Towards a Method for Monitoring Litter Pathways to the Aquatic Environment

Clean Europe Network

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1.0 Introduction

Litter, defined most simply as 'waste in the wrong place', is an extensive environmental problem, affecting both rural and urban areas, land and sea. It has many different types of negative impacts, whether environmental, social or economic. These range from costs incurred for prevention and clean-up (direct costs), to indirect costs such as impacts on the wellbeing of people and wildlife. Our understanding of the scale of the indirect costs is only just taking shape and it is likely that they are orders of magnitude greater than the direct costs.

Once litter has found its way into the environment, it ultimately ends up in the ocean. The accumulation of manmade materials in the ocean is a global environmental issue of increasing concern. Much work has been undertaken and is currently underway to assess the marine litter problem and develop coherent global approaches to tackle it.

An often cited statistic is that 80% of marine litter originates from land based sources. Although the empirical basis for this statistic could be more robust, it is likely to be correct in essence. This true of many litter statistics, because some aspects of the litter problem, such as abundance (rather than the more commonly measured prevalence according to some particular characteristic such as item type or material) are very difficult to measure cost-effectively. Additionally, monitoring effort is rarely standardized and this makes it more difficult to collate data to gain regional, national or global overviews. Also, there are some litter attributes, such as source or pathway, for which there is no robust monitoring methodology.

Dealing with litter once it has become oceanic is more difficult than dealing with litter at source. There are many junctures at which litter abatement measures can be implemented closer to litter sources. This is as true of abatement measures as it is of monitoring, an important part of litter management for which, as already mentioned, fully developed methods are not yet established.

The Clean Europe Network[1] has commissioned this report into the design and feasibility of a method for determining the sources and pathways of litter that finds its way into the freshwater aquatic environment. The aim is to develop a methodology

[1] The Clean Europe Network, launched in 2013, is a platform for EU organizations active in the field of litter to share best practice, research and expertise. In this way common approaches to litter reduction can be developed Europe wide, where this is of benefit. Its members include national NGOs that campaign on litter as well as packaging industry and recycling associations. The network members are:

An Taisce (Ireland)
AVPU – Association des Villes pour la Propreté Urbaine (France)
Der Gruene Punkt (Germany)
Håll Sverige Rent (Sweden)
Hoia Eesti Merd (Estonia)
Hold Danmark Rent (Denmark)
Indevuilbak (Belgium – Flanders)
Keep Baltic Tidy (Baltic countries)
Keep Britain Tidy (England)
Keep Northern Ireland Beautiful
Keep Scotland Beautiful
Keep Wales Tidy
Nederland Schoon (the Netherlands)
Vacances Propres (France)
Pack2Go Europe (EU – supporter)

that is a cost effective and practical way of monitoring litter and directing litter abatement actions that will support the achievement of a 25% reduction target for litter to the aquatic environment. Also in order to support this goal, a standardized litter monitoring approach for litter on land is also being developed by the Clean Europe Network. Commercial & Industrial

The basis of the proposed approach is as follows. Riverine litter is sampled both upstream and downstream of a test area, pre- and post- implementation of litter abatement measures targeted at different sources and/or pathways. This approach is intended to provide a robust empirical attribution of litter to particular sources and pathways. Riverine litter monitoring was chosen as it provides an accessible juncture between diffuse sources and vast sinks at which a sample of litter can be taken that is potentially representative of all land based pathways and sources of litter. This simplifies the design of the methodology making it easier to implement, and reducing monitoring costs. It will also directly produce the necessary data for the achievement of the desired land-based litter targets.

In order to develop this methodology, a literature review (Annex 1) was undertaken to assess

- Known Pathways to the Aquatic Environment,
- Assessment of Local Litter Indicators and Data,
- Monitoring Techniques; and
- Abatement Measures and Sources and Pathways Targetted.

The information gathered in was used to design a fully quantitative methodology (Section 2.3), and assess its feasibility. This includes an examination of how to choose suitable sites for pilot projects.

Thirdly, it is desired to produce a toolbox to help public authorities implement this monitoring approach. The toolbox is comprised of three progressive stages, each with a contribution to make towards the objective of identifying sources and pathways of litter and litter abatement. This allows public authorities to configure an approach suitable to the resources available to them, based on one or more stages. This is discussed in Section 3.0, and this will be developed and refined in 2015 as well as over the course of the pilot projects, in conjunction with input from stakeholders.

The Clean Europe Network hopes to use the methodology developed here in a series of four pilot projects in European locations in 2016-17.

1.1 Impacts of Litter

We have drafted a brief orientation for public authorities with regards to the latest research on the economic, social and environmental costs of litter. This is to make the case for the importance of engaging with the problem of litter, and encourage public authorities to use the toolbox.

Litter is much more than a form of “aesthetic pollution”, offending the aesthetic sensibilities of the beholder. It incurs considerable costs to clean up and has much wider reaching effects on communities and the environment. It must be borne in mind that the ocean is the final destination for riverine litter, and there is no way to recover the majority of this litter. For this reason, the accumulation of a synthetic material such as plastic in the environment has been described as one of the most ubiquitous and long lasting changes mankind has effected on the earth's surface; and this in just a half century.[2] Estimates of the contribution of land based litter to marine litter range from 80%-98% in Europe, based on data from the International Coastal Clean-up.[3]

Public authorities are well aware of the considerable costs incurred by cleaning up litter. A few examples of the cost of street cleansing provision are as follows:

- Netherlands: 250 million euro[4]
- England: £1bn[5]
- Scotland: £100m[6]

Although only a part of these budgets are devoted to picking up litter, it is still likely to be considerable proportion; for Scotland, a study estimated that of the street cleansing budget, £53m was spent dealing with litter and flytipping alone.[7]

There are many other costs incurred by litter beyond simply having to clean it up. These include:

- Local disamenity,
- Impacts on property values,
- Impacts on mental health,
- Litter as a signal of breakdown of social control and so a causal factor in crime,
- Fires (wildfires and vandalism),

[2] Barnes, D.K.A., Galgani, F., Thompson, R.C., and Barlaz, M. (2009) Accumulation and fragmentation of plastic debris in global environments, *Philosophical Transactions of the Royal Society B: Biological Sciences*, Vol.364, No.1526, pp.1985–1998

[3] Ocean Conservancy (2012) *The Ocean Trash Index - Results of the International Coastal Cleanup (ICC)*, 2012, http://www.oceanconservancy.org/our-work/marine-debris/2012-icc-data-pdf.pdf

[4] Deloitte (2010) *Rapport Kostenonderzoek Zwerfafval Nederland (Report on the Cost of Litter in the Netherlands)*, 2010, http://www.vng.nl/files/vng/vng/Documenten/Extranet/Milieu/20100715_Kostenonderzoek_zwerfafval_Deloitte.pdf

[5] Keep Britain Tidy (2014) *Which side of the fence are you on?*, 2014, http://www.keepbritaintidy.org/Documents/Files/Campaigns/WSOTFAYO-report-web.pdf

[6] Keep Scotland Beautiful (2012) National Spring Clean: Community Action for Safe and Healthy Neighbourhoods - Review 2012, 1 November 2012.

[7] http://www.zerowastescotland.org.uk/content/scotland%E2%80%99s-litter-problem-infographic-0

- Personal injuries; and
- Vermin.

A study into these 'indirect costs' of litter in Scotland estimated that these could potentially be an order of magnitude greater than the clean-up costs.[8]

Much impact evaluation has focussed on litter in the marine environment. The first study that attempted to monetize the direct and indirect financial impacts of plastic marine debris estimated a cost of $13bn.[9] They concluded that marine pollution is the most significant downstream impact of plastics. Components of cost included economic losses incurred by fisheries and tourism and time spent cleaning up beaches, plus impact on marine species (using willingness to pay studies on value society puts on marine species). This accounts for 17% of total lifecycle impacts; but there is a wide range of the proportion of total lifecycle costs attributable to marine impacts of debris in different sectors from 20% in the restaurant sector to <1% for the automobile sector. Marine debris accounts for 42% as a proportion of end-of-life impacts of plastics.

To give a little more detail regarding the impacts of litter once it reaches the sea, we reproduce here the list of impacts drafted by UNEP/IOC in their guidance on marine litter monitoring:[10]

- Environmental
    - Entanglements and ghost fishing,
    - Ingestion (intestinal blockage, malnutrition and toxicity),
    - Blockage of filter feeding mechanisms from small particulate (neustonic) plastic debris,
    - Physical damage and smothering of reefs, seagrasses, mangroves; and
    - Potential to vector marine pests including invasive species.
- Social
    - Loss of aesthetics and / or visual amenity,
    - Loss of indigenous values,
    - Antagonism against perceived polluters; and

[8] Eunomia Research & Consulting (2013) *Exploring the Indirect Costs of Litter in Scotland*, May 2013

[9] UNEP, Trucost, and The Plastic Disclosure Project (2014) *Valuing Plastic. The Business Case for Measuring, Managing and Disclosing Plastic Use in the Consumer Goods Industry*, accessed 30 June 2014,
http://www.trucost.com/_uploads/publishedResearch/Valuing%20plastics%20final%20report.pdf

[10] UNEP (2009) *UNEP/IOC Guidelines on Survey and Monitoring of Marine Litter*, 2009

- Perceived or actual risks to health and safety.

- **Economic**
  - Cost to tourism (loss of visual amenity and obstruction to beach use),
  - Cost to vessel operators (downtime and damage due to entanglements),
  - Losses to fishery and aquaculture operations due to damage or entanglements; and
  - Costs for clean-up, animal rescue operations, recovery and disposal.
- **Public Safety**
  - Navigational hazards (loss of power or steerage at sea is potentially life threatening),
  - Hazards to swimmers and divers (entanglements),
  - Cuts, abrasion and stick (puncture) injuries,
  - Leaching of poisonous chemicals; and
  - Explosive risk (gas cylinders frequently wash ashore in northern Australia, similarly dumped military ordinance is a problem off the Irish coast).

In addition, the impacts of microplastics are becoming clearer with increasing research effort devoted to it. Microplastics accumulate persistent organic pollutants and concentrate them within the marine environment. These are ingested by animals at the bottom of the food chain. It has been demonstrated that plastics which have accumulated pollutants in the environment can induce hepatic stress in fish and may induce changes in the hormonal system.[11]

Tackling land based litter and keeping track of riverine litter may represent the best junctures at which to stem the influx of litter before enters ocean. The closer to the source, the more effective prevention and mitigation will be and the more cost effective.

1.2 Context – Legislation and Research

In terms of the legislative context of this project, there has been recent progress in Europe on the establishment of quantitative targets for the reduction of marine litter.

[11] Rochman, C.M., Hoh, E., Kurobe, T., and Teh, S.J. (2013) Ingested plastic transfers hazardous chemicals to fish and induces hepatic stress, *Scientific Reports*, Vol.3,Rochman, C.M., Kurobe, T., Flores, I., and Teh, S.J. (2014) Early warning signs of endocrine disruption in adult fish from the ingestion of polyethylene with and without sorbed chemical pollutants from the marine environment, *Science of The Total Environment*, Vol.493, pp.656–661

This may be followed in due course by land based litter targets. The advantage of land based litter targets is that they will be more practical to monitor, and so might lend themselves to more effective management.

Marine litter targets currently under consideration include those that will allow the achievement of "Good Environmental Status" regarding marine litter, an obligation deriving from the Marine Strategy Framework Directive. These are:

- Trends in the amount of litter washed ashore and/or deposited on **coastlines**, including analysis of its composition, spatial distribution and, where possible, source,
- Trends in the amount of litter in the **water column** (including **floating at the surface**) and deposited on the **sea- floor**, including analysis of its composition, spatial distribution and, where possible, source,
- Trends in the amount, distribution and, where possible, composition of **micro-particles** (in particular micro- plastics); and
- Trends in the amount and composition of litter **ingested** by marine animals (e.g. stomach analysis)

Of note is the desire to assess source where possible.[12]

Individual Member States have set some targets based on these indicators, such as:

- The reduction of visible beach litter,
- Less than 10% of Fulmars have more than 0.1g of plastic in their stomachs (OSPAR EcoQO indicator),
- Reduction of land and sea-based waste sources, such as waste from beach tourists, ships, and reduced inflow from rivers and sewers,[13]
- The reduction of litter 'by catch' caught during fishing

It is of note that these are mostly not quantitative targets.

A quantitative "aspirational" target on marine litter has been proposed in the European Commission's Communication on the Circular Economy (2014).[14]

The proposal is for

> *"reducing marine litter by 30 % by 2020 for the ten most common types of litter found on beaches , as well as for fishing gear found at sea , with the list adapted to each of the four marine regions in the EU"*

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[12] European Commission (2010) *Commission Decision of 1 September 2010 on criteria and methodological standards on good environmental status of marine waters (notified under document C(2010) 5956)*

[13] InterSus, University of Trier, Milieu, UBA, and COM (2013) Issue Paper to the 'International Conference on Prevention and Management of Marine Litter in European Seas'

[14] European Commission (2014) Towards a Circular Economy: A zero Waste Programme for Europe. COM(2014)398

It also states that

> *"A second stage of the reduction target will be developed in due time, based on further analysis of the reduction potential from other land- and sea-based sources"*

The Marine Strategy Framework Directive itself states:

> *"By 15 July 2012, Member States had to make an initial assessment on the state of the marine environment and define 'Good Environmental Status' (GES) together with environmental targets and associated indicators. By 15 July 2014, they should have put a monitoring programme in place and by 2015, they should have their Marine Strategies in place."*[15]

Clearly, for marine litter, a Europe wide monitoring system is not yet in place but it is a clear indication that there should be one, and efforts on this are underway. Monitoring is essential if any target is to be met.

Most monitoring effort so far has been undertaken in the marine context; three approaches are possible, with an onus so far on the first two.

- Beach surveys,
- At sea surveys; and
- Estimates of amounts entering the sea

The only global, standardized approach implemented so far is a beach survey, the International Coastal Clean-up. On land, various NGOs and local governments have developed methods for assessing litter for the improvement of cleanliness of public spaces. A few academic studies have been published on riverine litter. For a detailed review, please refer to Annex 1.

Regarding litter, there are number of different attributes which could be used to monitor abatement or direct abatement measures:

- Abundance,
- Composition,
- Impacts,
  - Environmental,
  - Economic,
- Distribution (from source to sink),
  - Inland,
  - Rivers,
    - Surface,

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[15] European Commission (2008) *Directive 2008/56/EC of the European Parliament and of the Council Establishing a Framework for Community Action in the Field of Marine Environmental Policy (Marine Strategy Framework Directive)*

        - Water Column,
        - River bed,
        - Sediment,
    - Beaches (buried in sand),
    - Beaches (surface),
    - Sea,
        - Surface,
        - Water Column,
        - Sea floor,
        - Sediment,

And all of these can be measured for the following litter attributes, not limited to

- Item type,
- Material,
- Source; and
- Pathway,

in a variety of units. The number of these attributes alone and in combination gives instant insight into why litter research activities vary a great deal in terms of scope and methodology, and so why, without coordinated effort, standard methods will not emerge.

Source and pathway are particularly neglected attributes, though knowledge of them would be of great use for directing abatement measures. This is in great part because of the inherent difficulty in investigating them using the more common litter monitoring methods in use.

The 2014 Work Program for the Clean Europe Network addresses various gaps in the legislative and research contexts. One project is to review all land based litter monitoring methodologies and develop a prototype for a common European monitoring system.

Another goal is to see a land-based litter reduction target adopted by EU Member States of a 25% reduction of land based contributions to marine litter. CEN also plans to support the achievement of that reduction target.

This project feeds into these goals. It also should make comparable contributions to achieving marine litter targets, by providing a juncture for monitoring and managing litter before it ends up in the sea.

2.0 Methodology for Quantitative Field Research

The aim of this Section is to propose a method for pilot projects for the monitoring of litter, it sources and pathways to the aquatic environment. How a suitable pilot project site might be chosen is examined, as well as the cost and feasibility of the proposed method.

