need to understand the reasons why items became litter and the mode of entry in the marine environment.

In this report we adopt the term ***source*** to indicate the economic sector or human activity from which litter originates but specify further the ***means of release*** to indicate the mechanism or the way in which a given item leaves the intended cycle and/or enters the natural or urban environment and becomes a problem. The ***geographic origin*** can thus be defined by the geographic location of the source and where the release took place. This origin can be, and often is, distant from the sea or the site where ML item is recorded. Being able to distinguish between the waste that is generated locally, regionally and globally, is important when deciding on appropriate measures to prevent ML in a certain area.

Litter pollution in a given area can be of local origin – directly discarded on the beach or in the sea in that area – or can be transported from inland via rivers and runoff or transported from distant regions via ocean currents and the prevailing wind. Sometimes rivers or ocean currents are described as sources. However, these are actually ***transport mechanisms***, which move litter into and within the marine environment from various land- and sea-based sources. We consider a ***pathway*** to be the physical and/or technical means by which litter enters the marine environment.

E.g. a cotton-bud stick is improperly disposed of down the toilet (*means of release*) by consumers (*source*) and enters the marine environment through urban effluents (*pathway*). Even if the effluent is treated, the waste water treatment plant (WWTP) should not be considered as the source, since it was not responsible for the occurrence of the cotton bud stick in the first place. Nevertheless, WWTPs are partially active in retaining such items somewhere along their pathway and therefore can represent a stage on which intervention can be made.

Table 1 provides an example of how these five concepts can be applied to a few ML items found on the German coast. It is important to note that for the same type of items the sources, means of release and pathways can be different for different geographical locations, depending on human activities and behaviors, infrastructures and transport mechanisms that can generate and affect the composition of ML at a given site.

Table 1: Examples of sources, means of release, geographic origin, pathways and transport mechanism for a few marine litter items found on the Northern coast of Germany.

	SOURCE	MEANS OF RELEASE	GEOGRAPHIC ORIGIN	PATHWAY	TRANSPORT MECHANISM
COTTON BUD STICKS	Consumers / General Public	Improper disposal down the toilet	Households	Sewage systems and/or rivers	Sewage, rivers, ocean currents and tides
PLASTIC BAGS	Coastal tourism & recreation	Littering (e.g. on beach)	Local (e.g. coastal town or beach nearby)	Direct entry (if at beach) or e.g. windblown (if town nearby)	Wind and tides
	Consumers / General Public	Littering (e.g. on street, from car, in natural area)	e.g. Distant (inland town)	Distant - Wind (blown) and/or rivers	Wind, rivers, ocean current and tides
	Waste management at beach	Overflowing open bin	Beach	Direct input	Wind, tides and currents
NETS AND PIECES OF NETS	Fisheries	Discard or unintentional loss over board during net repair work at sea	E.g. Local fisheries, regional fisheries or distant fisheries	Direct entry - nets get washed or thrown overboard	Winds(drift), currents and tides
	Fisheries	Loss of nets and pieces of net during fishing (snagging)	E.g. Local fisheries, regional fisheries or distant fisheries	Direct entry - nets get snagged on wrecks, rocks etc. ripped off pieces of net remain attached to objects underwater or are released into the water column (ghost nets)	Winds (drift), currents and tides
	Fisheries and/or harbours	Discard or unintentional loss during net repair work on land or/and runoff from harbours	E.g. local fishing harbours	Direct entry - nets washed, blown or thrown (swept) into harbour basins and washed out to sea	Winds (blow-off), tides and currents
INJECTION GUN CARTRIDGE (Grease)	Shipping including fisheries	Discard or unintentional loss overboard at sea	Local (cartridges recorded on beaches are not fouled, not battered)	Direct entry from ships at sea	Winds (drift), currents and tides
TAHITIANS **(Plastic sheeting to protect mussel cultures)**	Aquaculture	Unintentional loss or discard after use	Distant – International - Northwest France/Atlantic coast of France	Direct input	Winds, currents and tides

In order to implement measures to combat ML pollution effectively, we need to have reliable information on where the litter recorded in a given area is coming from (sources, means of release and geographical origin) and how it is getting into the marine environment and the site where it is recorded (pathways and transport mechanisms).

2.1.2 Sea- and land-based sources

One of the commonest general categorisations of the origin of ML items is the division between sea-based and land-based input**. Sea-based origin** relates to litter that is directly (accidently or purposely) released into the sea by maritime activities e.g. shipping, fishing, offshore installations or dumping of refuse at sea. **Land-based origin** relates to activities which cause littering directly on the coast, such as beach tourism, but can also refer to litter generated in more distant areas, such as towns and industrial sites, and blown or washed into the sea.

Litter entering the environment via sewage outlets is considered as having a land-based origin, even though most sewage outlets are situated in rivers or discharge directly in to the sea. Similarly, riverine litter is sometimes considered to be land-based, even though some of the littering can occur by boats and ships navigating rivers. Following the terminology adopted in this report, rivers are a transport mechanism and effluents are the pathway of entry (see TGML report "Riverine Litter Monitoring – Options and Recommendations")

Whether ML is originating from a point source, such as a town or a beach cafe, or from a diffuse source, such as shipping, will also influence the choice of measures used to combat the problem.

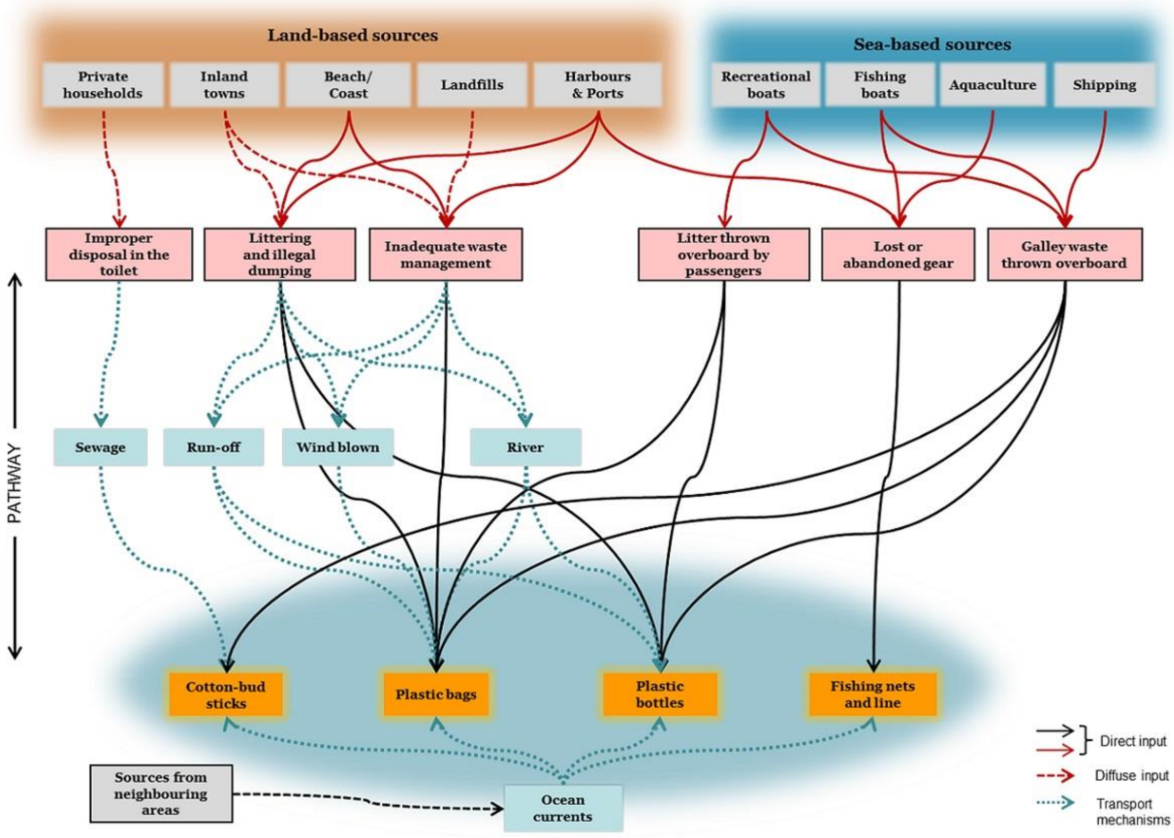

Figure 1: Multiple sea- and land-based sources (grey boxes) of 4 common items of marine litter and their potential pathways of entrance (blue boxes) into the marine environment. (Note: the size of the boxes does not reflect their relative importance)

2.2 The difficulty in determining the origin of marine litter items

Some easily identifiable items have a clear function and can be attributed, with a high level of confidence, to specific industrial or consumer sectors (e.g. tourism, shipping, fishing, effluent treatment) or points of origin. Fishing nets and pieces of fishing net are obvious examples of items, which can be attributed directly to a specific sector i.e. the fishing industry and cotton-bud-sticks are an example of a well-known point of origin i.e. improper disposal down the toilet by consumers.

However, many litter items cannot be directly connected to a particular source, way of release or pathway. Some items can have a number of potential sources and pathways of entry as well as geographic origins. For example, plastic drinks bottles can be left on beaches by tourists locally, thrown overboard by merchant shipmen, disposed of improperly in-land and washed into the sea through storm water overflows. They can also enter the sea via rivers and, because they are buoyant, can be easily transported into a given area by water currents and prevailing winds. Measures to combat the amount of plastic bottles in the marine environment will need to consider all these aspects in order to be effective.

The source and way of release of some ML items, especially fragments of larger ones, will be impossible to identify. However, investigations of floating litter in the marine environment and rivers, in combination with drift modelling, could, even here, supply us with some helpful information on their geographic origin.

2.3 Microplastics and other synthetic microparticles

Microplastics are small pieces of plastic litter < 5mm in diameter. They can be broadly categorised as having entered the environment as either as particles that are already <5mm, generally described as **primary microplastics**; or as having formed as a consequence of the fragmentation of larger items, in the environment, described as **secondary microplastics**.