2.1 Method Overview

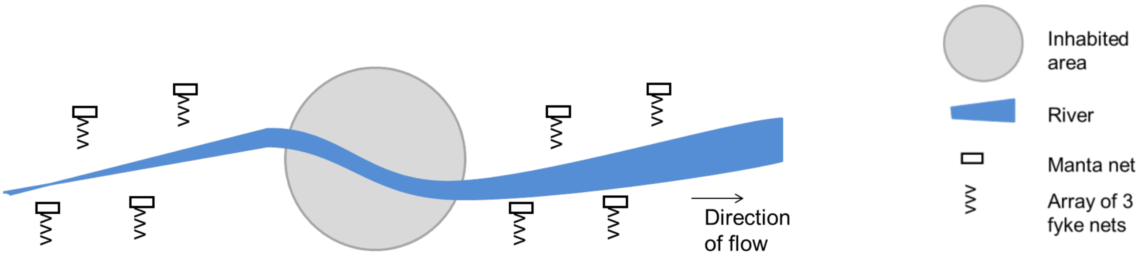
The aim of the pilot projects is to monitor litter, its sources and pathways to the aquatic environment, in different European locations. The strategy of the approach proposed here is to implement abatement measures targetted at different sources and pathways and then assess their impact on litter in the freshwater aquatic environment by monitoring riverine litter before and after implementation.

A diagram giving an overview of the process of carrying out a pilot project is presented in Figure 1.

Figure 1: Pilot project overview

Monitoring of riverine litter is planned for two junctures in the pilot projects (Step 2 and Step 5). The first is carried out before the implementation of abatement measures. It can be considered a baseline for future comparisons. Already, this is likely to provide a locality with new information regarding its contribution to litter in the aquatic environment. Secondly, monitoring is intended to be carried out post abatement measure implementation. This should provide an indication of how effective the measures were, but also, if they are sufficiently targetted to a chosen source or pathway, an indication of the contribution of that particular source or pathway to aquatic litter. The sampling strategy is represented in Figure 2.

Figure 2: Diagram to illustrate sampling design



This configuration of net deployment is repeated at an interval of days/weeks to complete sampling upstream and downstream, giving 16 net array deployments. This would be done both before and after abatement techniques are applied, giving 32 net array deployments in one testing cycle. Manta nets sample the surface of the water for floating litter. Fyke nets sample in the water column. See Section 2.3.1.1 for more details.

2.2 Method for Choosing Pilot Project Sites

The general characteristics of a suitable pilot site are as outlined below. Some of the aspects have been described in the methodology section; here the desired or ideal preconditions are recapped and available sources of data on each aspect are discussed.

- Suitable location relative to the river
- There should be suitable monitoring sites upstream and downstream of the pilot site
- Sites that have high vulnerability to littering
- Sites that have similar vulnerability to littering
- Sites that have similar vulnerability profiles with regard to sources and pathways of litter (allows better comparability between pilot sites
- Sites that allow a complementary selection of sources/pathways to be targeted to be chosen
- Sites that don't have many abatement measures in place for the source/pathway to be tested
- Sites that are not too large so that implementing abatement measures is affordable and appealing
- Localities that are willing and able to implement litter abatement measures
- Localities that are able to access and part fund monitoring resource.

2.2.1 Location Relative to River

The location of the pilot site relative to the river should be such that upstream and downstream monitoring sites can be found which capture the litter input of that pilot location, and not other locations outside the pilot that have their own potentially significant litter inputs. The monitoring sites should ideally encompass a stretch of river that drains as close to 100% of the pilot locality as possible. More information regarding suitable locations is provided in Section 2.7.

A pilot site should be also be an area of a public authorities' jurisdiction in contrast versus a whole river catchment.

Googlemaps (map view) provides information regarding public authority boundaries, which may be supplemented by Google searches regarding public authority divisions in different European countries to confirm the structure of local government and corresponding geographical boundaries,

Googlemaps (also, map view) provides information about the situation of an inhabited area relative to a waterway. A useful starting point for sites associated with significant waterways are the EEA lists of rivers in Europe by catchment area and country.[16] This provides a focus for examining the suitability of inhabited areas along rivers while tracing the path of the river on Googlemaps.

2.2.2 Availability of Suitable Monitoring Sites

Suitable monitoring sites have the following characteristics:

- Not too deep to allow fyke nets (see Section 2.3.1.1) to be staked to the river bed,
- Wide enough so that net deployment can be carried out without interfering with waterway navigation, and so waterway navigation does not create waves that interfere with nets,
- With some hard standing for the tethering of manta nets (see Section 2.3.1.1) to the crane assembly,
- Not tidal,
- Not near point sources of litter (e.g. municipal drain outfall, lakes, tributaries, inhabited sites, industrial sites, highways.),
- Not near piers, jetties or weirs that obstruct water or litter flow,
- With suitable access for a vehicle and a safe place to park; and
- Have the consent of the relevant authorities.

A key tool for assessing suitable monitoring sites is Google Earth or Googlemaps (satellite view). Site visits are also important. Google should be also be useful for

[16] http://www.eea.europa.eu/themes/water/european-waters/rivers/major-rivers-in-european-countries

finding out the tidal limits of the rivers being screened. Determining who the relevant authorities are will require research with the relevant public authorities.

2.2.3 Vulnerability to Littering

Ideally for the piloting of this methodology, areas should be selected that are particularly vulnerable to littering generally or to littering from a particular source or pathway, for a couple of reasons. Firstly, convincing public authorities to participate in a pilot will be easier if they perceive themselves as having particular issues with litter, whether in general or from a particular source. Additionally, it will be easier to detect differences in litter input pre and post abatement measure if the absolute magnitude of change is greater.

Choosing pilot locations that have similar vulnerabilities overall to littering would help to make data more comparable between sites; however this may be rather hard to achieve.

One way to assess overall vulnerability to littering would be to use the litter indicator approach developed by Öko, on the basis of national and regional publicly available datasets. The indicators they used were reviewed in the course of the literature review (Section A.1.2), but for convenience the indicators they used are listed in Table 1. For the purposes of this study, as the focus is land based litter, the “Marine transport of freight” data may not seems so relevant, but it does include inland ports also, so should still be included in the analysis. Additional data on the weight of goods carried on inland waterways in units of weight unloaded in a particular region could also be used, but it should be noted that this is only available on a country level and not a port by port basis.

Table 1: Litter Indicators for National Assessment

Litter indicators
Municipal waste management (groupings based on recycling, incineration and landfill rates as representative of general waste capture and management standards)
Population density – i.e. *Inhabitants in catchment area, People in the administrative area bordering directly to the shore* - in combination with - groups* for municipal waste management
Nights spent by residential and non-residential in tourist accommodation establishments - in combination with - groups for municipal waste management
Marine transport of freight; loaded and unloaded - in combination with - groups for municipal waste management
Plastic packaging waste disposed of - in combination with - groups for municipal waste management

*"groups" refers assessment Öko made of countries as to quality of solid waste management for countries - split into 4 groups, based on %recovery and %incineration

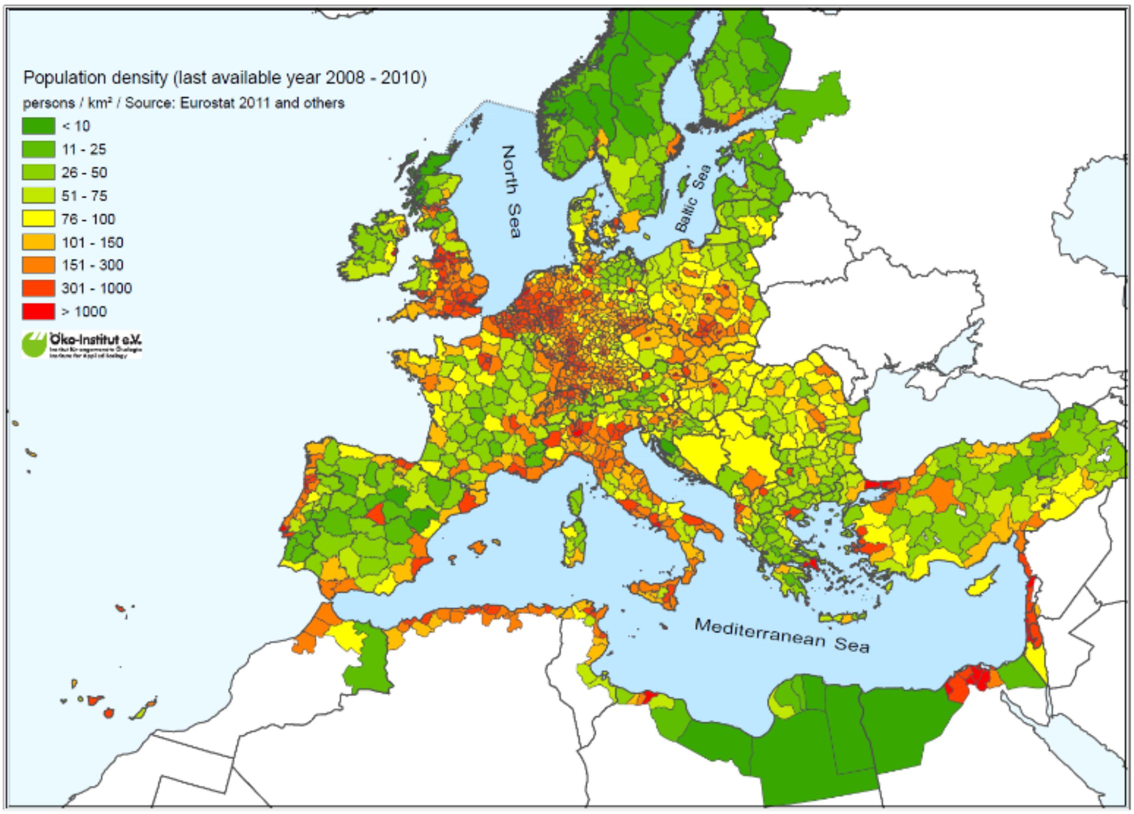
Each indicator was represented Europe wide in a series of 5 maps that can be used to assess a location's litter vulnerability (reproduced in Figure 3). Locations that are assessed as being more vulnerable to littering should be prioritized over those less vulnerable to littering. Ideally the maps could be integrated to produce a single map for 'litter vulnerability'. This integration could be done in a number of ways. One would be to convert the underlying data into a ranking for each indicator, by country, or by NUTS2 region if possible. The ranks could then be summed for each country or region, giving a final country by country or region by region litter vulnerability score. Alternatively, each indicator could be expressed as a proportion of an arbitrary scale, e.g. from 1-10, 1 being low litter vulnerability and 10 being high litter vulnerability. Scores for each indicator could then be summed to give an overall litter vulnerability score.

The data available in Öko study for the EU countries is presented in tabular format in Table 2, just for illustrative purposes. There are only 20 countries for which they have presented some of the indicators in a tabulated format, and it is on a country by country basis. In order to integrate this properly, base data should be obtained and formatted so information is represented in comparable geographical units, whether country level or NUTS 2 or NUTS 3 level. A calculation should then be performed in either of the two ways suggested above, and then this data can be represented visually using GIS mapping.

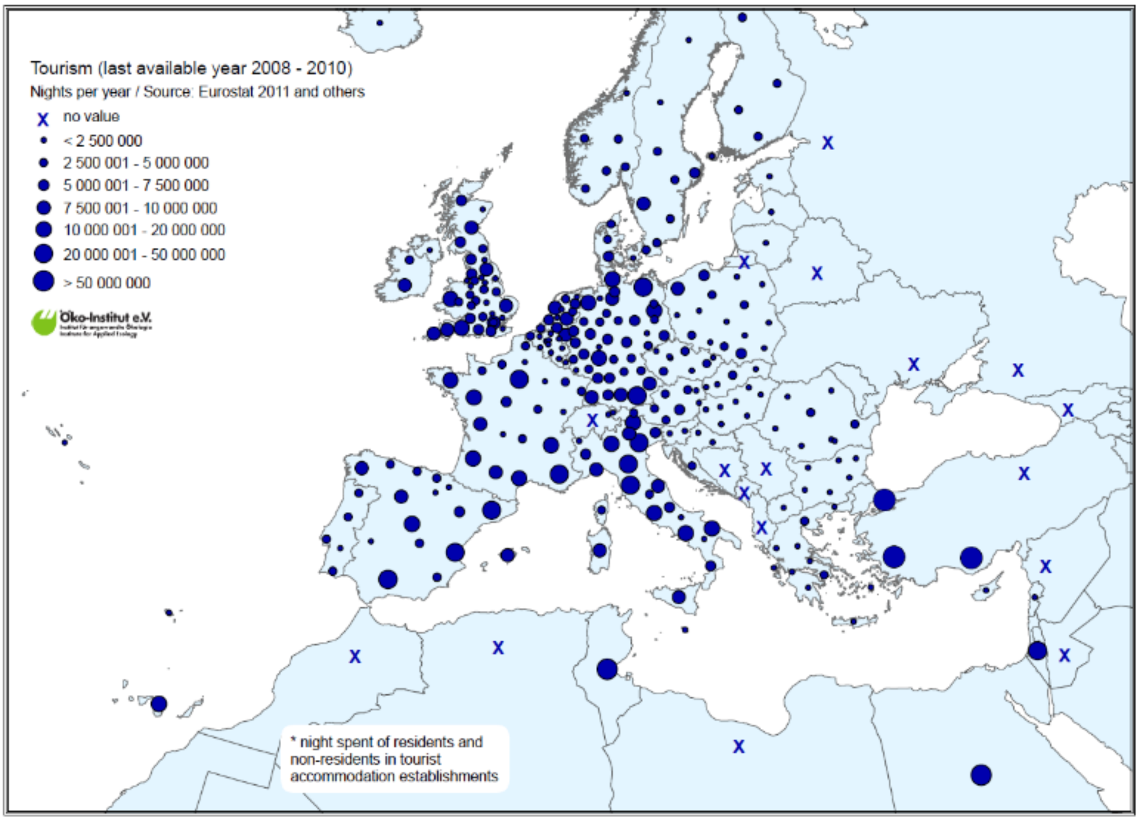
If this integration is not carried out, the last possible method would be to assess sites already selected on all the other criteria discussed in Section 2.2 such as location relative to river, or ability to implement abatement measures, for relative litter vulnerability using the litter maps below, rather than to look Europe wide and choose sites based within areas that have the highest litter vulnerability.

Figure 3. Maps for Assessing Litter Vulnerability from Öko-Institut Study.