Figure 2: Marine plastic fragments sorted by size in the lab (photo: Paula Sobral)

Microplastics are a particularly challenging fraction of ML in terms of determining their origins and pathways (Fig. 2). They can originate from a number of sources and enter via different pathways (Fig. 3). Major sources include fragmentation of larger items in the environment, release of abrasive additives from cosmetic and other products, release of fibres from the washing of textiles and the spillage of pre-production pellets or powders that are in transit or process prior to being made into everyday plastic items.

In addition to microplastics it has recently been suggested that there may also be substantial inputs of other synthetic particles, for example as a consequence of tyre wear on roads (Essel et al., 2015).

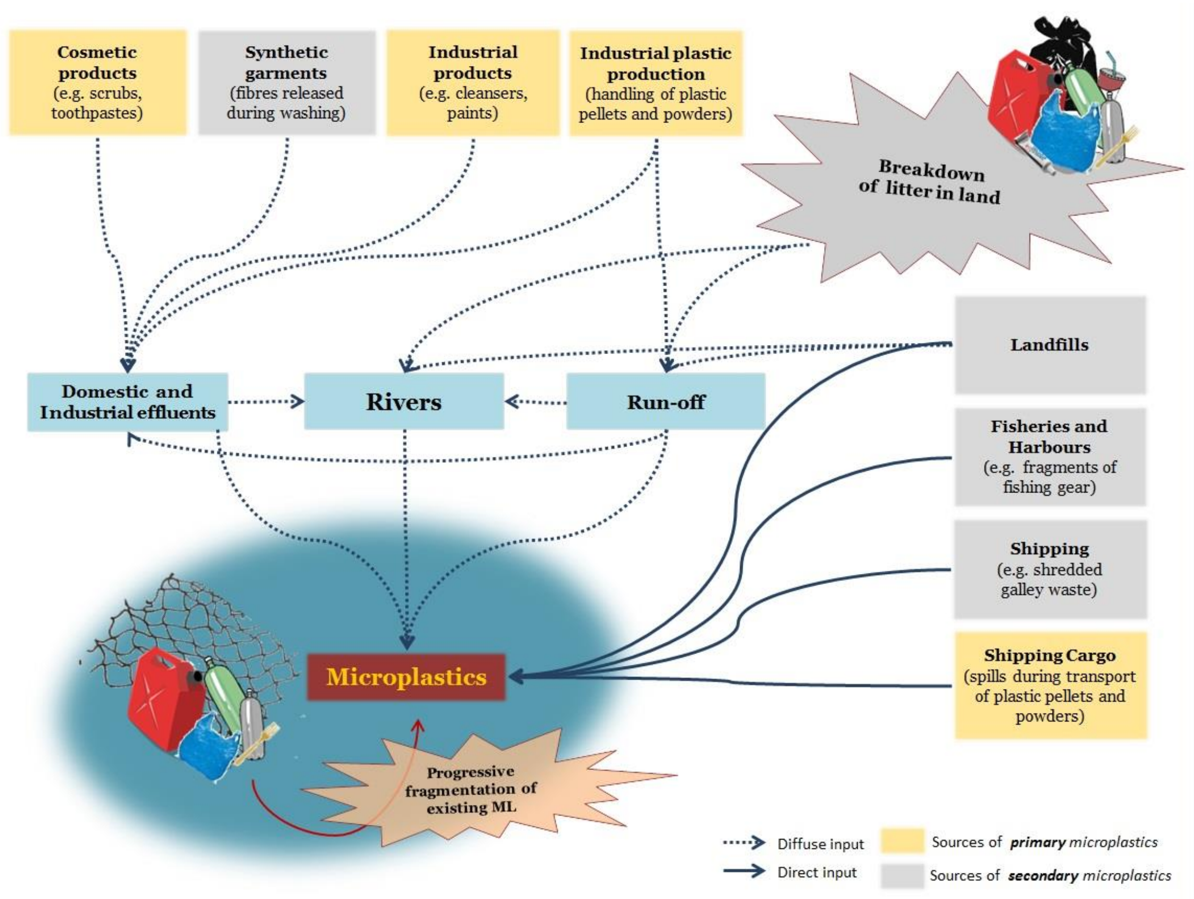

Figure 3: Key sources and pathways of microplastics found in the sea, indicating sources of plastic particles that have been produced as such ("primary microplastics"- yellow boxes) and those resulting from the fragmentation of larger items/pieces, either on land or in the sea ("secondary microplastics" – grey boxes). (Note: the size of the boxes does not reflect their relative importance)

Microplastics used as ingredients in products such as cosmetic and cleaning agents can enter the environment via sewage discharges into rivers as well as directly to the sea (Napper et al., 2015). Microplastic particles are also used as abrasives in industrial processes such as shot blasting and these can also be released into the environment. A further source of microplastics is synthetic fibres from textiles which can be released during washing. These can also enter the marine environment via sewage systems (Browne et al., 2011). Because of their size the concern is that microplastics will not be effectively removed by sewage treatment and will thus enter aquatic environments. Even where particles are removed by sewage treatment they still have the potential to enter the environment if the sewage sludge is subsequently disposed of onto land or dumped at sea (Zubris & Richards, 2005). Plastic pellets (also known as nurdles or "mermaids tears") and powders (for example those used in roto-moulding) can also enter the environment as a consequence of losses during handling and transport. A further direct input of small particles of plastic is release of shredded plastic waste during waste disposal, processing or recycling.

Finally, microplastics can also result from the progressive fragmentation of larger pieces of plastic litter as a consequence of weathering on land and at sea. This fraction is the so-called secondary microplastics. Such fragmentation is facilitated by light, particularly ultraviolet light, availability of oxygen and mechanical action and can be accelerated with increasing temperature.

It is extremely difficult to allocate a specific source to microplastic particles once they enter the wider environment. However, assessment of the types and concentrations at potential point sources, such as sewage outlets, or roadside storm drains may help to assess the extent of and trends in their entry via such pathways. Although the relative importance of these sources of microplastics is yet to be fully understood, rivers are likely to represent substantial pathways to the marine environment (Fig. 4) and it is therefore important to quantify the extent and types of debris entering the ocean from rivers.

Figure 4: Microplastics collected from the bank of River Meuse, in 2015 (photo: Gijsbert Tweehuysen)

Ultimately, policy measures will need to address the generation of microplastics, in particular those that can be prevented at the source (i.e. primary microplastics) but preventing also releases of larger items in land and at sea that can fragment into unquantifiable and unidentifiable smaller pieces.

3. Examples of marine litter sources and trends in Europe

In this section, a few examples of trends of key ML items that reflect particular sources are presented for European Regional Seas. It does not intend to provide exhaustive or baseline information but to illustrate the influence that distinct sources have in different areas and how analysis of ML can provide insight into its origin, and to support the design of strategies to address them.

3.1 Litter types and sources in the Baltic Sea

3.1.1 Cigarette butts on Baltic beaches

Cigarette butts are among the most frequent litter items found on beaches in several areas in Europe. Table 2 provides the average amount of cigarette butts found during surveys made with the Project MARLIN (2011-2013), on several beaches across the Baltic. The differences between beach types are clear, reflecting the influence of the proximity to point sources, i.e. improper disposal of cigarette butts by e.g. beach-users and visitors to the coast.

Table 2: Average amount of cigarette butts found in different types of beaches in the Baltic (MARLIN, 2013)

Beach Type	**Average amount of cigarette butts/100m**
All beach types	152,3
Urban	301,9
Peri-urban	111,5
Rural	49,4

3.1.2 Litter on beaches and seafloor in Germany

Extensive beach litter monitoring on 29 sites along the German Baltic coast revealed an average of 68 litter items per 100 meters of beach, with strong regional and seasonal differences. The number of items varied from 7 to 404 items, depending on the locations. During the spring months, deposits of litter on beaches were especially high, accounting for 35% of the entire annual number of ML items recorded. The lowest numbers were registered during winter. Similar to other regions, plastic is the dominant fraction (69 %), followed by paper (12%), metal (4%), glass (3.5%), rubber and textile (3% each) and wood (2%). In terms of number of individual items, unidentified fragments of plastics smaller than 50 centimeters account for around 30% of all ML recorded, followed by cigarette butts (9%), plastic caps and lids (7%), plastic sweet packaging (4%), plastic cords and strings (3%), plastic beverage packaging (3%) small plastic bags (3%) and single use plastic plates (2%).

Initial data from ML on the seafloor for the Baltic Sea area is available from studies carried out by the organization *Ocean Conservancy*. Their investigations revealed from 44 to 208 litter items per km^2, depending on the location, 36% of which were plastic bottles. The Nature And Biodiversity Conservation Union (NABU) has coordinated *Fishing for Litter* initiative in Mecklenburg West Pomerania since 2011. The litter caught in the nets during normal fishing operations seems to originate mainly from commercial and recreational shipping and from the fishing sector itself. According to their analysis, around 45% of items are metal items in the form of scrap, barrels and paint buckets and around 40% are plastic items consisting of rope, remains of nets and consumer related litter, such as sheets and packaging. So far, 1,700 kg of litter has been removed through this initiative (LUNG, 2015).

WWF (2011) estimated an annual loss of 5,500 to 10,000 cod gillnets in the Baltic Sea. In 2014, during a removal project in German Baltic waters, 4 tonnes of nets of different kinds were recovered from two wrecks in only five days.

3.2 Litter types and sources in the North East Atlantic

3.2.1 Maritime activities as sources of litter in the Southern North Sea

In areas with intensive bottom-trawl fishing activities, such as the Southern North Sea, ropes and nets (including fragments) are the most common items found during surveys of macrolitter on beaches. The results of 10 years of monitoring (Dagevos, 2013) show that "dolly" rope (ropes attached to the cod-end of nets to protect them from abrasion), pieces of rope and fragments of net are among the major items recorded. In the EU, 100,000 kg of dolly rope is used per year by the fishing industry. The "Dolly-rope Free Project" (http://www.dollyropefree.com/) estimated that between 10 to 25% of this material is lost at sea, as it is intended to protect the fishing net from wear. If an environmentally friendly solution can be found to protect fishing nets, this could have a major impact on reducing ML in this area. The pilot project started in the Netherlands in 2013 to look for alternatives to this material, which could greatly reduce the contribution of the fisheries sector to ML in the area.

In the Netherlands, pieces of plastic/polystyrene (excluding the net fragments) are the second most common item of beach litter, although their source is difficult to assess. Consumer packaging corresponds to 25% of beach litter and includes items such as plastic drink bottles, bottle caps, bags and snack wrappings. For some of these items (e.g. plastic bottle caps) a significant increasing trend has been observed (Dagevos et al., 2013).

The diversity and composition of the litter recorded during the German OSPAR Beach Litter surveys in the period 1991-2002, indicated that shipping, the fishing industry and offshore installations are very important sources of litter found on German and Dutch beaches (Fleet et al., 2009). This has not changed since the 1980s, when Vauk & Schrey (1987) stated that the major sources of litter in the North Sea were commercial shipping and fisheries. Although the OSPAR Beach Litter surveys indicated that approximately 40% of litter originates from sea-based sources, it is important to note that a similar percentage of litter was not able to be sourced. According to van Franeker & Meijboom (2002) other sources on the southern North Sea coast of the Netherlands are coastal recreational activities, the offshore industry and litter entering the North Sea by wind, currents, or river-transport from land based sources. Fleet et al. (2003) also reported records of litter items on the German North Sea coast identified as originating on the French Atlantic coast, which indicated that some litter enters the Southern North Sea from the English Channel.

3.2.2 Beach litter in North West Spain

In order to assess the situation of beach litter in the Galicia region (NW Spain), a seasonal series of sampling on three beaches (A Lanzada, Baldaio and O Rostro) were conducted. A total of 79 surveys were conducted from 2001 to 2010 on a stretch of 100 m and a stretch of 1 km.

In total 37862 beach litter items were counted and classified on the 100-m stretch and 7845 items on the 1-km stretch surveys (Gago et al., 2014). The average annual litter items on these beaches varied between 88 and 1016 items/100m. Plastic was the most dominant fraction, varying between 38% and 83%, with average percentages of 63, 38 and 83 for A Lanzada, Baldaio and O Rostro, respectively. Based on the Indicator-items methodology used by OSPAR (see section 4.1.1), fishing and the aquaculture sector are important sources in this area, being associated with 14% to 38% of the items recorded in the surveyed beaches (Gago et al., 2014).

3.2.3 Portugal

Biannual microlitter surveys on 10 beaches in Portugal, for two consecutive years (Antunes et al., 2013), revealed that the most common items are primary microplastics, of which 57% are plastic pellets. Statistically significant higher amounts were found downstream from plastic packaging converters, industrial sites and ports, which indicate probable sources of plastic pellets.

Plastic macrolitter (> 2.5 cm) accounted for only 8 % of the items found, the most common being cotton bud sticks (38 % of macrolitter) and fishing ropes and net pieces (35 % of macrolitter). Styrofoam pieces of various sizes represented 11% of all plastic items and can be related to fishing activities (fish is landed in styrofoam boxes) but also originate from consumer packaging, although their contribution cannot be quantified (Antunes et al., in preparation).

Recent surveys of litter caught in fishing trawls along the Portuguese continental shelf (depth range between 90-349m) (Neves et al., 2015), revealed that plastic was the dominant fraction (76%) and was present in all trawls. Approximately 40% of the collected litter was attributed to fishing activities, while it is also interesting to highlight that the highest density of litter was found near the mouth of river Tagus, probably related to the high population density in the Lisbon metropolitan area.

3.2.5 Beach litter in the UK

The majority of the top 10 items found during litter surveys in the UK are made of plastic. Small plastic pieces have been the number one item found during every Marine Conservation Society (MCS) Beachwatch Big Weekend survey since 1998. The main identifiable items are generally: Plastic caps and lids, crisp/sweet/lolly wrappers, cigarette butts, fishing net and net pieces < 50cm, plastic drinks bottles, rope diameter > 1 cm, fishing line (from anglers), plastic cutlery/trays/straws/cups, cotton bud sticks, plastic bags (including supermarket bags), metal drink cans and plastic food containers.

The sources percentages (see section 4.1 for the method of sourcing used by MCS), although fluctuating, are always roughly the same order with *Public*, *non- sourced* and *Fishing litter* being the major sources, followed by *sewage-related debris* and *shipping*. A small percentage of fly-tipped and medical litter, usually less than 1% is found every year.

Differences around the UK are also noted with higher levels of litter generally being found in the SW of England and Wales.

Sewerage systems as pathways of litter in Europe

Mainly due to historical reasons, most European cities operate **combined sewer systems**, in which both waste water and storm water are drained in one sewerage system.

Due to the hydraulic limitation of WWTP it is not possible to treat the whole amount of the drained water at WWTPs during heavy rainfalls. Therefore, the storm water runoff in combined sewer systems has to be either spilled out at combined sewer overflows (CSOs) into receiving waters or stored temporarily in reservoirs (CSO tanks). The excess flows spilled at the overflow have the potential to cause pollution of receiving waters with debris and contaminants if discharged without restriction.

In **separate systems**, a dedicated foul sewer is provided for foul flows only, with all storm run-off directed to the separate storm sewers.

Usually the first operating unit– *screening* – aims at retaining solids in the influent wastewater to the WWTP. There are several levels of screening, varying from coarse (> 50mm) to fine or micro screens (down to a few mm).

3.3 Aquaculture and tourism as sources of litter in the Adriatic & Ionian and Mediterranean Seas

In areas with intensive and extensive aquaculture activities mussel nets are among the most common items found. Recent findings from the DeFishGear project related surveys on beaches located along the coastline of the Adriatic and Ionian Seas show that mussel nets are the seventh most frequent items found (Vlachogianni et al., 2016). Furthermore, in surveys carried out along the Italian coastline , mussel and oyster nets were among the top three items recorded on beaches, while the results obtained from the seafloor surveys show that litter from aquaculture accounts for 15% of total items recorder (Pasquini et al., 2016). Indicatively some preliminary results from *Fishing for Litter* activities in the area show that mussel and oyster nets account for almost 30% of the total weight of the items collected.

According to the updated Report on Marine Litter Assessment in the Mediterranean (UNEP/MAP MEDPOL, 2015), the main groups of items found on beaches in the Mediterranean are sanitary items (mostly cotton bud sticks), cigarette butts and cigar tips, as well as packaging items and bottles, all likely related to coastal-based tourism and recreation. In particular smoking related waste seems to be an important problem in the Mediterranean as several other surveys suggest. The International Cleanup Campaign in 2013 found that cigarette butts were the most frequent items found on Mediterranean beaches, with abundances ranging from 35-62% of the total items recorded (ICC, 2014). The Marine Litter Assessment in the Mediterranean published in 2008 (UNEP/MAP MEDPOL, 2011) reported that 45% of the top twelve ML for the 2002-2006 period originated from smokers and included waste items such as cigarette filters and cigar tips, tobacco packaging and wrappers. More recent surveys confirm that smoking related items account for some 35% of the total number of items found in the Mediterranean (Öko-Institut, 2012; Arcadis, 2014).

Unsurprisingly, a considerable fraction of ML items recorded in the Mediterranean stem from tourism and recreational activities. These include not only smoking related items but packaging items such as food wrappers, caps/lids, plastic bottles, beverage cans, etc. The amount of litter during the tourism high season greatly increases, as several surveys show (UNEP/MAP MEDPOL, 2015). Indicatively, the results from a study carried out on 32 beaches on the Balearic Islands show that during the summertime recorded debris doubles in relation to the amounts recorded during the low season and seem closely related with beach use (Martinez-Ribes et al., 2007 – Figure 5). Also, in this study, cigarette butts were the most abundant items, accounting for up to 46% of the objects recorded during the high tourist season.

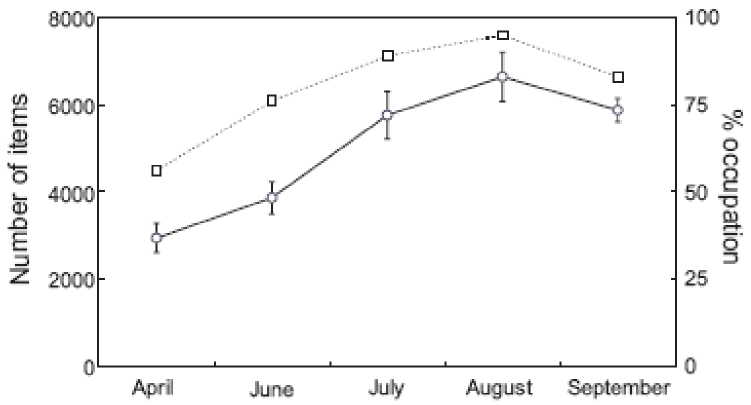

Figure 5: Monthly variation of mean (±SD) number of beach litter items (open circles) and percentage of hotel occupation for the corresponding date (squares) (Source: Martinez-Ribes et al., 2007).

Uncontrolled discharges also act as main sources of litter in the Mediterranean Sea. For example, approximately only one third of the 133 coastal cities in Algeria are controlling their waste discharges in adapted structures, without taking illegal deposit in account (Makhoukh, 2012). Furthermore, the percentages of inadequately managed waste in Mediterranean countries such as Albania, Algeria, Bosnia and Herzegovina, Egypt, Lebanon, Libya, Montenegro, Morocco, Syria, Tunisia is estimated to range from 23% to 67%, with a mean of 48.8% (Jambeck et al., 2015; UNEP/MAP MEDPOL, 2015),

3.4 Rivers as litter pathways in the Black Sea

According to several studies, improper solid waste management and illegal marine and coastal dumping are the most important sources of litter in the Black Sea (Suaria et al., 2015). It has been reported that at the southern part of the Black Sea, large amounts of municipal and industrial solid waste, mixed with hospital and hazardous waste, are being dumped on nearby lowlands and river valleys, directly on the seashore or even at sea (Berkun et al., 2005). Most uncontrolled coastal landfills and dumping sites are not protected from waves and thus serve as stationary sources of unknown (but admittedly large) quantities of ML (UNEP, 2009).