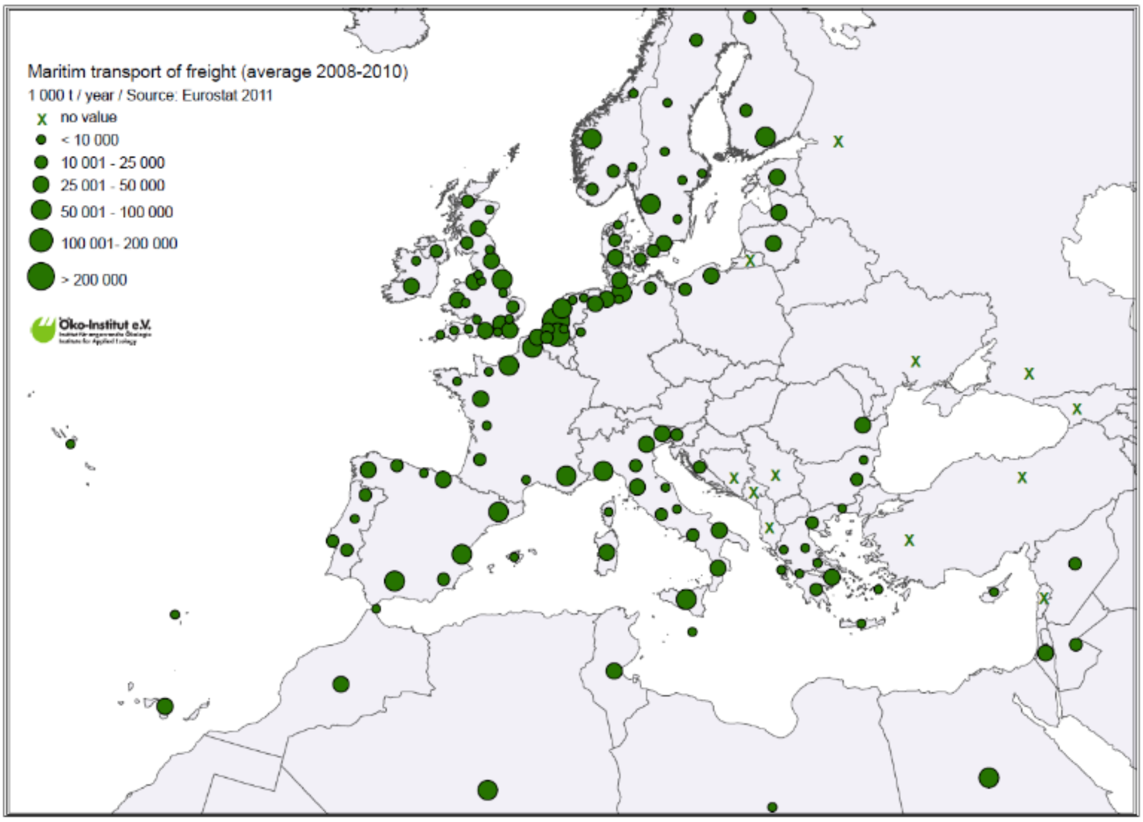
14.1 Population density of administrative areas (NUTS 3); Source: Eurostat and other data sources, consolidated by Öko-Institut 2011



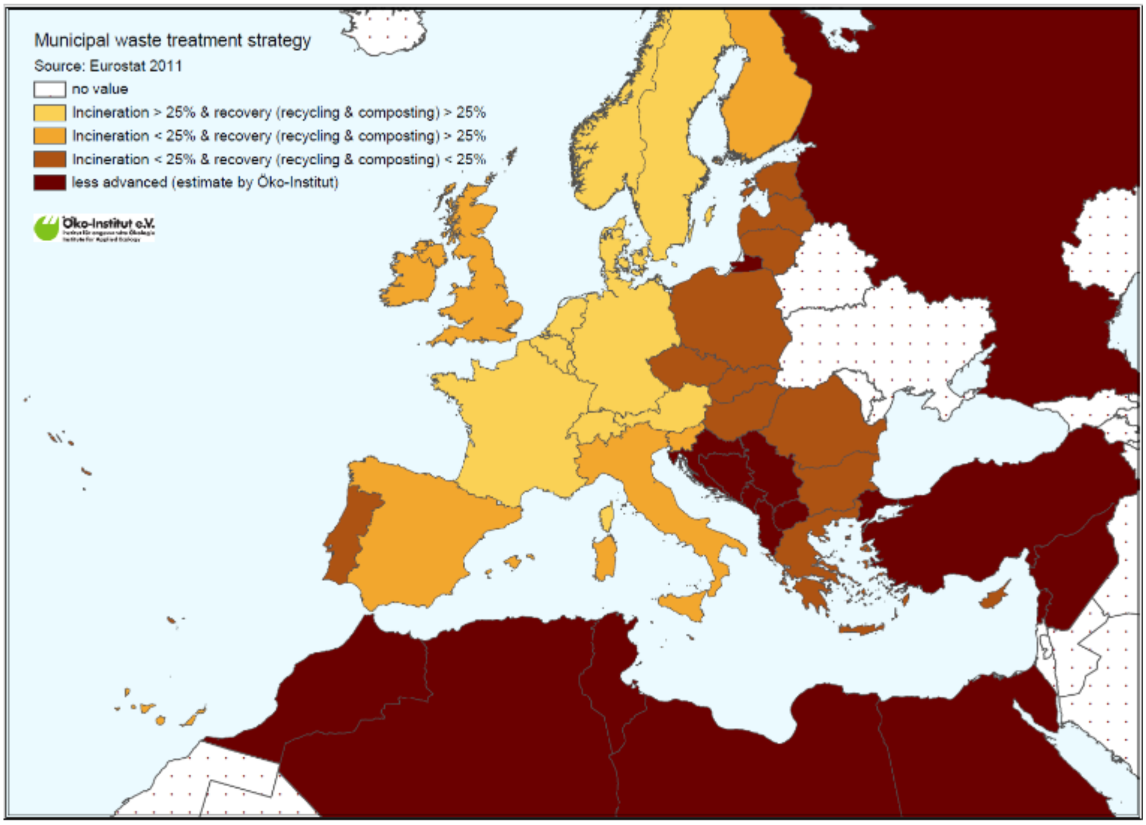
14.2 Nights spent by residential and non-residential in tourist accommodation establishments (NUTS 2); Source: Eurostat (2011) and other.



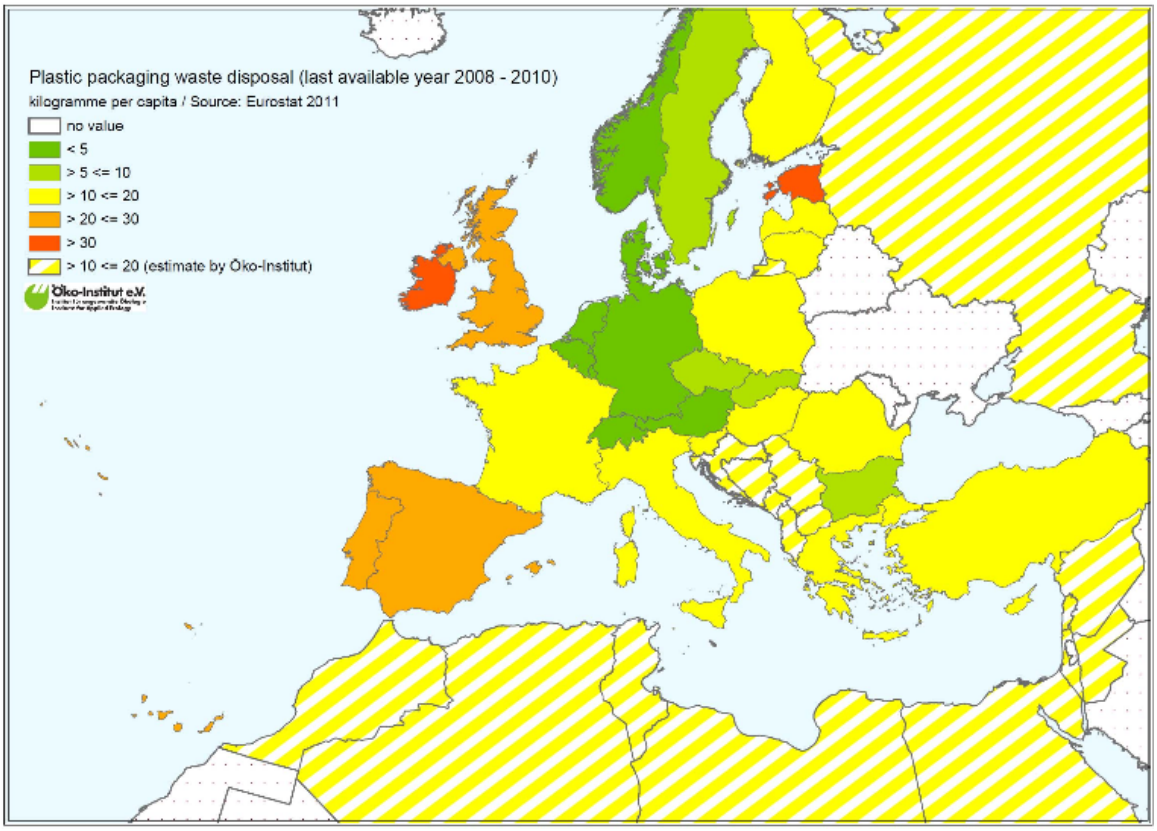
14.3 Maritime transport of freight: Total goods loaded and unloaded, average 2008 – 2010; Source: Eurostat (2011) and other



14.4 Current Waste Management; Source: Eurostat (2011) and estimates.



14.5 Plastic packaging waste disposed off; Source: Eurostat (2011) and estimates.



Source: Öko-Institut (2012) *Study on land-sourced litter in the Marine Environment*, 2012

Table 2: Litter Indicator Data for EU countries

Country	Different municipal waste management strategy	Calculated level of plastic packaging waste to be disposed of in 2008 [kg per capita and year]	Commercial freight at ports (unload and upload) 1000 t / year, average 2008 - 2010
Belgium	1	3.9	184,593
Croatia	4	12.5	/
Cyprus	3	17.8	6,004
Denmark	1	0.7	77,337
Estonia	3	41.5	29,339
Finland	2	11.1	15,991
France	1	13.7	84,760
Germany	1	1.2	184,899
Greece	3	18.8	89,531
Italy	2	14.3	395,262
Latvia	3	12.1	49,179
Lithuania	3	12.8	29,498
Malta	3	/	3,217
Netherlands	1	1.2	419,444
Norway	1	4.4	/
Poland	3	12.0	40,520
Slovenia	2	8.1	12,377
Spain	2	20.9	213,805
Sweden	1	7.8	128,642
UK	2	24.4	427,054

Source: Öko-Institut (2012) *Study on land-sourced litter in the Marine Environment*, 2012

It would be extremely useful, for the purpose of assessing litter vulnerability, to have the results of a standardised EU method for assessing the severity of land based littering; however that is a method being developed concurrently with this one by the Clean Europe Network. Perhaps by the time the pilot sites are being selected, some data will be available from the land based litter monitoring method.

2.2.4 Ability to Implement Litter Abatement Measures

A precondition for the selection of a pilot site is that the locality should be willing and able (in terms of adequate capacity and funding) to implement litter abatement measures. Especially convenient in this regard would be a locality where it is already known that a litter abatement measure will be implemented, so that monitoring can occur before and after implementation. The Clean Europe Network and its numerous contacts will be helpful for determining where in Europe these situations exist.

Sites that don't have many abatement measures in place already, would also be preferable, as they will be both perhaps most eager to engage with the piloting process, and will be, in theory, able to achieve greater reductions in litter, which are therefore, better detected. Additionally, this will give a truer picture of the contribution of a particular source or pathway to aquatic litter.

The need to find partners willing to implement abatement measures may place an upper limit on the desirable size of a pilot site. Smaller towns may find it more affordable and appealing to actually implement abatement measures. A city might find it a commitment of a scale that may not be appropriate taking into account their other commitments.

Abatement measures and how to choose them are discussed further in Section 2.6, and a full database of abatement measures is presented in Section A.1.4 and Annex 3.

2.2.5 Potential for Mobilisation of Monitoring Resource

It is important that localities should be able to access, support and part fund monitoring resource.

Whether a locality is able to access monitoring resource in a timely way depends on the monitoring method chosen and how it is implemented. The more quantitative the method, the more resource intensive it is. Also, the greater the likelihood that specialist input will be needed. As very few people are involved in riverine litter monitoring in Europe, this might represent a resource constraint. Student resource can be used to provide affordable labour.

The involvement of public authorities will require support in terms of manpower. This is necessary particularly for the stage where a localities' vulnerability to litter from different sources and pathways is assessed. This may take a significant amount of resource to track down and assemble the relevant data.

The involvement of public authorities will also require support in terms of funding. It is unlikely that the Clean Europe Network will be able to obtain complete funding for the pilot projects and it would be necessary for the remainder to be contributed by participating local authorities.

2.3 Monitoring Methodology

A literature review of different monitoring techniques (see literature review, Section A.1.3) was used as a basis for the design of a method for monitoring litter in the freshwater aquatic environment. This fully quantitative monitoring methodology takes the form of riverine sampling in the water with nets, and it is designed with the intention of producing high quality, robust datasets.

To this end, it records litter count, weight and composition and allows an estimate of abundance by standardizing the samples to throughput of water. Different net types are used to ensure that samples are as representative of riverine litter as possible. Sampling is carried out at upstream and downstream locations, at comparable times of year for both the before and after measurements.

In addition to these methodological features, both spatial and temporal repeats further ensure the sampling is as representative as possible, given the unpredictability of litter distribution.

2.3.1 Sampling Equipment

The choice of sampling equipment depends on:

- Where in the river cross-section sampling is taking place. This determines the type of net (e.g. manta net versus submerged net)
- The focus of the study in terms of the size of litter. One mesh size cannot cater appropriately for the whole size spectrum of litter because:
    - there is a trade-off between mesh size and the length of sample time (finer nets get blocked faster by silt and algae); and
    - the size distribution of riverine litter is likely to be heavily skewed towards smaller sizes, meaning that macro litter is less abundant than micro and meso litter.

This means that if a reasonable sample size for macro litter is to be obtained, the nets must be deployed for a longer period, and this needs larger mesh sizes to be done practicably (i.e. without having to empty and clean nets every 0.5 to 4 hours). Sampling for microlitter and macrolitter is challenging to carry out simultaneously.

2.3.1.1 Net Type (Location in river cross-section)

Shape, material and buoyancy affects where litter is found within a river. Flexible, film-like litter, tends to stay mixed in with the water column. Heavy materials (glass, metal, denser plastics) without trapped air pockets, may sink and travel slowly along the river bottom if they do not become completely embedded in sediment. Therefore it is important to be aware of the different biases that different sampling methods, or the decision not to use certain sampling methods, would introduce.

Litter sampling within the river bed would require a great deal of extra equipment, and there has been very little work done to base a method on. Dredging would involve the complication of need to measure litter accumulation – by first cleaning a section of riverbed of litter, and then waiting an extend time period, before measuring litter again. It is considered that in this case, the increased accuracy of the data provided may not warrant the extra expense and risk of using such a completely untested and challenging method.

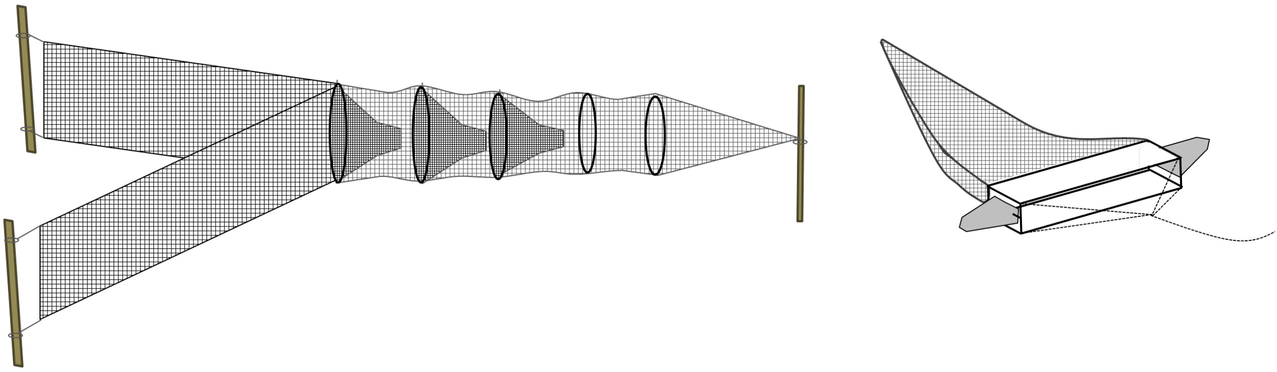
We also note the experiences from the DG Env Riverine Litter pilot, where considerable heterogeneity (unevenness) of litter distributions in the river was felt to undermine how representative stationary sampling was. This can be mitigated in a number of ways, and in terms of net type, use of booms in conjunction with manta nets, and using an array of fyke nets side by side with extended "wings", funnelling objects into the net, would help extend the area sampled.

For the pilot projects, we propose to use two different types of nets (Table 3, Figure 4) in order to provide coverage of the river cross section by sampling floating litter in the river surface or close to it (within ~15cm of surface) with manta nets, as well as sampling suspended litter a fixed distance from the river bed with fyke nets.