River discharges also play an important role in the amounts of litter that end up in the Black Sea every year (Bakan and Büyükgüngör, 2000; Topçu et al., 2013). The north-western Black Sea receives freshwater from a large number of rivers, including the second, third and fourth longest rivers in Europe, namely the Danube, Dnieper and Dniester, running across 22 different countries. The Danube alone, accounts for 60% of the total freshwater discharged into the Black Sea (Karageorgis et al., 2009) and it is probably responsible for a huge inflow of litter. For example, a study carried out in a flowing stretch of the Danube, between Vienna and Bratislava, estimated an average input of small plastic fragments into the Black Sea of about 4.2 tonnes per day (Lechner et al., 2014). According to the authors, the amounts of large floating items (>5 cm) were probably underrepresented in their study, given that downstream countries feature lower standards in wastewater treatment if compared to Germany and Austria and therefore the actual litter load at the river mouth is potentially much higher.

4. Existing approaches to determine the sources of marine litter

A wide variety of methods have been used over the years to determine the sources of ML, ranging from simple counts of items to more complex statistical methods. Here we give a brief overview of the main approaches used and outline one of the most promising methods for determining sources.

4.1 Attribution of marine litter to sources according to the type of item

This method is based on the assumption that certain ML items are typically or widely used by particular commercial or public sectors or are released into the environment via well-defined pathways (i.e. waste water). Specific items are attributed to a certain source or sources in order to judge the magnitude of the input from various sources to ML pollution within a given region.

An example of this method is the one applied by the Marine Conservation Society (MCS) in the UK. The MCS attribute all items on their survey forms to given sources. A summary of the different sources considered is given below:

Public litter - Items dropped or left by the public on the coast or inland and carried by winds and rivers

Fishing litter - Includes commercial and recreational items - e.g. fishing line, nets, rope, weights and buoys

Sewage Related Debris (SRD) - Items flushed down the toilet such as cotton bud sticks, tampons and panty liners

Shipping - Items dropped or lost from ships

Fly tipped - Illegal disposal of waste including furnishings, pottery and ceramics

Medical - Includes anything medical such as inhalers, plasters, syringes

Non-sourced - Items too small or damaged to identify or not obviously attributable to a given source.

See Annex I for the full list of MCS litter items and attributed sources.

4.1.1 Indicator-items

This method rather than assigning a category to all litter items uses only indicator items to define sources. This method has been used by OSPAR and applied in several studies (e.g. Gago et al., 2014). Table 3 shows the sources and potential indicator items.

The use of the OSPAR indicator items does not provide information on the relative importance of the different sources responsible for litter pollution for a given region, because only a small selection of items actually recorded on the coast are used as indicators. It can, however, give an indication of which sources are involved (i.e. if an indicator item is recorded then the source it indicates is responsible for a certain but unknown amount of litter pollution on that coast) and it can be used to calculate trends in the input from the sources listed in Table 3.

Table 3: Indicator-items used in the OSPAR Beach Litter monitoring programme to determine contribution of different sources (adapted from OSPAR, 2007)

Source	Indicators
Fisheries, including aquaculture	Jerry cans. Fish boxes. Fishing line. Fishing weights. Rubber gloves. Floats/buoys. Ropes/cords/nets <50cm, and >50cm, respectively. Tangled nets/cords. Crab/lobster pots. Octopus pots. Oyster nets and mussel bags.Oyster trays. Plastic sheeting from mussel culture ("Tahitians")
Galley waste from shipping, fisheries and offshore activities (*non-operational waste*)	Cartoons/tetrapacks. Cleaner bottles. Spray cans. Metal food cans. Plastic gloves. Plastic crates.
Sanitary and sewage-related waste	Condoms. Cotton bud sticks. Sanitary towels/panty liners/backing strips. Tampons/Tampon applicators.
Shipping, including offshore activities (*operational waste*)	Strapping bands. Industrial packaging. Hard hats. Wooden pallets. Oil drums (new and old). Light bulbs/tubes. Injection gun containers.
Tourism and Recreational activities	4-6-pack yokes. Plastic shopping bags. Plastic bottles/containers for drinks. Metal bottles/containers for drinks. Plastic food containers. Glass bottles. Crisp/sweets packets and lolly sticks.

4.1.2 Indicator-items for shipping and fishing

Earll et al. (2000) provide a thorough methodology and guidelines to assess ML from shipping (including fisheries) on UK beaches. They made a number of observations with regards to the identification of litter from shipping. These include:

1. Sites heavily contaminated by shipping litter often contain large, conspicuous items .e.g. pallets, buoys, netting.
2. Certain items or groups of items found together can indicate shipping litter:
    - Fishing debris
    - Galley waste
    - Domestic waste from crews
    - Maintenance wastes
    - Lubricants

- Waterproofing materials
- Buoyancy aids
- Packaging
- Oil and tar
- Equipment from oceanographic research
- Wrecked items, container items

3. An increase in shipping litter often leads to an increase in abundance and diversity of items
4. Domestic and commercial plastic containers are found in distinct groups:
   - Milk, vinegar, ketchup – galley waste
   - Washing up liquid, disinfectant, cloths, washing containers
   - Engine coolants and lubricants
   - Aerosol cans including lubricants and personal hygiene products
   - Metal polish
   - Injection gun containers for lubricants and silicone sealants
5. Large quantities of short pieces of line (1-20 cm) are associated with fisheries.
6. A distinctive part of shipping related litter is comprised of items, which are being used for another purpose, i.e. secondary use, e.g. plastic containers cut to use as bailers or as paint pots, tyres used as fenders

The document also provides a detailed "fact-sheet" for a long list of items and containers, addressing the function of those items in shipping context, some qualitative and quantitative information and suggestions of likelihood allocation to shipping, including attributions to specific types of vessels.

Generally though, it is a method for identifying whether or not shipping, including fishing, is a main source of litter on a given stretch of coast.

4.1.3 Value and limitations of the attribution of sources per type of item

The methods that allocate an item type to one specific source are simple and straightforward but have some limitations which should be taken into account when applying them to assess the magnitude of different sources of ML:

- They assume that all occurring items from a certain category originate from a particular source. This dismisses potential contributions from other sources and pathways;
- There are always a broad categories of items, which can potentially originate from multiple sources and pathways (e.g. drink bottles, caps/lids, bags);
- There can be regional differences in the source of a given item so the system can only be applied at a regional level;
- Usually there is little information on pathways of introduction into the marine environment;
- Such methods alone cannot be used to measure the relative importance of the different sources of litter in a given region.

Nevertheless, if applied with caution, such approaches can provide a preliminary indication of contribution of key sources.

4.2 Bar-codes and container information

Labels and bar-codes on litter objects can provide information on the country of production, the manufacturer, the product type and the age of litter items. However, labels can be lost or can be illegible and only items with a label or bar-code (not items like cigarette butts or cotton-bud-sticks) can be included in the analysis. Whilst this type of information provides additional data, with the increasing globalisation of markets this information should be analysed with caution, as a product can be produced and bought in a certain country, and discarded in another. Foreign labels can therefore indicate either transport from a neighbouring country or a "mobile" source, such as shipping.

Van Franeker (2005) categorised items found on beach clean in Texel in the Netherlands to a country of origin. The majority of items originated from the Netherlands or neighbouring regions, indicating that this method can be used to provide information on the likelihood of litter items originating form given sources as well as on their geographical origin (Fig. 6).

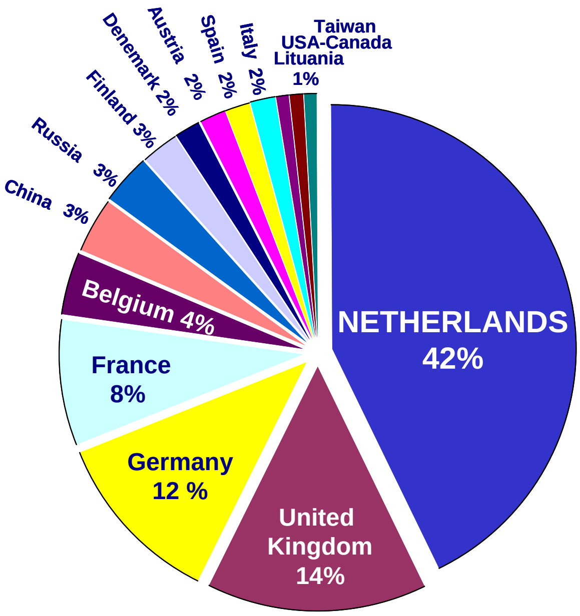

Figure 6: Proportions of countries of origin as derived from barcodes or label information on litter items found on Texel, April 2005 (translated from van Franeker, 2005)

Labels and in some cases the known function of a litter item (i.e. grease gun cartridges, paint tins, paint brushes for shipping) can also provide useful information on the source. Container or item design can be typical for a certain country, which could provide an indication of geographical origin. A high frequency of a certain type of container can provide strong indication of a systematic input from a single source.

4.3 Attribution of sources based on likelihoods

4.3.1 Matrix Scoring Technique (Tudor & Williams, 2004)

Tudor & Williams (2004) developed a method for assigning sources to litter found on the beaches of the Bristol Channel (UK) which could potentially be used on other beaches. The Matrix Scoring Technique was heavily based on earlier work on percentage allocation (Earll et al., 1999 in Tudor & Williams, 2004) and "Cross Tabulation Probability Scoring" (Whithing, 1998 *in* Tudor & Williams, 2004).

The Matrix Scoring Technique considers individual item categories and assesses the likelihood of it originating from a series of potential sources, taking into account the identity and function of the item, the beach location in terms of influence of particular activities and potential sources of litter, the "mix" of litter found, any indicator-items present and their quantity. Each individual litter item category, used for recording litter, is allocated one of a number of possible qualitative likelihood phrases - from "very likely" to "very unlikely" as well as an additional "not considered" - for each potential source. A prerequisite of this method is that a number of possible sources, such as shipping, fishing, tourism, fly-tipping etc. need to be identified in advance. When the qualitative likelihood of an item coming from a particular source has been decided, this is then translated to a scoring system, in which weighted numerical values are given.

Tudor and Williams (2004) tested the application of six phrases and tested the allocations of different scales of scores for these phrases. Table 4 provides examples of how such scoring systems can be formulated. System A is the simplest system, where the scoring scale simply goes from "0" for an item that is very unlikely to come from a specific source, to "4" for an item that is very likely to come from that source. If it is possible to assign the most likely source for a particular type of item with a high degree of confidence, but more uncertain to which degree other less likely sources contribute to the occurrence of item, then it may be desirable to assign larger weights to the likely or very likely sources. Examples of this are shown in the scoring systems B to E in Table 4. The scoring systems B to D have no score 0 (zero) in their systems, even for the likelihood "very unlikely". The rationale behind this is that it is difficult to entirely rule out the possibility that an item may not come from a source. However, as argued above, there may be some items that are so unlikely to come from a source that the particular item-source connection should not be included at all (such as the wooden pallet from the toilet). System E therefore introduces the class "not considered" with the score 0 for such cases.

Table 4: Examples of scoring systems translating qualitative likelihoods (left column) to numerical scores (right columns). See text for explanation of different scoring systems (adapted from Tudor & Williams, 2004)

Qualitative likelihood	Scoring systems				
	A	B	C	D	E
Very likely (LL)	4	9	16	16	16
Likely (L)	3	7	8	4	4
Possible (P)	2	5	4	2	2
Unlikely (U)	1	3	2	1	1
Very unlikely (UU)		1	1	0.25	0.25
Not considered					0

Whichever scoring system is used, the scores for each item-source combination are then used to calculate the relative contribution of the different sources based on the occurrence (frequency) of the different litter items as recorded e.g. during beach litter surveys. The result is an estimate of the proportion (or probability/percentage) of litter of each item type and all item types together coming from different sources. See Tudor & Williams (2004) for worked examples of this and also Annex II.

4.3.2 Identification of loopholes in the plastic cycle and local sources of marine litter through a bottom-up participatory approach

In the pilot project on plastic cycle and its loopholes in the four European Seas areas (Arcadis, EUCC and Milieu, 2012) the Matrix Scoring Technique was used as the basis for determining the contribution of different sources and pathways to ML recorded at specific study sites. For this study the definition of the likelihood of an item originating from a given source, from a list of top items occurring in the studied area, was done through a bottom-up approach involving key local stakeholders.

Groups with local knowledge and experts from key sectors such as waste management, local government, port authority, fisheries, plastic industries, met together to identify the activities, practices and potential dysfunctionalities in the systems (e.g. waste water treatment plants, fisheries, waste management in recreational areas) that were likely to contribute to ML in the area. They discussed and jointly defined the most adequate likelihood that each ML item has to originate from a series of potential sources, such as coastal tourism, recreational boating, fishing, shipping, general littering, improper disposal in the toilet and dumping sites.

4.3.3 Value and limitations of Matrix Scoring techniques

Matrix scoring techniques are likely to give a more accurate picture of sources and the relative importance of each type of source. That they allow for more than one source for each item type is, in most cases, probably a more realistic view than only assigning a single source to each item.

The quality of the results of such analyses depends on the quality of the input i.e. the allocation of the litter items found on the beach to possible sources, e.g. for plastic cosmetics bottles and containers, sun lotion bottles are more likely to be from beach-goers while shampoo bottles are more likely to be from merchant shipmen. Nevertheless, an important aspect is that this method can be used in a transparent way with stated motivations for individual likelihood choices.

Expert knowledge on what items recorded in the marine environment are used for and by whom, and also on the practices and deficiencies of local human activities that can contribute to ML in the area is crucial for this type of analysis. Another advantage of matrix scoring methods using qualitative classes is that they allow for input from different stakeholder groups and the assignment of likelihoods can be done in workshops, as described in section 4.3.2.

Tudor & Williams (2004) argue that, for a given source, the exact proportion of contribution from a source will probably vary between geographical areas. Similar conclusions have been drawn in other projects (e.g. Arcadis, EUCC and Milieu, 2012). The conclusion from this is that a single item-source assignment should not be used over a whole region, much less over the entire European scale. Whatever system is used, it should allow for different item-source assignments at different regional scales. While this of course is possible also with e.g. indicator item systems (see section 4.1.2), matrix scoring methods allow for systematic analyses of sources using the same system in different places but with likelihoods chosen for sensible spatial units, where the sources of individual items are identical.

4.4 Litter transport dynamics and models

Numeric modelling based on water circulation patterns can be helpful in understanding and predicting the transport and accumulation dynamics of ML in a certain marine region. There are several examples of tools that have been developed to predict dispersion and transport of litter (e.g. Lebreton et al., 2012). These are based on transport models, coupled with additional information that may consider specific properties of litter, such as density, buoyancy, etc.

The distribution of any particle in a fluid environment can be described through an Eulerian process, based on the integration of the advection-diffusion equation with maps of concentration as outputs, or through Lagrangian processes, based on the integration of stochastic models describing the trajectories of particles.

These models may help to better understand and describe input areas and patterns, hot spots, processes, including those affected by river plumes, large cities, coastal discharges and dispersion but also transboundary transport of litter.

These approaches can also help to define and locate mesoscale features enabling the description of possible accumulation zones, transport patterns and sources (see example in Fig. 7).

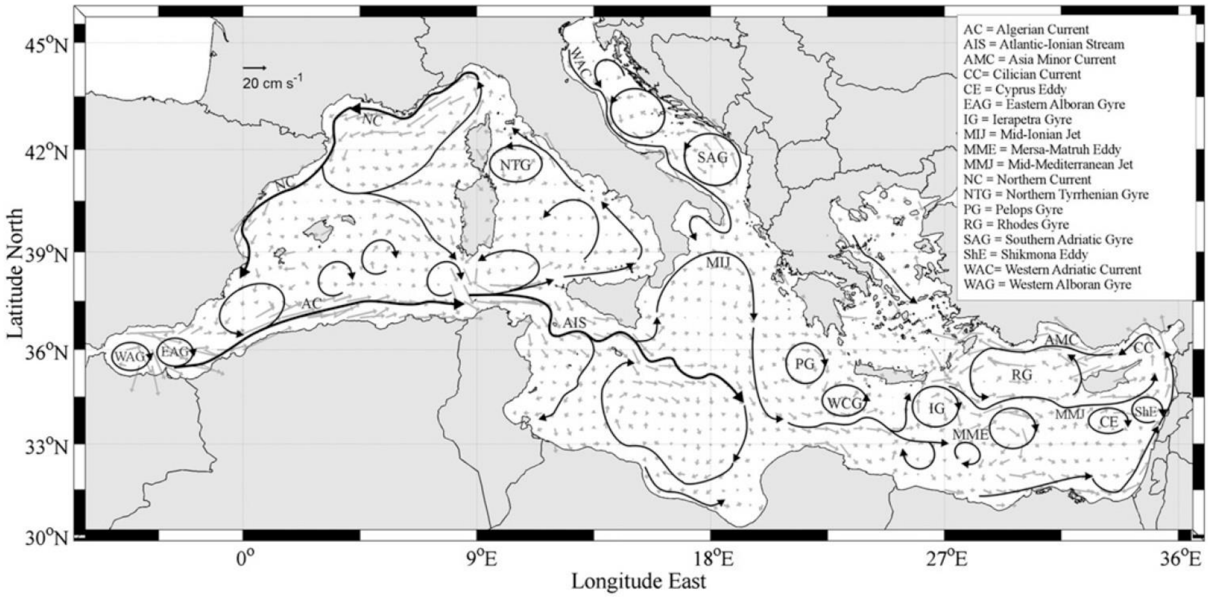

Figure 7: Schematic representation of the mean surface geostrophic circulation in the Mediterranean Sea in the period 1992–2010 (from Poulain et al., 2012).

5. Parameters on Use, Origin and Risk of marine litter items

In the pilot project *Case studies on the plastic cycle and its loopholes in the four European Seas areas* (Arcadis, EUCC and Milieu, 2012), a series of parameters have been developed and defined to characterise ML. These go beyond the traditional classification of ML into detailed items or materials and aim to provide an additional insight of ML items in terms of their ***Use***, ***Origin*** and associated ***Risk*** (Table 5). When applied to a certain data-set of well specified items, these parameters can better characterise the roots of the problem and possibly identify priority areas of intervention. They allow a quantification of the following aspects:

- **Use**: the proportion of items that are originally used as packaging and the different types of packaging; the use durability to which items were designed for; if items were designed for professional or consumer use;

- **Origin**: the stage of the life cycle at which items have been inadequately or purposely released into the environment; which sectors and economic activities are associated to the loss or discard of those items; was the release likely to be accidental or intentional;

- **Risk**: the potential associated impacts (entanglement of and ingestion by marine life, aesthetics degradation, beach user safety, etc.)

These parameters allow clustering and breaking down the overall data into more appropriate and useful scales to support decision-making. They serve as a complement to the trends of occurrence of single categories of items and can help to identify priorities and strategies for the prevention of certain types of waste.

Table 5: List of parameters developed and applied in the Pilot Project "4 Seas" to analyse ML data (adapted from Arcadis, EUCC and Milieu, 2012).