Table 3: Equipment - Nets

Name	Description	Sample time	Positioning	Net size [Mesh size]
Manta net with boom	This net is for sampling surface floating macro litter	3 days	Water surface	30cm x 1m x 2m (H x W x L); [1cm]
Modified fyke net	This net is for sampling macro litter in the water column. Arrays of 3 fyke nets maximize sample size. 'Wings' join the nets and extend area sampled. Removal of internal funnel component so wildlife can't be trapped.	3 days	Water column, fixed distance to river bed	50cm diameter, 2 m length, [1cm]

Figure 4: Sampling Nets



a. Fyke net b. Manta/neuston net

2.3.1.2 Mesh Size (Size limits, sample time and sample size)

For this project, the focus is macro litter (greater and equal to 2.5cm, the maximum dimension of a cigarette butt.

There are some sources of litter (industrial) that produce slightly smaller sized litter (nurdles, plastic pellets used in plastics manufacture – around 3 - 5 mm) without fully entering into the realm of microplastics which are not the focus of this study. Although this study would be more representative of the sources and pathways of litter to the aquatic environment if we can include nurdles, it would require much more resource. This is because different types of nets (around 1-2 mm mesh size) are needed and shorter sample times (30 seconds to a few hours, depending on the amount of algae and silt in the water) requiring constant attention. Therefore an "add-on" method has been developed (see Section 2.3.1.3) for the purpose of looking at smaller litter, though we consider it optional relative to the 'core' method, to be used only when there is a specific need.

So, to simplify the monitoring design we propose to restrict the sampling to litter >2.5cm. Accordingly, we propose a mesh size of ideally around 1cm, thought to be adequate to catch a good sample of cigarette butts, and allowing a longer sampling time for litter >2.5cm. As per Morritt et al, who used fyke nets of relatively large mesh size, initially we would propose a sample time of three days.

In terms of upper sample size limits, it is likely that the sampling nets will impose an upper size limit of around 50 cm for fyke nets. The upper limit will be larger for manta nets (especially if deployed with booms). Care should be taken that upper bars do not constrain the sampling ability of manta nets for medium-large objects, and that the side floats are able to suspend this at a decent height above the water (around 15cm – most floating items float with the majority of their bulk under the surface of the water).

2.3.1.3 Sampling for smaller sizes of litter

Microplastics are usually sampled down to 0.333mm, the standard smallest mesh size for a sampling net. This kind of net can normally be deployed for 30 seconds – 30 mins, depending on the state of the water in terms of algae and silt. As per the DG Env Riverine Litter pilot, drag can be monitored and the sample time curtailed when it becomes too great.

Table 4: Equipment - nets for sampling smaller litter sizes

Name	Description	Sample time	Positioning	Net size [Mesh size]
Manta net	This net is for sampling surface floating litter all the way down to microlitter.	Up to 0.5 hours	Water surface	50cm x 15cm [0.333mm]
Submerged net	This net is for sampling microlitter in the water column	Up to 0.5 hours	Water column	50cm x 15cm [0.333mm]

Other elements of the methodology are the same as for macro litter. Because of the much shorter sample time however, a number of technical repeats (for example, three repetitions) can be carried out to increase the sample size of micro litter.

2.3.2 Number of Repeats

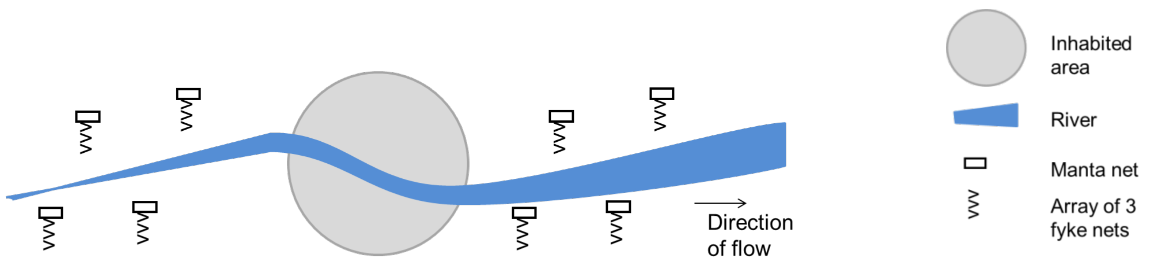
Monitoring needs some level of repetition to produce high quality data. The more variable the data, the more repetition is needed to achieve an acceptable level of accuracy and precision. For this pilot, the acceptable level is one which allows changes to be distinguished of the sort of magnitude we expect to see when litter abatement measures have been put in place. Unfortunately, given the general lack of quantitative data regarding litter quantities, it is impossible to know what amount of repetition is necessary to achieve this *a priori*, so the initial proposal for the pilot necessarily veers on the conservative side, by building in various different kinds of repeats, even though it will make the methodology more resource intensive.

The different types of repetition we propose to carry out are listed below:

- Repeats on both sides of the riverbanks, no more than 1 km apart (spatial repeat)
- Repeats at least two different places along the riverbank (spatial repeat)
- Repeats in exactly the same spot but at a distance of days/ weeks (temporal repeat).

This equals 2 x 2 x 2 = 8 deployments of the two types of net. The sampling design is illustrated in Figure 5.

Figure 5 Diagram to illustrate sampling design



This configuration of net deployment is repeated at an interval of days/weeks to complete sampling upstream and downstream.

Carrying out this sampling design upstream and downstream totals 16 net array deployments.

This would be done both before and after abatement techniques are applied, giving 32 net array deployments in one testing cycle.

If 4 of each net are obtained to allow simultaneous deployment, this allows best comparability between samples, and this simultaneous deployment would be carried out twice, to obtain the temporal repeat. Although this requires more resources to purchase the nets, the time it would save (2 trips, one to set nets and one to collect nets; versus 5 trips, to set and collect the nets for the different spatial repeats in series) is likely to outweigh this expense.

Ideally sampling would additionally be conducted in the middle of the river, as far as navigation channels permit, however this also would require the use of a vessel. A variant would be to use a bridge to anchor equipment from so as to position it in the middle of a river. This may restrict possible monitoring sites. However, apart from these considerations, it is desirable to achieve a balance between repetition and cost effectiveness, therefore we have omitted middle of the river sampling from the method.

Variation in litter distribution can also be taken into account by using trawling versus stationary methods. Trawling limits the time span of the sample, which is problematic for getting a good sample size for macrolitter. It also entails more requirements as regards vessels and equipment, or perhaps a limitation on the monitoring locations (anything tidal or near river mouths needs larger vessels for trawling). It should be noted that the manta net and submerged nets, if trawled, can be done with same piece of equipment if construct “Catnet” type net support (as per DG Env Riverine Litter pilot). This would constitute considerable resource savings. Taking all these pros and cons into account, we have chosen stationary methods as less expensive and complex, with spatial repetition used to take into account variability in litter distribution instead.

2.3.3 Units, Dataflow

It is very important for this methodology, that absolute versus relative quantification be used. This increases the quality of the data as it is more comparable between repeats, seasons and different pilot locations. In addition, we would like to assess in real terms, what is the contribution of different sources and pathways to litter in the freshwater aquatic environment. Doing this is impossible with any degree of accuracy with compositional data alone, because it is not standardized in any way to abundance. With composition data alone, it is not possible to tell the difference between augmentation of other sources/pathways, versus reduction in the target source/pathway.

For this reason, the preferred method is to both weigh and count the litter sampled in the river, which is then standardized to throughput of water, which is estimated with the help of a flowmeter and depth meter, plus the dimensions of the sampling nets.

Litter should be dried before weighing, and any significant silt or algae deposits removed.

We would like to use an item type schema to characterize the litter that can cater for all the litter sampled. The rationale for using an item type list is because it provides more information to help elucidate sources and pathways (even simply extra validation of the method) and also provide information which can be related to easily and so can be used to hold the attention of the public and policy makers. We base the item type list on the TSG ML litter list. The TSG ML list contains 217 items in total, however this is a master list of categories for scoring in detailed beach surveys, sea floor surveys, visual floating litter surveys, as well as simplified beach surveys. For example, barrels are included as an item for sea floor surveys but not beach surveys. Similarly, microplastics are not included in the beach survey list. The detailed beach survey list has 165 items. We took this list and took out any items that were definitely only marine related, such as mussel nets or octopus pots. However this only led to the exclusion of 9 items, as there are many fishing related items that could derive from freshwater fishing. There are quite a few items, that because of their weight, are unlikely to be sampled by this method. There are 12 of these items. We note that in contrast to land-based litter surveys, the list is more detailed within categories (e.g. many types of bottles are scored rather than just bottles) as well as additionally containing all kinds of household items and sewage related debris. This extra detail is considered justified as it is the case that more types of litter will be found in riverine environments as compared to selections of land areas, and also, the detail is useful for this method, as it can help attribute source and pathway. The "riverine item list" is shown in Table A1, in Annex 4. Items excluded on the basis of their marine nature and size/weight are also indicated. This leaves 144 items, categorised into 9 material types, which although not expressedly used in this work, is useful to provide comparability with other studies, and also as a way of quickly zoning in on the correct item on the list while scoring. If it is decided that smaller items are to be surveyed, then the section of the TSG ML list relevant to items <5mm should be included in addition to "riverine litter" list.

For calculation the throughput of the net, the formula is:

Sample throughput (m^3) = (Average flow velocity) (m/s) **x** *net width (m)* **x** *net [submerged] height (m)* **x** *sample time length (s)* for a rectangular mouthed net; and:

*Sample throughput (m^3) **=** (Average flow velocity) (m/s) **x** π (net radius (m))^2 **x** sample time length (s)*

for a circular mouthed net.

Litter load is calculated in the following way:

Litter load (kg/m^3) = sum of all weight of litter samples (kg)/Total sample throughput (m^3)

River discharge is calculated as

*Discharge (m^3/s) **=** Average flow velocity (m/s) **x** area of river cross section (m^2)*

Therefore total litter load of the river, i.e. the amount of litter passing by a particular point in one day, is calculated as

Total Litter (kg/day) = Litter load (kg/m^3) x Discharge (m^3/s) x 86400 (number of seconds in a day)

2.3.4 Other Equipment

A variety of equipment is needed to support the fully quantitative sampling method proposed and does make it the most resource intensive and specialized. It is probably best to enlist the help of researchers that can help set up the system and provide support deploying it, in all the pilot locations. Other equipment not mentioned above:

- Transport, trailer,
- Laptops,
- Portable crane,
- Dinghy,
- GPS,
- Flowmeter and depthmeter plus mount,
- Tarps and bags (transparent rubble bags – durable, for transport; smaller, finer bags also, to aid sorting),
- Scales (spring and hook – like luggage scales),
- Stakes, mallets, rope; and
- Covered, dry space for sorting.

2.3.5 Monitoring Sites

Each different type of net has some limitations in terms of where it can be deployed and this has to be taken into account when choosing monitoring sites. For example, fyke nets have to be staked to the river bed and so in very deep river basins there may not be appropriate sampling locations. Sloping riverbanks with no hard standing are more difficult to deploy stationary manta nets from, if a crane is used to deploy them. Ideally, the location should allow the use of both types of net.

Care should also be taken to ensure that monitoring locations not be too near to things that can act as point sources of litter, or to heavily influence litter distribution.

For example very close to tributaries or lakes or just near municipal outfall conduits. If these are within the test location and included within the pilot they should be at a reasonable distance from the monitoring location. For example, lakes have been noticed to produce concentrations of litter in some instances;[17] but they may represent excellent test areas for assessing the contribution of waterways recreation to litter in the aquatic environment.

Likewise location relative to inhabited sites, industrial sites and access roads, should also be chosen carefully for the same reasons.

Attention should be given to other features such as piers, jetties and weirs to ensure they do not block the flow of water necessary for sampling, or obstruct litter flow in any way.

Large vessels may also induce waves or current reversals that can damage or empty sampling nets, so some thought should be given to avoiding interference from vessels. This is a particular issue with nets that are left to accumulate litter for several days.

Locations need to be able to provide a suitable place to set up additional equipment, or package samples within a reasonably close distance to the actual monitoring location, some kind of hard standing would be useful for this. Safe parking for vehicles, especially if researchers are staying on location, is also a necessity.

Obtaining permissions is also an important part of the process for choosing monitoring sites and takes an appreciable amount of time and planning.

2.4 Definition of Sources/Pathways

The particular source or pathway whose contribution to riverine litter is to be assessed must be selected at an early stage in the implementation of the methodology, so that abatement measures required to tackle it can be planned and implemented in good time.

As a first step therefore, it is necessary to define list of sources and pathways that can be used within this methodology, as standard. Table 5 shows one categorisation based on the review of known sources of litter and pathways in Section A.1.1, as relevant to the freshwater environment (i.e. neglecting those categories only relevant to the marine environment), and based on the following principles.

Firstly, the categorisation is intended to be as simple as possible, so some redundancy has been eliminated. At the same time, the list should be comprehensive and not neglect sources of litter. Nine source categories have been chosen to strike this balance.

[17] Gijsbert Tweehuysen http://wastefreewaters.wordpress.com/2012/04/

Table 5. Sources and Pathways to the (Freshwater) Aquatic Environment

Sources (and notes)		Pathways
Public - Flytipping		Direct, Drains
Public - General littering	Except smoking, excluding recreational use of waterways, including both pedestrians and vehicle based.	Drains
Public - Smoking related	Pedestrians and vehicle based	Drains
Public - Recreational use of waterways and riverbank	Boating, cruising, transport, camping, picnicking. fishing Including routes near water ways.	Direct
Sewage - Treated and untreated	Including CSO discharge	Sewage
Waste collection/treatment	Including landfills with poor containment/erosion Including poor presentation of waste by public for collection Including inadequate street cleansing	Direct, Drains
Agriculture	Inc. flytipping and poorly contained waste/materials	Direct
Construction & Demolition	Inc. flytipping, poorly contained waste/materials and erosion	Direct
Other Commercial & Industrial activities	Outfall, inadequate waste management	Drains

Secondly, the categories should be such that there are abatement measure(s) alone or in combination that can target *predominantly* one category. This rules out some ways of categorising pathway as they are rather too vague – such as 'vector' or 'intention' when used alone. Pathway needs some reflection of physical location to be able to be targeted by abatement technique. Therefore, only three pathways have been chosen, based on physical location:

- Directly over land-water junction, whether by water, wind or direct dumping ("Direct"),
- Municipal drains ("Drains"); and
- Municipal sewerage and CSOs ("Sewage").

This categorisation of pathway means that each source corresponds to one or two pathways. If vector, intention, distance of origin or diffuse/direct attribute types are incorporated into the schema, this would lead to many more subcategories and complicate our subsequent methodology. Where a source of litter would be targetted by different abatement measures depending on the pathway, the source has been split into separate categories (e.g. public – general littering [drains] and public – waterways recreation [direct]). If the pathway makes no difference to how you might target abatement measures to a source, they have been considered together within one source categorisation (e.g. public – flytipping [direct/drains]).

If a category cannot be individually targetted by an abatement measure, but the category can be monitored using an indicator item, both types of information can be used to inform the estimate of a source/pathway's significance.

Thirdly, any category should be likely to be large enough that a reduction in litter coming from that category will be detectable by the monitoring technique. This is why pedestrian versus vehicle users have not been separated as sources; but have separated smoking versus general litter, as smoking litter is known to be a particularly large category of litter.

We also would like to mention here this very simple categorisation from Gijsbert Tweehuysen (Waste Free Waters) – a categorization based on a mixture of litter attributes, such as physical location and item type.[18]

- Fly-tipping and illegal dumping in the flood plain,
- Run-off from streets and roadsides in the catchment area,
- Sewage overflows to rivers and tributaries; and
- Industrial Spills (pellets and scrap).