Example of Questions	Parameter	Choice options
What is the % of different materials that compose ML? What is the predominant material in ML?	**Material**	***(One-to-One relation)*** Artificial Polymer; Rubber; Cloth/textile; Paper/cardboard; Processed wood; Metal; Glass / Ceramic; Other
At which stage of their life-cycle are the items released into the environment?	**Life cycle phase**	***(Likelihood – 4 levels)*** Pre-consumer PROCESSING; Pre-consumer TRANSPORT; Consumer/Industrial DISPOSAL; POST-disposal
Which % of ML corresponds to packaging?	**Use category**	***(One-to-One relation)*** Packaging; Use; Raw Material
How is the distribution of ML packaging items across packaging types?	**Packaging type**[1]	***(One-to-One relation)*** Primary; Secondary; Tertiary; Quaternary; Unknown/multiple; Not relevant
Which % of ML is designed for a short life / single-use?	**Use durability**	***(One-to-One relation)*** Short life, single use; Long lasting item; Multiple-dose/use

[1] Following Article 3.1 Packaging and Packaging Waste Directive 1994/62/EC

Example of Questions	Parameter	Choice options
What is the % of ML that originates from professional/industrial use?	**Source activity**	***(One-to-One relation)*** Individual/Consumer; Professional/Industrial; Unknown
What are the proportions of different sectors as sources of ML in the area? Which are the predominant sources?	**Sources** **(human activity)**	***(Likelihood – 6 levels)*** Fishing; Shipping; Other Maritime Industries; Aquaculture; Coastal/Beach tourism; Recreational boating; Agriculture; Ports; Construction & demolition; Other industrial activities; General household; Toilet; Dump sites/ landfills; Waste collection/transport; … (other human activities relevant for the site/area can be added)
What is the proportion between sea-based and land-based sources of ML in the area? Can indicate whether efforts should target maritime activities and management or land-based activities, processes and behaviours.	**Main origin**	***(Likelihood – 4 levels)*** Sea-based; Land-based
To what extent ML is generated by intentional behaviour? Can provide indication on the need of measures that encourage or discourage certain behaviours.	**Way of Release**	***(Likelihood – 4 levels)*** Intentional; Accidental
To what extent litter is reaching the sea by a certain pathway	**Pathways**	***(Likelihood – 4 levels)*** Direct input; Indirect -sewage; Indirect - inland waterways and storm culverts); Indirect - others
What is the % of ML that is likely locally generated?	**Geographic origin**	***(Likelihood – 4 levels)*** Local (short distance); National (within the country); Transboundary
What is the potential harm on associated to ML in the area? Can support identification of priorities/ items that may raise more concern	**Potential harm**	***(Multiple-choice)*** Ingestion (by marine life); Entanglement of species; Invasive species; Maritime hazards (aquaculture, fishing,, shipping); Coastal recreation safety; Aesthetics; Toxicity

6. Recommendations

In this section we highlight some key aspects and provide some recommendations about the process of identifying the sources and pathways of ML, which starts with detailed data recording of ML items and the knowledge about the site and human activities that may affect it. Finally, we make some considerations on how this information can be used to help design and monitor effective measures.

6.1 Data collection and site characterization

- **Correct identification of items and their function**: adequate identification of the nature of each litter item recorded in monitoring protocols is crucial. Adequate training of surveyors and the use of photographic guides, like the one developed by the OSPAR pilot project on ML, can be very useful. Caution must be taken when attributing a function to an item and therefore the associated sector or activity, as some items can have uses other than the one they were originally designed for. This applies to so-called secondary use items e.g. tyres with ropes still attached used as boat fenders; cut containers used as water bailers or bait containers; plastic water pipes used in fisheries for lobster pot construction, etc. Any information that provides further insight into the use of items should be recorded.
- **Detailed and informed recording of items**: In order to be able to assess potential source contribution for ML, it is necessary to identify and classify ML items into consistent, systematic and specific categories that can provide as much detail to their nature and use as possible. Very broad categories such as "bottles" are limited in the amount of information they can provide on sources, as this depends on identification of particular use and sector associated – e.g. "bottles containing chemicals" vs "beverage bottles". Monitoring methodologies vary in the degree of item detail they are able to generate (see further discussion in the TGML Report: Galgani et al., 2013). Beach litter surveys, using a detailed list of item categories, have the potential to generate such data.
- "**New" / unknown items**: It is common that non-listed items appear in litter surveys, as a reflection of technological and design development or input from new sources (Fig. 8). New items should be recorded with as much detail as possible (preferably photographed and collected) and investigations carried out to determine the identity and function of the item. This often requires dialogue with a range of stakeholders and exchange of information through existing expert platforms or working groups.

Figure 8: Disposable aluminium barbecue on a UK beach as an example of "new" occurring items that can become marine litter as they appear in the market (photo: Gill Bell, MCS)

- **Characterization of the site**: In terms of identification of sources, the characterisation and close knowledge of the factors affecting the surveyed site are at least as important as the detailed recording of items. The site should be well characterised in terms of when, where and how the survey site and its surroundings are used (e.g. proximity to shipping lanes, fishing grounds, intensity of tourism, particular events, etc.), as these factors can influence the types and amounts of ML items occurring on the site. In addition, hydrographic conditions & patterns and geo-physical elements (e.g. pattern of currents, littoral drift, influence of rivers, accumulation areas), which can also influence the occurrence and distribution of litter should be determined. Transport models can provide additional insight into this characterization.

6.2 Allocation of likelihoods of ML items originated from different potential sources

- **Considering the whole mix of items:** Items should not be considered independently from other items – although most items are not in themselves directly linked to a source, if the litter they are found with point to one specific source (e.g. shipping) then the likelihood of other items arising from that source is likely to increase The indicator-item approach can provide a preliminary insight on the influence of particular sources.
- **Function of certain items:** it is important to include a detailed description of the individual litter items, which make up each category recorded on survey forms (use, contents of packaging, writing on labels etc.) as well as an estimation of the time each item has been in the marine environment (weathering, fouling, best-before dates). In this process it is important to know the function of items in a certain sectorial context. The identification of so-called secondary use items i.e. items which serve a different purpose to which they were initially designed (e.g. tyres used as fenders or plastic containers cut to hold paint see Earll et al., 2000) can also play an important role in determining a given source.
- **Additional information provided by items:** Any information that can be recovered from labels, such as language, place of manufacture, dates etc., will provide an indication of whether the litter items are from local, regional or distant sources. The level of fouling found on litter items can also provide an indication of how long the items have been in the sea. Completely clean items will indicate that the source is local and that the item has not spent much time in the marine environment.
- **Bring-in local knowledge** of the dysfunctions and loopholes within activities and socio-economic processes that may be generating ML, by engaging hands-on stakeholders from key sectors to help identify likely sources and pathways of ML in the area. The process of involving key stakeholders in identifying loopholes and sources of ML has the additional value of raising awareness among participants about the issue and paving the way to design possible solutions. Furthermore, it creates a sense of ownership and acceptance of the results and future measures that are based on these outcomes.
- **Influence of the surveyed location:** Item allocation to sources should consider carefully the local context in terms of environmental factors (e.g. proximity to a river mouth) and the influence of activities and uses that may be generating litter (e.g. bathing/tourist area, agriculture, fishing grounds, shipping lanes, etc.). The same litter categories on a different beach would produce a different set of probabilities. It can be assumed that the closer the surveyed site is to a potential source, the more likely it is that part of the litter originates from that source e.g. litter found on an urban beach will likely reflect more the influence and recent input from nearby sources (e.g. tourism, river, industries, city, etc.) while litter on a more remote beach will tend to reflect better ML that is present in the sea.

Both types of sites can provide important and complementary information and be combined to better assess inputs and the "state" of the environment.

- **Improved knowledge of items used in different activities:** A detailed study of the items that are actually used by specific sectors (e.g. beach tourism) can provide much insight into where and by whom they ML items recorded are being used. This information is essential for setting likelihoods e.g. the OSPAR category plastic food containers covers a wide range of products some of which could be typical of use by tourists others could be typical of use on ships i.e. in the galley. Detailed studies of litter items found in the marine environment can also provide valuable information on the geographical origin of those items, which will also help in assigning likelihoods. Such detailed studies should be carried out on a sample of the litter found in the environment before setting likelihoods and repeated at regular intervals (perhaps annually) to ensure that the likelihoods used in the Matrix Scoring process are still correctly assigned.

6.3 Approach to attribute likelihoods (including scoring system)

- Develop/implement procedures to make the reasoning/motivation behind the likelihood analysis as transparent as possible. This can make the source attribution more credible and makes it easier to compare it between regions/groups
- Choose a scoring system that suits the important characteristics of the knowledge about litter items and sources. For example, in our testing of likelihood scoring systems we found it reasonable to incorporate a score of 0 for items that are logically unlikely to come from a specific source. Furthermore, we found it reasonable to put a high weight on sources that presumably contribute greatly to a single type of item. Both these considerations lead us to recommend a scoring system similar to system E in Table 4.

6.4 Step further to strategies and measures

- **Differentiating between sources and pathways** and obtaining detailed knowledge on both aspects can help to tailor target-specific measures and interventions, in an effective and feasible way. Some measures can focus on the source, others intervening at a certain stage of the pathway of entry and others on both. Which measures are going to be more effective, for example in reducing the number of cotton-bud sticks entering the marine environment, will depend on the sources and pathways. A manager can therefore consider different options, such as: implementing filters in sewage systems; addressing people's behaviour; or change the product (e.g. wood or paper instead of plastic), considering aspects of feasibility, cost-effectiveness and fair share of responsibilities and burden of costs. In this specific example, while improving the sewage system may seem the obvious solution in some cases, this may involve large investment in changing or upgrading infrastructure (and only affect households that are connected to treatment stations) and behaviour change or product redesign could represent cheaper and more effective options.
- **Considering upstream measures:** It is important to note that the most effective measures may not come from targeting a seemingly obvious source e.g. a person dropping food packaging on the street. The greatest return on effort, both financially and environmentally may actually come from looking further up the litter/supply chain. By examining the whole life cycle of the litter item from production to disposal it may become clear that redesigning the product or the product packaging would greatly reduce the likelihood of that item being littered. Truly targeting the problem at an early stage will almost certainly be more effective than end of pipe solutions.

- **Temporal trends of certain items**: once a monitoring programme is established in a systematic and regular way, it becomes possible to analyse trends in terms of quantities of certain items. It may be possible to link increasing or decreasing significant trends of a certain ML item with trends in socio-economic and recreational activities, processes and policies that may affect the generation of such item. For example, beach litter surveys in the Netherlands indicate a significant increase in the amount of bottle caps between the periods 2002-2006 (15 caps/100m) and 2009-2013 (23 caps/100m). This may reflect the increase in sales of small bottles without a deposit from 456 million in 2005 to 681 million in 2012. Similarly, balloons increased from 8 items/100m for the period 2002-2006 to 16 items/100 m in 2009-2013. This may indicate an increase in balloon releases as they became more popular in recent years and could be substantiated by investigating if there was an increase in permits for balloon releases.
- **Monitoring effectiveness of measures**: A consistent monitoring programme on ML and the identification of sources of specific items can also reflect the effectiveness of implemented measures. The *Bag It and Bin It* Campaign in the UK, during 1997 to 2002, aimed at reducing the incidence of sanitary related debris on beaches and riverbanks through a programme of promotion, education and partnership between NGOs, Environmental Agencies and Product Manufacturers. This awareness campaign targeted mainly women between the ages of 15-45 and included awareness raising through media, label on packaging and endorsement by large retailers and producers. MCS Beachwatch results indicated a steadily declined in cotton bud sticks and sewage related debris when the national campaign was running but this trend was reversed once the national funding ceased. Another example of a clear influence on ML due to measures on specific type of items is the occurrence of plastic bags on Irish beaches following the introduction of a tax on plastic shopping bags in Ireland, in 2002. The effect of the tax was not only a 90% reduction of plastic bags provided in retail outlets (Convey et al., 2007) but also a marked decline in bags found on beaches, according to Coastwatch beach monitoring data, from an average of 18 plastic bags/500m in 1999 to 5 in 2003.

7. Conclusions

In order to implement sensible measures to reduce marine litter pollution, reliable data on the relative contribution of the different sources to the total amount of ML present in a certain area is needed, as well as information on its geographical origin and pathways of entrance to the marine environment. Only then will it be possible to identify the responsible polluter, in the correct region, and design effective measures to prevent litter from entering the sea.

The use of indicator items, i.e. a selection of items which certainly originate form a given source, can help identify sources, and the general mix of items occurring in a given compartment of the marine environment (seabed, beach etc.), can give an indication of the main source of litter in that compartment. However, although they provide an important indication of the sources involved, both will not supply information on the relative amounts of litter originating from different sources.

The Matrix Scoring Technique is an approach that considers the likelihoods of a single litter category originating for a series of potential sources. Compared to the use of indicator items, this methodology is likely to give a more accurate picture of sources and the relative importance of each type of source, in a certain area.

In order to be able to use the Matrix Scoring Technique effectively a sound knowledge of the litter items found in the marine environment in the region is essential. It is important to identify in detail the different items, which are recorded under a given category of the survey protocol during surveys. The allocation of likelihoods of ML items originating from a given source needs to consider a number of factors, which influence the composition and amounts of litter recorded at a given site or in a given region. Initially local topography, geography and local human activities need to be taken into account. Knowledge of the proximity to river mouths, towns or concentrated human activities e.g. tourism, agriculture, fishing, shipping can provide vital information on which sources are likely for a given area. Thus, when considering the likelihoods of a certain category of items originating from a series of potential sectors and activities, their relative impact should be assessed in terms of influence in the sampled site (i.e. disposing behaviour of individuals, proximity to the sampled site, etc.) but also intensity of that activity.

The use of local knowledge of where, how and when which types of litter are being lost or disposed of into the marine environment and which socio-economic processes are generating ML is indispensable. These data should therefore form the basis of discussions with people from key sectors that may generate or influence the generation of ML. Additionally, further classification of ML items in terms of parameters related to their use, origin and associated potential risk, such as the ones provided in this report, can further help to identify strategies for intervention.

References

Antunes, J., Frias, J.G.L., Micaelo, A.C. and Sobral, P. (2013). Resin pellets from beaches of the Portuguese coast and adsorbed persistent organic pollutants. Estuarine, Coastal and Shelf Science, 130: 62-69. doi: http://dx.doi.org/10.1016/j.ecss.2013.06.016

Antunes, J., Frias, J, Raposo, I. and Sobral., P. Marine litter in Portuguese beaches. Manuscript in preparation.

Arcadis, EUCC and Milieu (2012). Pilot project Case studies on the plastic cycle and its loopholes in the four European Seas areas. European Commission. Project number BE011102328.

Arcadis and EUCC (2014). Marine litter study to support the establishment of an initial headline reduction target. SFRA0025. European commission / DG ENV, project number BE0113.000668, 127 pages. Available at: http://ec.europa.eu/environment/marine/good-environmental-status/descriptor-10/pdf/final_report.pdf

Bakan, G. and Büyükgüngör, H. (2000). The Black Sea. Marine Pollution Bulletin, 41: 24–43.

Berkun, M., Aras, E. and Nemlioglu, S. (2005). Disposal of solid waste in Istanbul and along the Black Sea coast of Turkey. Waste Management, 25: 847-855.

Browne, M., Crump, P., Niven, S., Teuten, E., Tonkin, A., Galloway, T. and Thompson, R. (2011). Accumulation of Microplastic on Shorelines Worldwide: Sources and Sinks. Environmental Science & Technology, 45: 9175-9179. doi: 10.1021/es201811s

Convery, F., McDonnell, S. and Ferreira, F. (2007). The most popular tax in Europe? Lessons from the Irish plastic bags levy. Environmental and Resource Economics, 38: 1–11.

Dagevos, J. J., Hougee, J.A. van Franeker, J.A., Wenneker, B., van Loon, W. and Oosterbaan, A. (2013). OSPAR Beach Litter Monitoring In the Netherlands. North Sea Foundation, Utrecht. Available at: http://www.noordzee.nl/wp-content/uploads/2013/11/20130909-Dagevos-etal-NLBeachLitterMonitoring-2002-2012-Final.pdf.

Earll, R.C., Williams, A.T. and Tudor, D.T. (2000). Pilot Project to establish methodologies and guidelines to identify marine litter from shipping. A report to the Maritime and Coastguard Agency, (Research project 470). Prepared by CMS.

Essel, R., Engel, L. and Carus, M. (2015). Sources of microplastics relevant to marine protection in Germany. Nova-Institute GmbH, Hürth, Germany, 48pp. ISSN 1862-4804.

Fleet, D. M. (2003). Untersuchung der Verschmutzung der Spülsäume durch Schiffsmüll an der deutschen Nordseeküste - Untersuchung der Müllbelastung an den Spülsäumen der deutschen Nordseeküste – Umweltbundesamt - FAZ 202 96 183, ss. 166.

Fleet, D., van Franeker, J., Dagevos, J. and Hougee, M., (2009). Marine Litter. Thematic Report No. 3.8., in: Marencic, H.V., J. de (Ed.), WaddenSea Ecosystem. Common Wadden Sea Secretariat, Trilateral Monitoring and Assessment Group, Wilhelmshaven, Germany, Quality Status Report 2009. WaddenSea Ecosystem No. 25, p. 11.

Gago, J., lahuerta, F. and Antelo, P. (2014). Characteristics (abundance, type and origin) of beach litter on the Galician coast (NW Spain) from 2001 to 2010. Scientia Marina, 78: 125-134. doi: 10.3989/scimar.03883.31B

Galgani, F., Hanke, G., Werner, S., Oosterbaan, L., Nilsson, P., Fleet, D., Kinsey, S., Thompson, R., van Franeker, J., Vlachogianni, T., Scoullos, M., Mira Veiga, J., Palatinus, A., Matiddi, M., Maes, T., Korpinen, S., Budziak, A., Leslie, H., Gago, J. and Liebezeit, G. (2013). Monitoring Guidance for Marine Litter in European Seas. JRC Scientific and Policy Reports, Report EUR 26113 EN, (p. 120).
http://publications.jrc.ec.europa.eu/repository/handle/JRC83985

Gasperi, J., Dris, R., Bonin, T., Rocher, V. and Tassin, B. (2014). Assessment of floating plastic debris in surface water along the Seine River. Environmental Pollution, 195: 163-166.

GESAMP (2015). Sources, fate and effects of microplastics in the marine environment: a global assessment (Kershaw, P. J., ed.). (IMO/FAO/UNESCO-IOC/UNIDO/WMO/IAEA/UN/UNEP/UNDP Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection). Rep. Stud. GESAMP No. 90, 96 p.

International Cleanup Campaign/Ocean Conservancy (2014). Turning the tide on trash - 2014 Report. 16-21.

Jambeck, J.R., Andrady, A., Geyer, R., Narayan, R., Perryman, M., Siegler, T., Wilcox, C. and Lavender Law, K. (2015). Plastic waste inputs from land into the ocean. Science, 347: 768-771.

Karageorgis, A., Kourafalou, V., Anagnostou, A., Tsiaras, K., Raitsos, D., Papadopoulos, V. and Papadopoulos, A. (2009). River-induced particle distribution in the northwestern Black Sea (september 2002 and 2004). Journal of Geophysical Research, 114.

Lebreton, L.C.-M., Greer, S.D. and Borrero, J.C. (2012). Numerical modeling of floating debris in the world’s oceans. Marine Pollution Bulletin, 64: 653–661. doi: 10.1016/j.marpolbul.2011.10.027.

Lechner, A., Keckeis, H., Lumesberger-Loisl, F., Zens, B., Krusch, R., Tritthart, M., Glas, M. and Schludermann, E. (2014). The Danube so colourful: a potpourri of plastic litter outnumbers fish larvae in Europe's second largest river. Environmental Pollution, 188: 177–181.

LUNG - Schriftenreihe des Landesamtes fpr Umwelt, Naturschutz und Geologie Mecklenburg-Vorpommern (2015). Heft 3. ISSN 1439-9083.

Makhoukh, M. (2012). Pollution par les déchets solides en Algérie. Stratégie de gestion Intégrée des zones côtières en Algérie? Bilan et diagnostic. /MATE-PAP RAC/ 2012, 42 pages.

MARLIN (2013). Final report of the Baltic marine litter project MARLIN. Litter Monitoring and raising awareness 2011-2013. 29pp. http://www.projectmarlin.eu/sa/node.asp?node=3005.

MCS – Marine Conservation Society (2013). Full results and methods of the 2013 Beachwatch Big Weekend.

Martinez-Ribes, M., Basterretxea, G., Palmer, M. and Tintoré, J. (2007). Origin and abundance of beach debris in the Balearic Islands. Scientia Marina, 71: 305-314, Barcelona (Spain). ISSN: 0214-8358.