Each of the four categories refers to an number of different sectors/sources, but could be related directly to one or two main sources based on judgement (Table 6) This is a good candidate for a simpler schema than the 9 source, 3 pathway scheme tabled above, if necessary, however initially we will assess the feasibility of the 9 source, 3 pathway scheme.

[18] Tweehuysen, 27/02/3013 http://wastefreewaters.wordpress.com/2013/02/

Table 6: Four Category Schema for Pathway and Source

Pathway	Source
Fly-tipping and illegal dumping in the flood plain	Public and commercial sector
Run-off from streets and roadsides in the catchment area	Public and waste sector
Sewage overflows to rivers and tributaries	Public, water companies
Industrial Spills (pellets and scrap)	Industry (could add, agriculture)

2.5 A Priori Assessment of Sources and Pathways

Ideally the initial focus of a pilot project should be on the source or pathway that is likely to make the biggest contribution to riverine litter. In subsequent cycles of abatement measure implementation and evidence gathering regarding its effectiveness, different sources and pathways can be targetted.

Determining the likely most important sources and pathways for litter in a particular location can involve an assessment of litter indicators. A wide range of different litter indicators were reviewed in Section A.1.2. Some of these (national ones, following the approach used by Öko) will already have been used for choosing pilot sites. These will be supplemented by a more extensive assessment, using whatever relevant local data is available and local stakeholder experience.

To support this process a checklist has been developed, to produce an assessment of how likely a locality is contributing to riverine litter via the various sources and pathways.

The checklist is presented in an excel file constituting Annex 2. A preview is shown in Figure 6.

Figure 6: Preview of Source and Pathway Checklist

Source	Pathway	Category	Indicator	Geographical Level	Question	Notes	Scoring
Agriculture	Direct, Drains	Public Perceptions and Attitudes	Community	Local	Would you characterise local farmers and workers as being invested in their local community and environs?		Y=0, N=1
Agriculture	Direct, Drains	Public Perceptions and Attitudes	Attitudes to Place (Public attitudes)	Local	Do local farmers and workers report flytipping awareness and knowledge and intention to dispose of waste generated correctly?		Y=0, N=1
Agriculture	Direct, Drains	Public Perceptions and Attitudes	Attitudes to Place (Litter awarenes	Local	Do you have any outreach activities to local farmers and workers on proper waste management with a flytipping component?		Y=0, N=1
Agriculture	Direct, Drains	Public Perceptions and Attitudes	Adequacy of Facilities	Local	Are disposal facilities for waste generated perceived as adequate by local farms and workers?		Y=0, N=1
Agriculture	Direct, Drains	Waste and Water Management	Waste Management of Agricultural Plastic Waste	National	Is a large quantity of agricultural waste generated in this municipality? (Can perhaps work out ' calculated disposal rate').	May need to develop numerical th	Y=1, N=0
Agriculture	Direct, Drains	C&I activities adjacent to rivers	Agricultural land use near waterways	Local	Is there a large land area adjacent to rivers devoted to agricultural use?	May need to define levels and scores.	Y=1, N=0
Agriculture	Direct, Drains	General Indicators	Litter Generation Areas/Land use categories	Local	Is there a large percentage of agricultural land use in this locality?	May need to define levels and scores.	Y=1, N=0
Agriculture	Direct, Drains	General Indicators	Heavy Precipitation Events	Local or national	Is this locality prone to heavy precipitation events, especially after spells without rain? Are the local waterways prone to flashy flow?	May need to define levels and scores.	Y=1, N=0
Agriculture	Direct, drains	State Indicators	Flytipping incidents (near waterways or coastlines)	National and/or local	Are there a significant number of flytipping incidents of agricultural waste in the locality? (And near waterways?)	May need to define levels and scores.	Y=1, N=0 - plus one extra point for Y near waterways
Agriculture Total							
C&D	Direct, Drains	Public Perceptions and Attitudes	Community	Local	Would you characterise local C&D businesses as being invested in their local community and environs?		Y=0, N=1

This initial framework needs developing further to determine thresholds for 'significant levels' of some of the indicators, but it is likely that this will need calibrating in conjunction with real data gathered during the pilots.

It must be borne in mind that there is no way of ranking the potential contributions of the different sources and pathways at this stage by this method; instead a crude score of number of 'risk factors' as a proportion of the maximum total score for each source/pathway may serve as a way of discriminating between them in terms of the potential predisposition of a locality to suffer from each, relative to the maximum.

Alternatively, choice of source or pathway to assess in the first monitoring cycle can also be influenced by:

- An item type whose impact is perceived to be unacceptable by the public authority,
- An item type perceived to be particularly prevalent by the public authority,
- Policy context – i.e. what a public authority has not yet addressed or what they may be about to address.; and
- Any other item that a public authority finds important e.g. because of public perception or any other reason (e.g. cigarette butts).

2.6 Choice of Abatement Measures

We reviewed a wide range of abatement measures in Section A.1.4. The methodology proposed here relies on the ability to relate abatement measures to particular sources and pathways; this is done in the abatement measure database. Many of the abatement measures, with modifications, can target various separate sources and pathways. Some are only able to target several at once. We propose that the abatement measure database be used to provide an overview of abatement measures, sortable by individual source. This would provide a large portfolio of measures an authority might like to choose from to build up a strategy to target the source they have chosen to target in any particular monitoring round. Accompanying this feasibility study is an excel file, containing the litter abatement database as presented in Section A.1.4, with supplementary columns allowing sorting by source (Annex 2). Individual worksheets have been produced for each source in this way and are also included in the workbook. A preview is shown in Figure 7.

Figure 7: Preview of Abatement Measure Database

ID	Name (URL)	Name	URL	Details/Examples	Type of measure	Source
1	Penalties / Enforcement for littering (can target to areas near waterways if desired)	Penalties / Enforcement for littering (can target to areas near waterways if desired)	http://w		Command and Control	Public - General Litterir Public - Smoking, Public - Waterways Rec
2	Penalties / Enforcement for flytipping (can target to areas near waterways if desired)	Penalties / Enforcement for flytipping (can target to areas near waterways if desired)			Command and Control	Public - Flytipping, Agriculture, C&D
3	Increase fixed penalty notices for littering and flytipping (can target to areas near waterways if desired)	Increase fixed penalty notices for littering and flytipping (can target to areas near waterways if desired)	http://ec		Command and Control	Public - General Litterir Public - Smoking, Public - Waterways Rec Public - Flytipping, Agriculture, C&D
4	Cleaning and maintenance of riverbeds and dry rivers (rieras)	Cleaning and maintenance of riverbeds and dry rivers (rieras)	http://w	Cleaning up dry riverbeds that attract fly-tipping. Relevant for riverbeds that are often dry.	Volunteer initiative / Collection & Prevention	Public - Flytipping, Agriculture, C&D
5	Updating sewer network	Updating sewer network	http://w	Updating sewers to avoid litter washed from streets and sewage being released during periods of heavy rain. Possibly only relevant to areas with combined drains rather than separate drains between municipal sewage and street run-off. Can either separate sewage (expensive) or increase the capacity of storm tanks. Also can make sure that storm tanks and combined systems are well mainted with no cracks so that if the water table rises, capacity of system to deal with storm water improved.	Investment in infrastructure and equipment	Sewage - Treated/Untre
6	Improving water treatment standards	Improving water treatment standards		Increasing tertiary level sewage treatment and implementing better filtration such as membrane filtration systems.	Investment in infrastructure and equipment	Sewage - Treated/Untre
7	Grit chambers (or other filtration system) for unconnected drains	Grit chambers (or other filtration system) for unconnected drains	http://w	For drains unconnected to WWTP: grit chambers may help collect litter that has been swept into drains by rainwater, however, systems that have some filtration will never be able to get rid of all waste (e.g. microbeads, so prevention is seen by some as far preferable.)	Investment in infrastructure and equipment	Public - General Litterir Public - Smoking, Public - Flytipping
8	Legislate for higher standards of treatment at treatment plants and reduce the allowed stormwater overflow	Legislate for higher standards of treatment at treatment plants and reduce the allowed stormwater overflow	http://ec		Command and Control	Sewage - Treated/Untre
				Making this connection to WWTPs will ensure that litter swept into sewer systems by rain will not be discharged to the environment. However, for		

Review | Public - Flytipping | Public - General Littering | Public - Smoking | Public - Waterways recreation | Sewage | Waste Collection Treatment | Agriculture | C&D | Other

The initial choice of abatement measures will be based on the source a locality has decided to target.

At that point, the locality should assess what measures it has already implemented and choose those which would be most additional to its current efforts, in the most cost effect way.

Attention also has to be given to the further tailoring of an abatement measure to the target if it is clear that it otherwise would be likely to affect many different sources.

Ideally the applied measures collectively should bring about 100% of the maximum potential litter abatement for a particular source, in order for the relative importance of the contributions of different sources or pathways to be judged accurately, however realistically, this will not be the case. The next best outcome is for the abatement measures to deliver a detectable difference in riverine litter input, and for them to be roughly equivalent in terms of the percentage of the maximum potential litter abatement they can or will achieve.

It may be decided that measures that can't possibly distinguish between sources – e.g. litter traps, waste management plans are not suited to this method; on the other hand, litter item types could be used to support attribution to a source or pathway, especially for distinctive types of litter such as sewage related debris. Additionally, it might be decided that as long as these types of measures do not predominate in the 'mix', they are still acceptable.

There are also a number of measures (#56-68 in the database) that are unlikely to be able to implemented on a local level, and/or where it is unlikely that localities be found in countries which are implementing this nationally at the right time point for pilots. These have not been included in the source-specific lists. Also, monitoring is included in this batch as does not result in less litter per se, as well as the fact that it looks at all sources and there would be no sense in carrying out the monitoring but tailoring it to a particular source or pathway; the marginal cost of including all items would be so low that it would be a waste not to include them.

2.7 Geographical Location of Test Area and Boundaries

Regarding the boundaries of a pilot site, the decision must be made as to whether to consider a catchment area as one unit or an inhabited area. We would recommend that the boundaries of a pilot project be a public authority boundary rather than a hydrological catchment area. This is so that monitoring upstream does not have to be done in a sample of many tributaries. Also it means that the pilot project area constitutes one public authorities' jurisdiction making gaining permissions and implementing abatement measures easier.

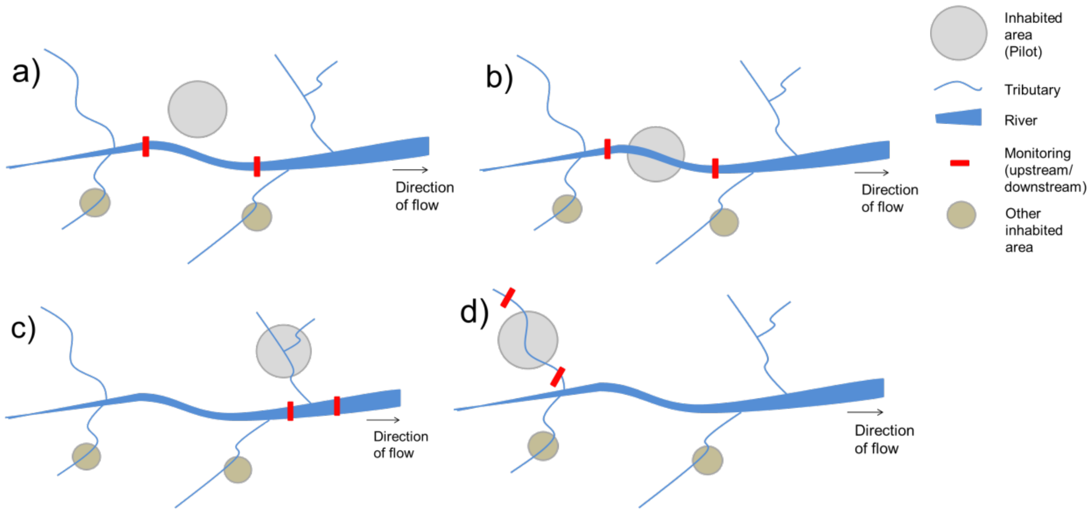
Initially, we proposed making multiple sites the subject of one pilot, providing extra negative controls – i.e. comparing litter input of a site that did not implement a certain abatement measure or set of measures with a sociodemographically matched 'twin' site. However given the resource intensity of a fully quantitative or even semi quantitative monitoring scheme, we think that this may overcomplicate the method and have not explored this further.

In terms of geographical location, the pilot site should be chosen carefully with respect to its position within a catchment. The goal is to find sites where upstream and downstream monitoring can be undertaken in a way that captures the litter input of that pilot location, and not other locations outside the pilot that have their own potentially significant litter inputs. Ideally upstream and downstream monitoring should encompass a stretch that drains

- as close to 100% of pilot locality as possible and
- no further significantly inhabited areas. (If there is a lot more to the catchment but just rural, low input areas, that would be fine).

Examples of suitable locations are shown in Figure 8.

Figure 8: Suitable pilot locations

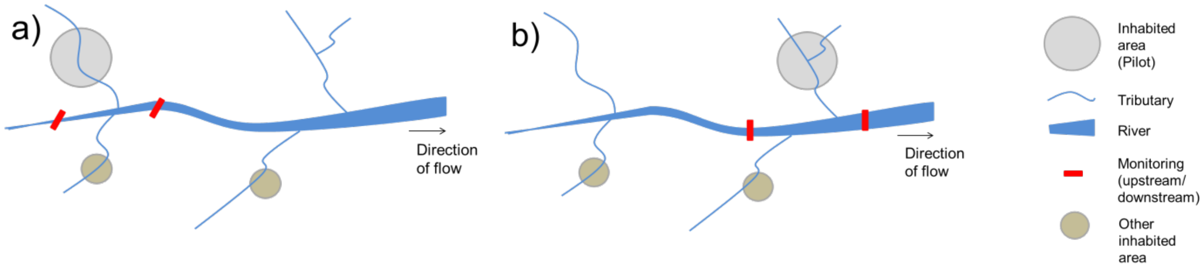


It is highly desirable to have only one upstream monitoring location, to keep costs down. Therefore where multiple tributaries meet within the pilot site, suitable monitoring locations can still be placed as per Figure 4c).

The suitability of the location depicted in Figure 4 d), is dependent on monitoring upstream and downstream in the depicted locations. Here the pilot area is on a tributary, and other tributaries flow into the main river at the same point it does,. Contrast with a similar situation in Figure 9 a) where the set-up is considered less suitable, because of further tributaries joining in the only place upstream and downstream monitoring could take place.

In Figure 4c), if many tributaries conjoin within the locality, this is fine if upstream and downstream monitoring locations can be found in a main river that do not involve drainage from other inhabited areas. But if this is not possible, as in Figure 5 b), it does not constitute a suitable site.

Figure 9: Less suitable pilot locations



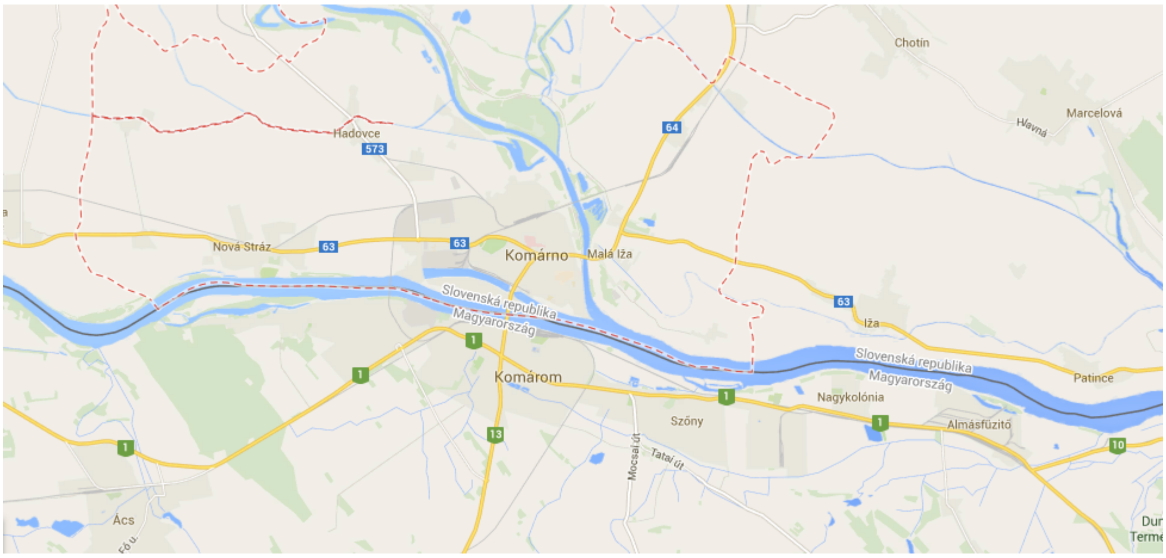
We recognize that although there exists an ideal in terms of pilot site geography, in reality, catchments have a degree of complexity which might mean that many sites are ruled out on the basis of their geography. If too many sites are ruled out on this basis, a compromise will have to be made and site will have to be chosen on the extent to which they most closely resemble the 'ideals'.