Napper, I. E., Bakir, A., Rowland, S. J. and Thompson, R. C. (2015). Characterisation, Quantity and Sorptive Properties of Microplastics Extracted From Cosmetics. Marine Pollution Bulletin, 99: 178-185.

Neves, D., Sobral, P. and Pereira, T. (2015). Marine litter in bottom trawls off the Portuguese coast. Marine Pollution Bulletin, 99: 301-304.

Öko Institute (2012). Study on Land sourced Litter in the Marine Environment. Review of sources and literature. Öko Institut report. 128 pages. http://www.kunststoffverpackungen.de/show.php?ID=5262), 1

OSPAR (2007). OSPAR Pilot Project on Monitoring Marine Beach Litter: Monitoring of marine litter in the OSPAR region, 75pp.

Pasquini, G., Ronchi, F., Strafella, P., Scarcella, G., Fortibuoni, T. (2016). Seabed litter composition, distribution and sources in the Northern and Central Adriatic Sea (Mediterranean). Waste Management, xxx, xxx-xxx. Poulain, P. M., Menna, M. and Mauri, E. (2012). Surface Geostrophic Circulation of the Mediterranean Sea Derived from Drifter and Satellite Altimeter Data. *Journal of Physical Oceanography*, 42(6).

Suaria, G., Melinte-Dobrinescu, MC., Ion and G., Aliani, S. (2015). First observations on the abundance and composition of floating debris in the North-western Black Sea. Marine Environmental Research, 107: 45-49.

Topçu, E.N., Tonay, A.M., Dede, A., Öztürk A.A. and Öztürk, B. (2013). Origin and abundance of marine litter along sandy beaches of the Turkish Western Black Sea coast. Marine Environmental Research, 85: 21–28.

Tudor, D. and Williams, A. (2004). Development of a ‘Matrix Scoring Technique’ to determine litter sources at a Bristol Channel beach. Journal of Coastal Conservation, 9: 119-127.

UNEP (2009). Marine Litter: A Global Challenge. Nairobi: UNEP. 232 pp.

UNEP/MAP MEDPOL (2011). Assessment of the status of marine Litter in the Mediterranean Sea. UNEP(DEPI)/MED WG.357/Inf.4, 55 pp.

UNEP/MAP MEDPOL (2015). Updated Report on Marine Litter Assessment in the Mediterranean. UNEP(DEPI)/MED WG.421/Inf.18.

Van Franeker, J.A. and Meijboom, A. (2002). LITTER NSV, marine litter monitoring by Northern Fulmars; a pilot study. Wageningen, Alterra, Green World Research. Alterra-rapport 401, 72 pp.

Van Franeker, J.A. (2005). Schoon strand Texel 2005: onderzoeksresultaten van de schoonmaakactie van het Texelse strand op 20 april 2005. Alterra speciale uitgave 2005/09. Alterra, Texel, 23pp.

Van Franeker, J.A. and Meijboom, A. (2006). Fulmar Litter EcoQO Monitoring in the Netherlands 1982-2004 in relation to EU Directive 2000/59/EC on Port Reception Facilities. Report for the Ministry of Transport, Public Works and Water Management (VenW), contract nr GTL/ZH/2.53.2.5012. Alterra, Texel, 41pp.

Vauk, G. and Schrey, E. (1987). Litter pollution from ships in the German Bight. Marine Pollution Bulletin, 18: 350-352.

Vlachogianni, Th., Zeri, Ch., Ronchi, F., Fortibuoni, T., Anastasopoulou, K. (2016). Marine Litter Assessment in the Adriatic and Ionian Seas, DeFishGear project.

WWF (2011). Ecological effects of ghost net retrieval in the Baltic Sea. Pilot Project: Collecting ghost nets. Final Report, 30pp. ISBN: 978-83-60757-49-9

Zubris, K. A. V. and Richards, B. K. (2005). Synthetic fibers as an indicator of land application of sludge. Environmental Pollution, 138: 201-211.

List of abbreviations and definitions

CSO	Combined sewer overflows
EU	European Union
ICGML	Intersessional Correspondence Group on Marine Litter
ISPRA	Italian National Institute for Environmental Protection and Research
MAP	Mediterranean Action Plan
MEDPOL	Marine pollution assessment and control component of MAP
MCS	Marine Conservation Society
ML	Marine Litter
MSFD	Marine Strategy Framework Directive
OSPAR	Oslo/Paris Convention (for the Protection of the Marine Environment of the North-East Atlantic)
TGML	MSFD Technical Group on Marine Litter
UNEP	United Nations Environment Programme
WWPT	Waste Water Treatment Plants

List of figures

List of tables

Annex I - Marine Conservation Society full list of litter items and attributed sources (MCS, 2013)

Public Litter:	4/6 pack yokes, plastic bags (including supermarket), plastic drinks bottles, plastic food containers, plastic toiletries bottles, plastic caps / lids, cigarette lighters / tobacco pouches, combs / hair brushes / sunglasses, crisp / sweet / lolly / sandwich wrappers, cutlery / trays / straws / cups, pens, plastic shoes / sandals, shotgun cartridges, toys / party poppers / fireworks / dummies, polystyrene fast food containers / cups, balloons / balloon string, clothing / shoes / beach towels, disposable barbecues, metal bottle caps, metal drink cans, foil wrappers, household batteries, animal faeces in bags, animal faeces not in bags, paper bags, cartons / tetrapak (e.g. fruit juice), cigarette packets, cigarette stubs, paper cups, newspapers / magazines, corks, ice lolly sticks / chip forks, glass bottles, glass pieces.
Fishing:	Fish boxes, fishing line, fishing net and net pieces <50cm, fishing net and net pieces >50cm, floats (fishing buoys) / reels, plastic lobster / crab pots and tops, string and cord diameter <1cm, polystyrene buoys, polystyrene fish boxes, rubber boots, heavy duty gloves, tyres with holes, fishing weights / hooks / lures, metal lobster / crab pots and tops, wood lobster / crab pots and tops.
Sewage-Related Debris:	Condoms, cotton bud sticks, nappies, tampon applicators / tampons, toilet fresheners, towels / panty liners / plastic backing strips, wet wipes, other sanitary items.
Shipping:	Plastic cleaner bottles, foreign plastic bottles, plastic oil bottles, industrial packaging / crates / sheeting, mesh bags (e.g. vegetable), Rope diameter >1 cm, strapping bands, aerosol cans, metal food cans, oil drums, cartons / purepak (e.g. milk), pallets / crates, light bulbs / tubes.
Fly Tipped:	Traffic cones, tyres without holes / wheels, cloth furnishings, car parts / car batteries, scrap metal / appliances / paint tins, pottery / ceramic.
Medical:	Inhalers, plasters, syringes, other medical items.
Non-Sourced:	Plastic pieces <2.5cm, plastic pieces >2.5cm, other plastics, fibreglass, foam / sponge / insulation, polystyrene packaging, polystyrene pieces <50cm, other polystyrene items, light weight gloves, rubber pieces <50cm, other rubber items, cloth pieces, sacking, other cloth items, wire / wire mesh / metal pieces, other metal items, cardboard, other paper items, paint brushes, wood pieces (not twigs), other wood items.

Annex II - Example of attribution of matrix scoring likelihoods applied to a set of marine litter items on a Swedish beach

	Item Code	Frequency (nr items)	%	Tourism (beach users)	Sewage	Fly tipping - land	Land (run off)	Shipping	Offshore	Fishing
Industrial packaging, plastic sheeting	40	1046	47.2%	UU	UU	UU	U	LL	P	P
4/6-pack yokes	1	327	14.8%	L	UU	UU	U	P	U	UU
Other plastic/polystyrene items	48	310	14.0%	P	UU	UU	U	P	P	L
Rope/cord/nets > 50 cm	32	174	7.9%	UU	UU	UU	UU	P	P	L
Other wood < 50 cm	74	104	4.7%	UU	UU	UU	P	P	P	P
Strapping bands	39	60	2.7%	UU	UU	UU	U	L	L	P
Balloons	49	51	2.3%	L	UU	UU	P	UU	UU	UU
Plastic/polystyrene pieces < 50 cm	46	47	2.1%	L	UU	UU	P	U	P	P
Drinks	4	24	1.1%	LL	UU	UU	P	U	P	U
Bottles	91	22	1.0%	LL	UU	UU	P	U	P	P
Injection gun containers	11	11	0.5%	NC	UU	UU	UU	L	L	P
Cartons/Tetrapacks	62	9	0.4%	L	UU	UU	P	P	P	U
Food incl. fast food containers	6	8	0.4%	LL	UU	UU	P	UU	U	UU
Engine oil <50 cm	8	6	0.3%	NC	UU	UU	U	LL	L	P
Drink cans	78	5	0.2%	LL	UU	UU	P	U	P	U
Other textiles	59	2	0.1%	L	UU	UU	U	U	P	P
Crates	70	2	0.1%	NC	UU	UU	P	LL	P	P
Aerosol/Spray cans	76	2	0.1%	P	UU	UU	P	L	L	P
Corks	68	1	0.0%	L	UU	UU	P	UU	U	U
Pallets	69	1	0.0%	NC	UU	UU	P	LL	P	P
Paint brushes	73	1	0.0%	UU	UU	UU	UU	L	P	P
Light bulbs/tubes	92	1	0.0%	NC	UU	UU	UU	L	P	U

FINAL SOURCE CONTRIBUTIONS							
Scoring system	Tourism (beach users)	Sewage	Fly-tipping (land)	Land (run off)	Shipping	Offshore	Fishing
A	12.4%	0%	0%	12.3%	33.3%	21.1%	20.9%
E	14.3%	1.9%	1.9%	8.0%	45.3%	13.3%	15.5%

LB-NA-28309-EN-N

JRC Mission

As the science and knowledge service of the European Commission, the Joint Research Centre's mission is to support EU policies with independent evidence throughout the whole policy cycle.

EU Science Hub
ec.europa.eu/jrc

@EU_ScienceHub

EU Science Hub - Joint Research Centre

Joint Research Centre

EU Science Hub

Publications Office

doi:10.2788/018068
ISBN 978-92-79-64522-8