In Figure 10, a site closely resembling a good location is shown, while in Figure 11, a contrasting site is depicted.

Figure 10: An example of a geographically suitable site, Ingolstadt, Germany

Source: Googlemaps

Figure 11: An example of a geographically less suitable site, Komárno, Slovakia.



Source: Googlemaps. The River Vah joins the Danube at Komárno, after having traversed 406 km of Slovakia, draining about 17k km^2 of the country, compared to the Danube whose total catchment within Slovakia (thus including that of the Vah) is around 45k km^2.[19]

Rural and urban locations are suitable for this method however it must be borne in mind that rural areas will be associated with fewer inhabitants, and fewer litter inputs. This might make it difficult to obtain a litter sample size large enough to detect small differences. This is especially true if the rural area is downstream of a large urban area with large litter inputs. Therefore if rural areas are chosen, they should be not be downstream of a large urban area.

Pilot sites should also have suitable monitoring sites both upstream and downstream of a suitable locality, in terms of availability of hard standing, access, freedom from interference by structures in the waterway etc, in so far as possible. (Suitable monitoring sites are defined in Section 2.3.5).

Further to these considerations, if the rivers are tidal, especially if this involves some flow reversal, the likelihood that either litter is washed out of the net, or that a net might be damaged, is increased, with corresponding increase in the risk of data loss. Therefore tidal sites are to be avoided.

2.8 Time Span and Relationship of Pilot Sites to Each Other

The overarching strategy presented here does, in contrast to indicator item approaches, impose the limitation that one before and after monitoring period can only test one or an undifferentiated group of sources and pathways at once, not multiple sources and pathways separately and concurrently. This potentially increases

[19] EEA, Major European Rivers http://www.eea.europa.eu/themes/water/european-waters/rivers/major-rivers-in-european-countries

the time needed to build up a fuller picture of litter sources and pathways for any one place.

This can be circumvented by considering the 4 pilot projects as providing complementary data, choosing the sources/pathways to be tested in a complementary fashion and integrating the data post pilot. Ideally the 4 pilot sites would be matched according to various sociodemographic factors (the simplest being population size, income per capita and urban/rural character), and also be similar in terms of overall litter vulnerability and vulnerability according to different sources or pathways.

Riverine litter is highly variable with respect to season, both because of seasonal changes in river input (generally waste increases in summer as more people are consuming on the go), as well as changes in river throughput (much higher in winter). Therefore it is best if litter monitoring pre- and post- abatement measure be carried out at the same time of year. This would constrain one complete testing period to one year.

A great deal of variability in litter levels is also induced by the weather. When taking pre- and post- abatement measure samples care should be taken to note weather conditions (amount of dry and wet weather before sampling) and avoid monitoring until several days after extreme events (such as storms or flash floods).

The fact that some litter abatement measures will need time to implement and demonstrate their effect, also makes it preferable for one set of before and after testing to span a period of at least a year. Subsequent years could see follow up monitoring picking up effects over a longer timespan. This would be especially useful for abatement measures that need time to bed in (for example, behaviour change campaigns).

Because of the difficulty of securing funding for a full year (funding is often granted part way through a funding cycling, meaning the time available to carry out work is rather less than one year), one configuration of the pilot project would be to consider this methodology an ongoing strategy for litter monitoring and action over several years. The first year would be for assessing sources and pathways *a priori*, gathering baseline data, preparation and application of abatement measures. The second year would complete the monitoring cycle; and should be enough to understand whether the approach is successful. Given success is demonstrated, each subsequent year could be used for honing in on a different sources and pathways, or different sets of them.

Before concluding this section, we would just like to consider two additional configurations, which have been ruled out on the basis of cost and complication.

An alternative testing strategy would be to carry out several rounds of testing within one yearly period (e.g. 4, quarterly periods), which would have the advantage of being able to test more than one source/pathway per year. However to provide comparable pre and post-abatement measure data, either the seasonal variation in litter influx must be modelled or a year's worth of litter monitoring must be carried out the prior year at seasonal intervals. This would need a biennial pilot period and the increased monitoring likely to be both cost prohibitive, and difficult to align with annual funding cycles.

Even with an 'annual' testing cycle, it would be a great advantage to carry out monitoring in two seasons, rather than just one. For example if monitoring could be carried out in both summer and at the end of winter, this might capture minima and maxima of litter throughput and increase our understanding of litter flux. This would lead to a testing cycle of 18 months, taking into account pre-abatement measure summer and winter levels. However this is also likely to be both cost prohibitive, and difficult to align with annual funding cycles.

2.9 Integration of Data

Using quantitative measures allows better comparisons to be made between pilot sites. The data gathered will be able to demonstrate:

- The amount of litter a locality is contributing to riverine litter *and* how this compares to other localities
- How much reduction in litter was achieved by a or a suite of abatement measures (%)
- If these abatement measures are targeted appropriately to a source or pathway, how much a particular source or pathway contributed to riverine litter (%) at a minimum
- If enough pilots are eventually conducted, the absolute contributions of different sources in different localities.

Using as many of the abatement measures as possible that can be targeted to the chosen source or pathway is important, to maximise the magnitude of change in litter levels and so capturing as much of the contribution of a source or pathway as possible. Choosing pilot locations that that don't have many abatement measures in place already would also help in this regard. Choosing sites that have similar vulnerabilities overall to littering would also make studies more comparable.

If these conditions are satisfied, enough information regarding litter reductions should be obtained for building up a picture of the relative importance of the contributions of the different sources and pathways tested.

If these conditions are not satisfied, then it will probably take several rounds of abatement measure testing to build up a picture of the importance of different sources/pathways, to produce a full picture of sources and pathways for one location.

There are inevitably some limitations to the ability of the four pilot projects to be able, together, to provide a complete picture of sources and pathways. One is because we are limited, within one testing cycle, to examine only one source or pathway. Secondly, there will be some variation caused by pre-existing abatement measures that affect a particular source or pathway. It is very difficult at this stage, without much data regarding the evaluation of abatement techniques, to take into account, additive effects versus synergies, that conspire to either make some measures more effective or less effective, such as behavioural spill-over or campaign fatigue.

2.10 Assessment of Cost and Feasibility of Pilot Studies

A fundamental part of a feasibility assessment is the estimation of costs. Table 7 details a bottom up approach to costing, estimating cost for each piece of equipment, plus number of days of work for each step of the method, plus their cost.

The spreadsheet presented as Annex 5 contains this costs accompanied by references to suppliers for equipment. The costs are built up making the assumption that the same equipment will be transported between the four pilot sites and will not need procuring four times.

It would be possible in many cases to cut these costs down by

- Increasing the amount of work delivered by volunteers, public authority staff, or students,
- Obtaining second hand equipment,
- Renting equipment,
- Using equipment owned by a contractor; and
- Cutting down on the amount of replication in a sampling location.

However in the first instance the costing has been drafted as comprehensively as possible, as most of these possibilities are not guaranteed.

The final sum, 183,000EUR, is for 4 pilots, with pre-survey litter source and pathway assessment and pre-abatement measure baseline monitoring being carried out in the first year. A total has also been calculated including post-abatement measure monitoring, which comes to 261,000EUR. This is to give some idea of how much could be achieved at what cost, if public authorities chose only to partake of the first stages of the methodology, versus carrying out all the stages.

Table 7: Estimated Financial Costs

Presurvey assessment of litter sources		Person days	Euros	Notes
1. Regional Indicator assessment		/	/	This step will already have been don selection of pilot
2. Local Indicator assessment	Contractor	1.5	1,014	
	Public Authority help in kind	3.0	/	
3. Stakeholder experience based assessment	Contractor	1.5	1,014	
	Public Authority help in kind	3.0	/	
Subtotal			2,029	PER P
Repeated for 4 pilots	x 4		8,114	FOR 4 PI
Contractor cost per day (no VAT)			*676*	*Based on Junior Consultant day*
Public authority help in kind cost per day minus VAT			*133*	**Not included in final*
Survey		**Person days**	**Euros**	**Notes**
Pre-survey and post-survey tasks				
Obtaining permissions for sampling		2	1,699	
Identifying potential monitoring sites and site visits		3	2,549	
Obtain/analyse auxiliary data		3	2,549	
Compare results to other pilots		1	850	
Subtotal		*9*	*6,798*	

Survey tasks	Repeats: Accounting for Upstream/Downstream sampling			
Deploy nets - 4 riverbank locations, 2 temporal repeats	2	4.0	6,798	2 days to net 4 locations inc current prof 2 days to net temporal repeat inc cu pro
Gather nets - 4 riverbank locations, 2 temporal repeats	2	2.0	3,399	1 days to gather nets including sa packing = 2 with temporal re
Analyse samples - weighing, categorising, contents of 16 net samples	2	4.0	6,798	4 manta net catches and 4 fyke net catches, twice over for the 2 temporal rep (=16 net samples), 0.25 days each = 4 The samples won't be *that* larg keeping separate will take time to re
Data analysis - absolute quantities, assessment of variation between samples		3.0	2,549	
Subtotal		*23*	*19,544*	
Subtotal including upstream and downstream measurement		31.0	26,341	
Subtotal including repeated survey tasks post abatement measure		54.0	45,885	PER P
Subtotal including repeats for 4 pilots	x 4	216.0	183,540	FOR 4 PI
Contractor cost per day (no VAT)			*850*	
Equipment	**Items**	**Cost per unit (£)**		
Buying, sourcing equipment (person days)	2	666	1,699	
Manta nets	4	780	3,981	

Fyke nets	12	175	2,679	
Transport including fuel	1	15,500	19,776	
Subsistence for contractor	120	30	4,593	
Trailer - 3.0 x 1.5 x 1.8	1	3,850	4,912	
Laptops (one for recording flow meter data, one for data analysis)	2	350	893	
Portable crane x4	4	2,500	12,759	
Dinghy with small outboard motor	1	1,980	2,526	
GPS	1	200	255	
Flowmeter and depthmeter (Aquadopp) plus mount	1	11,500	14,672	
Tarps and bags, gloves (transparent sacks – durable, for transport; smaller, finer bags also, to aid sorting)	var	100	128	
Scales (spring and hook – like luggage scales, plus finer with large bowl)	var	25	32	
Stakes, mallets, rope	var	100	128	
Covered, dry space for sorting, with sink if possible	4	0	0	
Subtotal			69,033	
GRAND TOTAL (4 pilots - baselining only)			182,513	
GRAND TOTAL (4 pilots - baselining and post measure monitoring			260,688	

In terms of practicability, there are some limitations imposed by the extent to which this methodology is quantitative. The more quantitative the method, because of the great variability of both litter input and its distribution within the riverine sampling environment, the greater resources needed to carry out the method. It has been decided to prioritise a more quantitative method in this feasibility study because

- It enhances the likelihood of success of the method in terms of detecting change and determining contribution of different sources/pathways to aquatic litter;
- It will provide quantitative data which is a conspicuous evidence gap in terms of litter monitoring and which will facilitate target setting and achievement; and
- It complements the more qualitative land based monitoring methods being developed concurrently.

We would recommend that there be some level of expert input to oversee the monitoring effort at the different pilot locations, if not to carry out the monitoring in its entirety. This provides the following advantages:

- The data is collected and processed consistently;
- Time spent training is reduced; and
- Equipment sharing can be facilitated.

These all will lead to saving of resources and increase the ease with which the method can be implemented in different pilot locations, improving practicability in different public authority settings.

In terms of applicability in different public authority settings, this methodology does impose some limitations regarding what different settings it can be implemented in. These restrictions have been dealt with in Section 2.2 as part of the definition of suitable pilot sites with respect to their location relative to a river, availability of suitable monitoring sites, and willingness and ability to implement litter abatement measures. These preconditions are likely to restrict the number of suitable pilot locations considerably but it should be possible, Europe-wide, to identify more than enough sites suitable for piloting. With the increasing visibility of litter and marine debris on the international agenda, increasing motivation for action, and as this methodology hopefully proves its usefulness, more public authorities will hopefully engage with the process, increasing the number of localities will and able to implement abatement measures and also, commit resources to monitoring effort.

During and after the pilots are carried out, it will be a useful exercise to keep track of several aspects of the methodology, so that costs, practicability and applicability can be evaluated *ex post*. A list includes and is not limited to:

- Resources utilized for determining suitable pilot sites and engaging public authorities,
- Public authority resources utilized,
- Contractor/researcher resources utilized,
- Equipment costs,
- Implementation challenges,
- Whether the method successfully provided useful and valuable information for the local authority such as, contribution of a locality to riverine litter; and
- Whether the method successfully managed to determine the contribution of a source/pathway to riverine litter input.

3.0 Toolbox

Over the course of the pilot projects, it would be useful to take elements of the methodology and create a toolbox that could be used by public authorities to:

- Predict what the predominant sources and pathways of litter in their areas are;
- Assess what measures might be used to tackle them and also;
- Evaluate the effect of the measures.

Each stage will provide useful information for the public authority, and as the stages are progressive, a public authority can carry out one, two or all three, of the stages to the extent that resources allow.

The first stage of the approach is carried out pre-survey and can essentially be a desk-based analysis, for identifying, *ex ante*, the likely importance of particular sources or pathways (Section 3.1).

The second stage of the approach is to identify abatement measures that target those sources or pathways deemed to be most important within the survey area. (Section 3.2)

The final stage is to gather evidence about the local priority sources or pathways by applying abatement measures and seeing what the effect on riverine litter downstream of the public authority area is (Section 3.3).

3.1 A Priori Assessment of Source/Pathway Prevalence

We would like to develop the litter indicator checklist further (Section 2.5 and Annex 2 Spreadsheet) so it is a useful tool for a public authority. Finding out information regarding the many items on the checklist should be an informative process for a public authority, giving them an opportunity to consider all the different possible sources and pathways for litter to the aquatic environment, and whether in their locality, they may be particularly vulnerable to one source or another.

Aspects that still need to be developed are, firstly, thresholds for when a particular litter indicator becomes significant or not. This could be a Europe-wide or regional average, for example.

Secondly, more will be discovered about the types of information a public authority will likely have available, in the implementation of the methodology. The resource needed to complete the checklist process should also be assessed. These things should be used to refine the checklist process over time.

3.2 Identification of Most Appropriate Interventions

The litter abatement database presented in Section A.1.4 and the Annex 3 spreadsheet can form the basis for choosing interventions that can be implemented relevant to the sources/pathways a public authority wishes to tackle. This would be of value whether it wishes to go on to the evidence gathering stage or not. If desired (and this increases the effectiveness of the monitoring methodology in assessing the contribution of different sources/pathways to aquatic litter) the interventions should be tailored further, as far as possible, to particular sources/pathways, either by targetting them geographically (e.g. waterside areas, different land-use categories) or in terms of stakeholders (e.g. commercial activities, smokers, members of the public.)

3.3 Evidence Gathering

At this point, if the public authority wishes (and we would strongly recommend) they can implement the monitoring aspect of the methodology as detailed above. This will be refined over the pilot period and developed into a streamlined, simplified guide so that the public authority can understand at a glance the rationale for the monitoring methodology and how this will be implemented in its locality; plus what it can expect to gain from the monitoring efforts.

A.1.0 Annex 1 – Literature Review

A.1.1 Known Sources of Litter and its Pathways to the Aquatic Environment

Practically all data we have relevant to the sources and pathways of litter to the aquatic environment comes from marine debris studies. Below we review several, assessing which elements are relevant to inland sources of litter. We also assessed whether any sources or pathways were missing from previously used categorisations. This section is concluded by a working list of sources and pathways as a starting point for this project. It should be borne in mind that while we would generally define sources as being the sector of society or industry responsible for releasing the litter into the environment, and pathway as how litter finds its way into the aquatic environment once is has been released, classifications are not always clear cut and there are several different litter attributes which can be used to define 'pathway', such as vector, intention or location.

A.1.1.1 Sources

Many different classifications of sources exist within marine debris monitoring programs, and these classifications define what information is available about the contributions of these sources to marine debris. The only global monitoring program that has a standardized data recording method is the International Coastal Clean-up (ICC), which has been coordinated internationally by the Ocean Conservancy (a US environmental advocacy group) since 1989. The ICC categorizes debris items into five sources, all of which are of relevance to inland litter sources, albeit with unquantified contribution of coastal versus inland/waterway activities:[20]

- Shoreline & Recreational Activities – e.g. food-related litter, plastic and paper bags, clothing, shoes, toys, shotgun shells;
- Ocean/Waterway Activities – e.g. bait containers, strapping bands, tarps and plastic sheeting, pallets, nets, line, rope, and traps, light bulbs, oil bottles, cleaner bottles, fishing lures;
- Smoking-Related Activities – e.g. filters, lighters, tobacco packaging;
- Dumping Activities – e.g. appliances, batteries, building materials, car parts, drums, tyres; and
- Medical/Personal Hygiene – e.g. condoms, diapers, syringes, tampons/applicators.

According to this classification, in Europe, smoking- related activities are the source of most debris (51%), with shoreline and recreational activities making the next largest contribution (40%) (Table 8). Regionally, further distinctions can be made although it

[20] Ocean Conservancy (2012) *The Ocean Trash Index - Results of the International Coastal Cleanup (ICC)*, 2012, http://www.oceanconservancy.org/our-work/marine-debris/2012-icc-data-pdf.pdf

is important to note that this does not reflect abundance, just composition, so comparing the absolute contribution of different sources from region to region is not possible with this type of data.

Table 8: Sources of Marine Debris by Region; ICC data

RSCAP	Baltic Sea	Black Sea	Mediterra-nean	North-East Atlantic	Total (Europe)
Shoreline & Recreational Activities	57%	16%	31%	55%	40%
Ocean/Waterway Activities	3%	2%	5%	20%	8%
Smoking-Related Activities	38%	80%	62%	23%	51%
Dumping Activities	3%	0%	2%	2%	2%
Medical/Personal Hygiene	0%	1%	1%	1%	1%

Source: The Ocean Conservancy 2012 The Ocean Trash Index.

One way of categorizing debris by source is by defining it simply as derived from land-based versus sea-based sources. If we consider shoreline, smoking, dumping and medical waste as land-based, the area with the lowest proportion of land-based debris is the North East Atlantic at 80%, and the highest is the Black Sea, with 98%. This range reflects how predominant land activity derived debris is likely to be. However we consider that none of these categories will contain items exclusively from sea or inland sources, so this should be taken into consideration. The proportion of land derived debris is likely to be overestimated if we group the categories in this way. These figures will be maxima.

The ICC scoring method, because it is based on the attribution of item types to sources, has the following limitations regarding the information it can provide about the sources of debris. The choice of item type and its attribution will cause some sources to be underestimated or neglected, and others to be overestimated. Because it does not (and cannot) include all item types (e.g. plastic pellets), it cannot estimate the contribution of the corresponding source to marine debris (the manufacturing industry). There are also many items that it does not consider because it is difficult to assign them exclusively to one particular source. An example is plastic sheeting, which might derive from the agricultural sector as covering for polytunnel greenhouses, from use as tarpaulins from commercial shipping or fishing activities, or as covering for building materials in the construction industry. Many items types it does consider could derive from multiple sources. For example, many of the

“Shoreline and Recreational Activities” items could derive from urban run-off, inland recreation near rivers or bodies of water, or poorly contained or dumped household waste. This illustrates the difficulty with making assumptions regarding source from item type alone. There will always be limitations to the extent to which it is possible to assign items to a source.

An interesting methodology to overcome the limitations of marine litter monitoring methods as regards determination of source was used in a pilot study for the European Commission. The aim was to determine points at which plastic waste was escaping legitimate management systems in the EU through a mixture of workshops and interviews with stakeholders in Member States and data modelling.[21] Fifteen different sectors were identified, contributing to marine debris which are presented in Table 9. Around nine of these (asterisked) are sectors relevant to inland sources of litter. Recreational boating and recreational fishing will be relevant to both sea and land based sources – arguably contributing more to marine litter as a sea based source; but given that recreational use of lakes and rivers will be a source of litter in land, it should be included in a list of inland sources.

In the pilot study, a set of assumptions was made about the probability that a particular item type is associated with each sector. A score/weighting between 0 to 16 was assigned to six levels of likelihood (negligible, very unlikely, unlikely, possible, likely and very likely) of an item deriving from each source. In this way one item type could be assigned to multiple sources, but with different likelihoods. The score was used to calculate prevalence ratios for the 15 sources. The probabilities were informed by OSPAR ‘indicator-item’ types (which are considered to be attributed to certain sources) as well as interview/workshop information to help validate the assumptions made about the probabilities based on local experience. The result was a semi-quantitative framework allowing attribution of litter types to sources and hence the determination of the contribution of different sources to marine litter, as presented in Table 9 and Table 10 (in the latter table, categories grouped for better comparability with ICC data). This methodology, the “Matrix Score Technique” was taken from a study of litter in the Severn Estuary (UK).[22] The item type list was based on the MSFD Technical Subgroup on Marine Litter’s methodology with some higher level categories added from the OSPAR 100m survey categorization (2009), to collect supplementary data. Some of the existing data had been collected according to the OSPAR method (107 items, 11 categories). Some had been collected according to other, local schema.

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[21] Arcadis (2012) *Case studies on the plastic cycle and its loopholes in the four European regional seas areas*, Report for DG Environment, 2012

[22] Tudor, D.T., Williams, A.T., and Environment Agency (2001) *Investigation of litter problems in the Severn Estuary/Bristol Channel area. R&D Technical Report E1-082/TR*, 2001,Tudor, D.T., Williams, A., and Paskoff, R. (2004) Development of a ‘Matrix Scoring Technique’ to determine litter sources at a Bristol Channel beach, *Journal of Coastal Conservation*, Vol.10, No.1, pp.119–127

Table 9: Marine Debris by Source (% count), in four EU locations. Regional Sea Area represented by each location in brackets.

Sector	Riga (Baltic Sea)	Costanta (Black Sea)	Barcelona (Medite-rranean)	Oostende (North East Atlantic)	Total
Agriculture*	1%	0.02%	1%	1%	1%
Aquaculture	0%	0%	0%	3%	1%
Construction & Demolition*	4%	4%	4%	6%	4%
Coastal/Beach Tourism	25%	3%	32%	26%	21%
Dump sites/landfills*	0%	5%	0%	1%	2%
Fishing	3%	2%	3%	12%	5%
General Household*	12%	20%	11%	5%	12%
Other industrial activities*	1%	1%	1%	2%	1%
Other maritime industries	0.01%	3%	0.01%	8%	3%
Ports	5%	2%	4%	8%	5%
Recreational Boating*	6%	10%	6%	10%	8%
Recreational Fishing*	3%	46%	3%	3%	14%
Sewage*	29%	0.32%	26%	1%	14%
Shipping	4%	2%	4%	10%	5%
Waste collection/treatment*	7%	3%	6%	4%	5%

*Inland litter source relevant categories

Source: Arcadis (2012) *Case studies on the plastic cycle and its loopholes in the four European regional seas areas*, Report for DG Environment, 2012

Table 10: Marine Debris by Source, grouped for better comparison with ICC data, (% count), across four EU locations. Regional Sea Area represented by each location in brackets.

Sector	Riga (Baltic Sea)	Costanta (Black Sea)	Barcelona (Mediterranean)	Oostende (North East Atlantic)	Total
Recreation and tourism*	34%	59%	41%	39%	43%
Sewage	29%	0.3%	26%	1%	14%
Waste Collection/Treatment/Landfill/Household**	19%	28%	17%	10%	19%
Shipping, fisheries***	12%	8%	10%	41%	18%

* Sum of Coastal/Beach Tourism, Recreational boating and Recreational Fishing categories

** Sum of Dumpsites/landfills, General Household and Waste collection/treatment categories

*** Sum of Aquaculture, Fishing, Other maritime industries, Ports and Shipping categories

Source: Arcadis (2012) *Case studies on the plastic cycle and its loopholes in the four European regional seas areas*, Report for DG Environment, 2012

This method suggests that in the North East Atlantic, ocean/waterways activities ("Shipping, fisheries") are responsible for more debris (at least 41%) than perhaps suggested by the ICC results (20%); this means that inland sources contribute less to marine litter according to this method than according to the ICC data. However for the other sea regions, land based sources appear to make higher contributions to the litter problem (>82%). The EC Pilot study ascribes much higher proportions of debris to the Sewage Sector for the Mediterranean and Baltic (26 and 29% respectively) than the ICC results (1 and 0% respectively). Also it allows more comprehensive attribution to the Waste Management Sector, which is a quite significant proportion, at 10-28%. The comparison between the two methods demonstrates what a difference different methods for the use of item type to attribute source make to estimates of prevalence and hence what we assume about the relative importance of different sources.

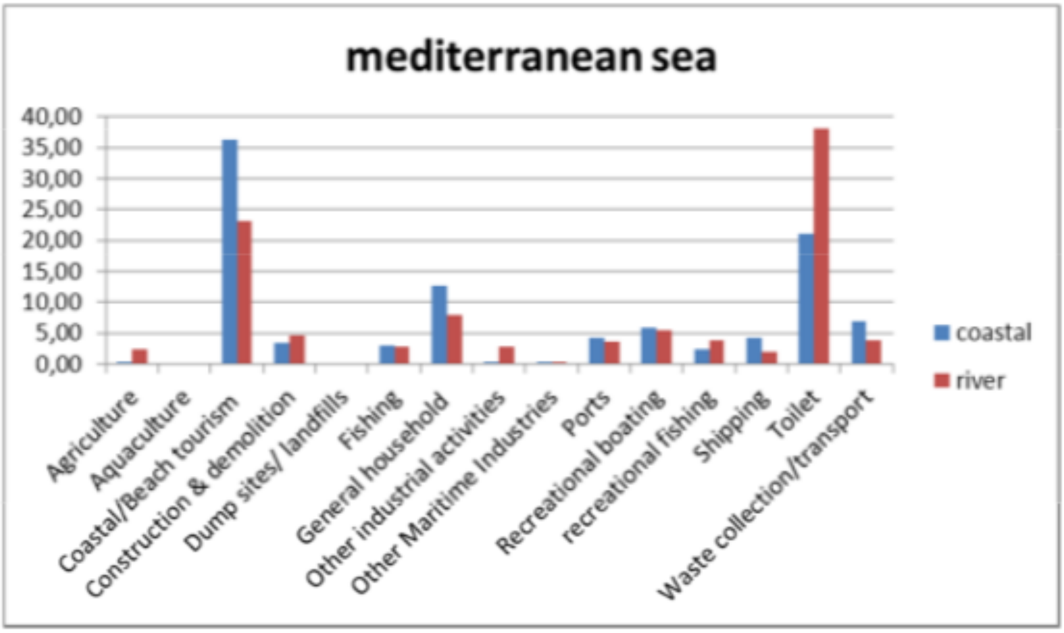
Interestingly, they attempted to use data in their possession to compare riverbank litter and coastal litter, in some locations. In Barcelona, a noticeable difference was the greater number of sanitary items found for the "river" samples. In Riga (Baltic), as an example, the result was that there was not a big difference between riverbank litter and beach litter regarding sources (Figure 12). This is rather curious for several reasons. Sources that specifically appear to be very sea exclusive (such as fishing –

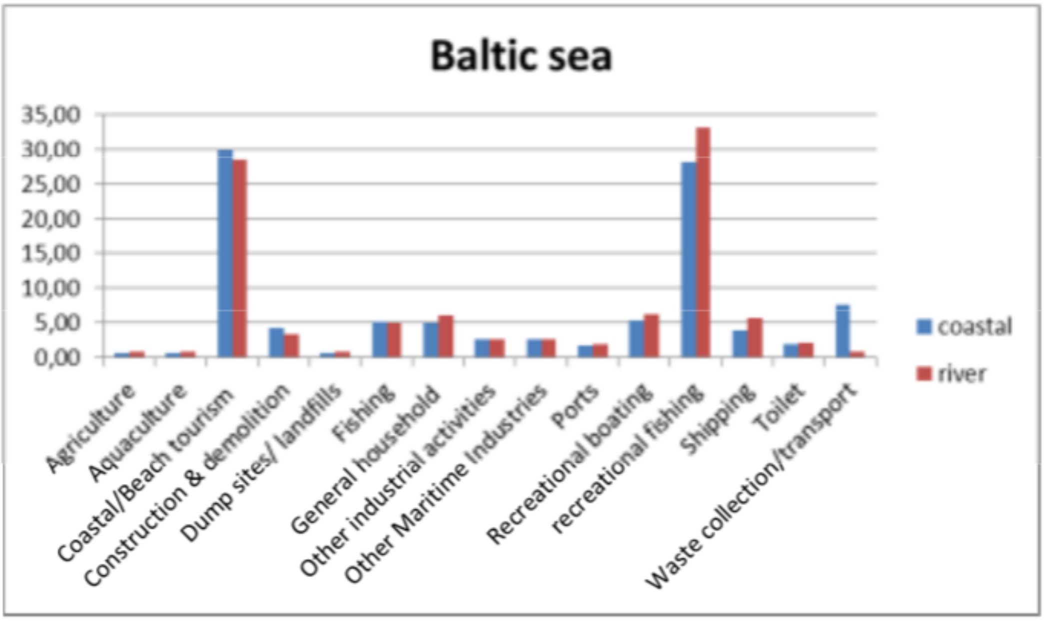
remember, recreational fishing is a separate category, maritime industries, shipping and ports) have as much or bigger representation in riverine samples. This rather throws doubt upon the method or perhaps survey sites themselves in their suitability for distinguishing inland and coastal sources. For some sites (Barcelona) it seems that “river” simply refers to a coastal site located in the proximity of a major river discharge or considered to be affected by riverine inputs. However there is not enough information in the report to allow us to evaluate this data well. For other sites, (Riga (Baltic) and Costanta (Black Sea)) the word “riverbank” is explicitly used. The sites may be however have been close to the mouth of rivers and adjacent to ports, in tidal estuaries, which may explain the similarity between the coastal and ‘river’ samples.

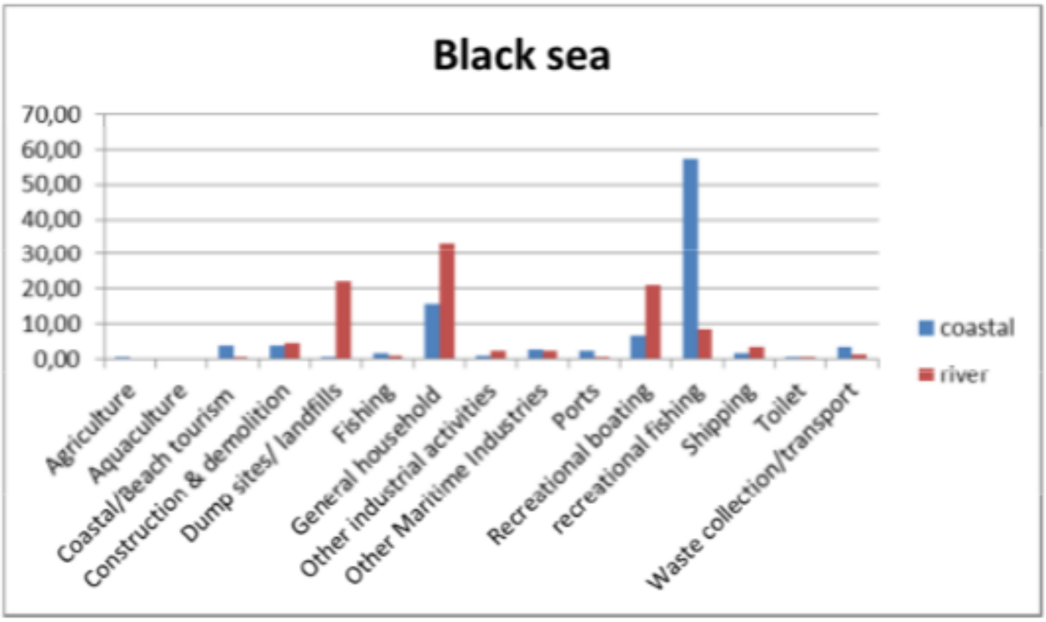
The data for Costanta (Black Sea) makes a little more sense intuitively, with more household waste and recreational fishing items appearing in the ‘riverbank’ samples, and more maritime/industrial items appearing in the coastal samples. However there are still some unexpected similarities (e.g. “Other maritime industries” associated items – seem similar for both).

It is possible the probabilities assigned to items for their likely sources were not adjusted for coastal versus river sites, and this might also explain why some counterintuitive trends are seen. If so, it would highlight a pitfall, that of using methodologies that are not tailored adequately to the research location.

Figure 12: Source of litter indicated by site surveys in Barcelona (Mediterranean), Riga (Baltic), both coastal and river







Source: Arcadis (2012) *Case studies on the plastic cycle and its loopholes in the four European regional seas areas*, Report for DG Environment, 2012

An overview of Regional Seas reports published by UNEP catalogued major sources of marine litter.[23] The list is reproduced below and features an even more detailed breakdown than the above. Aside from the approaches used above to attribute item types to the categories, much of the information that exists about these sources is simply related to reports that support the fact that they exist, or anecdotes, with

[23] UNEP (2009) *Marine Litter - A Global Challenge*, April 2009, http://www.unep.org/pdf/unep_marine_litter-a_global_challenge.pdf

scarce quantitative information, or simply 'common sense' about what is possible and likely. This list does not distinguish source (as in sector of society/industry) and pathway (means by which debris reaches the ocean). The list is grouped into land based sources and sea based sources; note that the land based sources include coastal activities.

- Land based sources:
  - Wastes from legal and illegal dumpsites located on the coast or river banks;
  - Rivers and floodwaters;
  - Industrial outfalls;
  - Discharge from storm water drains;
  - Untreated municipal sewerage;
  - Littering of beaches and coastal picnic and recreation areas;
  - Tourism and recreational use of the coasts;
  - Fishing industry activities;
  - Ship breaking yards; and
  - Others
- Sea based sources:
  - Shipping;
    - Merchant;
    - Public transport;
    - Pleasure;
    - Naval;
    - Research;
  - Fishing;
    - Vessels;
    - Angling;
    - Aquaculture;
  - Offshore mining and extraction;
    - Vessels;
    - Offshore platforms;
  - Authorized and unauthorized dumping at sea;
  - Fishing gear (ALDFG);

- Illegal, unreported and unregulated fishing activities; and
- Tsunamis, hurricanes and other natural disasters.[24]

In the course of research into sources and pathways to the aquatic environment, we also noted the following observations regarding specific sources.

Regarding public behaviours leading to indiscriminate littering, no robust quantitative statistics exist on littering in terms of the absolute amount of material generated by this behaviour. Inferences can be made based on the frequencies of typically littered items, and that is the basis of the estimation of marine debris generated from shoreline and recreational activities by the ICC; the proportion was 65%, as mentioned above. The item types contributing to this category would likely cover riverine litter from inland sources too. One might assume that most of the items counted constitute litter rather than accidentally lost items. The figure could therefore be viewed as a maxima of the contribution of public littering to marine debris.

We note that untreated sewage may get into waterways via combined sewage overflows or incorrectly connected plumbing,[25] and there are many places in the world where there is no sewage treatment (although it is not clear what percentage of wastewater this applies to). It is not just untreated sewage that is a source of litter. Treated sewage is also contributing to debris entering the marine environment, simply because treatment is unable to capture all the relevant material. One example is clothing fibres derived from washing clothes, which were determined by one study as a dominant source for the microplastic particles sampled.[26] Microplastic particles in exfoliants or cleaning agents can also get into the water system via legitimately treated sewage, though there is no systematic monitoring in this regard.[27] Another source of litter identified from sewage treatment is the accidental release of sewage discs (used to increase the surface area for treatment bacteria to grow on) from plant discharge outlets. In Hooksett, New Hampshire, up to 8 million plastic discs were released.[28] Two other incidents were also identified, in Groton, Connecticut (a million discs released)[29] and Mamaroneck (New York).[30] Another example is cotton bud sticks – treatment plant filter mesh size is inadequate to stop all of them.[31] Cotton

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[24] Thompson, R., Moore, C., Andrady, A., Gregory, M., Takada, H., and Weisberg, S. (2005) New Directions in Plastic Debris, *Science*, Vol.310, No.5751, pp.1117–1117

[25] http://www.theguardian.com/environment/2013/jul/07/england-polluted-beaches-tide-of-filth

[26] Browne, M.A., Crump, P., Niven, S.J., Teuten, E., Tonkin, A., Galloway, T., and Thompson, R. (2011) Accumulation of microplastic on shorelines worldwide: sources and sinks, *Environmental Science & Technology*, Vol.45, No.21, pp.9175–9179

[27] Fendall, L.S., and Sewell, M.A. (2009) Contributing to marine pollution by washing your face: Microplastics in facial cleansers, *Marine Pollution Bulletin*, Vol.58, No.8, pp.1225–1228

[28] http://www.gloucestertimes.com/local/x814643010/City-advances-sewage-disc-cleanup/print

[29] http://www.nashuatelegraph.com/news/913108-196/disks-in-the-river-wasted-material.html

[30] http://theloopny.com/blog/news/larchmont-beach-mystery-once-hit-block-island/

[31] Berkley, C., and ENCAMS (2007) *Sewage related litter: flushing toilets onto beaches : research report*, 2007

bud sticks are an item type not scored by the ICC, yet have been shown to be a significant item in surveys in the North-East Atlantic and the Mediterranean where they are a counted item type (in OSPAR and MAP litter surveys).[32] Microplastics are also not scored by the ICC. This goes to further evidence the types of knowledge gaps that can arise simply as a result of scoring methodology. The relevant ICC category (medical/personal hygiene) may therefore be underestimating the extent of the contribution of this sector to marine debris. Also, it is not able to assess the relevant contribution of related but different sources (treated/untreated sewage). A survey in the UK revealed that 57% of the population had disposed of solid items down the toilet in the past year, which, given the significant contribution of sewage and medical related items to marine debris, supports this source for this particular pathway. However one historical event concerning medical waste, the “Syringe Tide” that affected New Jersey and New York in the late ‘80s, was traced, rather than to sewage related debris, to improper waste management at the Fresh Kills Landfill on Staten Island.[33] This illustrates the difficulty with making assumptions regarding source from item type alone.

In many countries, the informal waste sector contributes significantly to waste management. Whether there are practices in this sector that make the creation of marine debris more likely, such as lack of containment, is unknown, and their general contribution to marine debris, likewise. This however is unsurprising given that even the relative size of this sector in most regions represents an unknown.[34]

Industrial outfall incidents are known to contribute to marine debris – the identification of ‘Taprogge balls’, small abrasive sponges used for cleaning pipes in power stations and other industrial systems, in marine debris is evidence that this sector is a source of marine debris; though there is no measure of how significant this source is.[35]

It is known that cruise ships generate a large amount of waste, which is likely to be similar in type to household waste. If losses are occurring from cruise ships, it will not be possible to make this attribution item type scoring methods and so the amount of debris generated by passenger vessels remains an unknown quantity. Passenger vessels on rivers and lakes will also be sources of waste and potentially debris; these will be subsumed into other larger categories in the studies summarised above so the relative contribution is unknown.

A US based initiative for collecting and recycling monofilament line from marinas, camps and boating access points has processed 9 million miles of line since 1990, indicating how much might otherwise be ending up in the environment. There are

[32] InterSus, University of Trier, Milieu, UBA, and COM (2013) Issue Paper to the ‘International Conference on Prevention and Management of Marine Litter in European Seas’

[33] http://en.wikipedia.org/wiki/Syringe_Tide

[34] Lange, U., and Linzner, R. (2013) Role and size of informal sector in waste management – a review, *Proceedings of the ICE - Waste and Resource Management*, Vol.166, No.2, pp.69–83

[35] http://www.sas.org.uk/campaign/ufos/

several examples in the UK as well as the US, of campaigns targeting anglers which is evidence that this is considered a significant source of debris.[36] However there is no way of quantifying this via the monitoring currently undertaken.

A.1.1.2 Pathways

Litter monitoring initiatives are less likely to consider pathway as opposed to source. This is likely to be because it is even harder to associate item types with pathways than it already is to attribute them to sources. The fact that the distinction between source and pathway is not always clear (e.g. should 'riparian flytipping' be a "source" category or a "pathway" category) is also a source of confusion. Some different ways of categorizing pathways are summarized in Table 11.

Evidence for pathways tends to be anecdotal or qualitative, so it is difficult to determine how prevalent the different mechanisms are. Below we discuss pathways and information available about them, or rather lack thereof.

Table 11 Different methods for the definition of litter 'pathway'

Method	Ref	Categories
By intention and source	UNEP (2009)	Negligent – Loss
		Negligent - System failures
		Negligent - Outdated and inadequate waste management practices
		Intentional - Public behaviours leading to illegal waste disposal/indiscriminate littering and dumping
By vector	UNEP (2009)	Human - By direct dumping
		Water - Transported by storm water, via drains and rivers towards the sea
		Wind - Blown into the sea.
By physical pathway, vector and source	UNEP (2009)	Wastes from legal and illegal dumpsites located on the coast or river banks
		Discharge via Industrial outfalls
		Discharge from storm water drains
		Discharge from municipal drains

[36] http://www.rspca.org.uk/adviceandwelfare/litter/fishing, https://canalrivertrust.org.uk/news-and-views/features/guidelines-for-fishing-along-canals-and-rivers, http://www.mcsuk.org/wales/Working+with+you/Working+with+you/Hang+on+to+your+tackle+campaign, NOAA (2007) Reeling In Marine Debris - A Reference Guide to Recycling Monofilament Fishing Line

		Untreated municipal sewerage
		Litter dropping close to waterways and wind/water transport across land/water threshold.
By physical pathway, vector and source	Arcadis (2012)	Direct (on site dumping)
		Diffuse (sewage)
		Diffuse (inland waterways and rieras)
		Diffuse (others)
By intention	Arcadis (2012)	Intentional, including negligence
		Accidental
By geography of origin	Arcadis (2012)	In situ generation
		Local (short distance)
		Long distance or transnational

Full references: UNEP (2009) Marine Litter - A Global Challenge; Arcadis (2012) Case studies on the plastic cycle and its loopholes in the four European regional seas areas, Report for DG Environment.

The overview of Regional Seas marine litter reports (UNEP 2009) characterized the major pathways by which marine litter was considered to find its way into the sea according to intention and source, as well as, separately, by vector. No quantitative information is provided in the report. Clearly part of the difficulty is that establishing pathway is not easy and each category given above, for example, cuts across many sectors and will have a huge range of point sources and possible pathways that fall within those broad categories. There can only be very disparate information available for each one and many different types of research projects would be needed to provide the necessary data. We are not aware of any major monitoring program or standardized methodology for determining the amounts of material travelling via these pathways or vectors.

The modelling approach taken within the EU by Arcadis (2012) lead to the following conclusions being made for the different Regional Seas.

In the North East Atlantic, around 36% of litter was thought to represent accidental loss, meaning the remainder was from intentional or negligent actions. Direct disposal (dumping) rather than diffuse sources was thought to be the main pathway by which litter arrived in the sea. The analysis did not highlight rivers as an important source of litter, though local stakeholders suggested it might be. It was thought that litter did not tend to travel too long before it got to the sea, though there was some evidence of waste travelling long distances..

In the Mediterranean, only around 26% of the debris was thought to come from accidental losses, the remainder from intentional disposal or neglect. Diffuse sources were highlighted as being particularly important (>60% of litter), with sewerage and inland waters important contributors. The distance travelled by the waste was thought to be short, though there was some evidence of waste travelling long distances.

In the Baltic it was thought that around 40% of litter represented accidental losses. Diffuse sources, via poor waste containment or cargo loss, were thought to be particularly important. 25% of litter items were though to travel far before reaching the sample sites, a relatively high proportion.

In the Black Sea, only around 17% of litter was thought to derive from accidental losses, highlighting a particular issue with intentional or negligent disposal of waste. Direct disposal rather than diffuse sources were thought to be predominant. The distance travelled by the waste found on the coast was thought to be generally short.

In conclusion, all areas suffered particularly from litter input from neglectful or intentional actions, and litter was more likely to be created in this way; with the Black Sea performing worst in this regard. Areas differed as to whether diffuse or direct sources of waste were thought to be more important. And mostly, the litter items were though to originate from reasonably close by.

This modelling approach perhaps represents the only effort to establish relative contributions of pathway that we are aware of; however extensive analysis of the data they had was not presented.

We also looked for other sources of information on particular pathways and this appears below; they all refer to vectors:

- Water – run off and storm water, via drains and rivers

There is scattered estuarine monitoring data and this is reviewed in detail for the methodological review (Section A.1.3.2). The headline results are from a study of the Danube, which estimated debris input to the sea as 4.2 tonnes per day,[37] and a study of the Los Angeles and San Gabriel rivers, which estimated their input of debris to the sea as 10 tonnes per day.[38] There are also some other studies of note in regard to water as a vector. For example, after one storm, 81g/m^3 of plastic debris was recorded in storm water running from the land to the sea, and this was considered a major vector for marine debris as a result.[39] In California, Total Maximum Daily Loads (TMDL) are being established for river pollutants including rubbish; one study measured litter loadings in run off after storms as between 3 and 17 kgs per hectare of catchment area, in order to provide information for the setting of these TMDLs for

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[37] Lechner, A., Keckeis, H., Lumesberger-Loisl, F., et al. (2014) The Danube so colourful: A potpourri of plastic litter outnumbers fish larvae in Europe's second largest river, *Environmental Pollution*, Vol.188, pp.177–181

[38] Moore, C.J., Lattin, G.L., and Zellers, A.F. (2011) Quantity and type of plastic debris flowing from two urban rivers to coastal waters and beaches of Southern California, *Journal of Integrated Coastal Zone Management*, Vol.11, No.1, pp.65–73

[39] Ryan, P.G., Moore, C.J., Franeker, J.A. van, and Moloney, C.L. (2009) Monitoring the abundance of plastic debris in the marine environment, *Philosophical Transactions of the Royal Society B: Biological Sciences*, Vol.364, No.1526, pp.1999–2012

litter.[40] Another instance of water as a vector was the Japanese tsunami of 2011, which was estimated to have deposited 1.5m tonnes of marine debris in the ocean.[41]

- Human – by direct dumping

The ICC makes its estimate of the contribution of dumping to marine debris (2%) via the monitoring of indicator item types such as car parts, tyres, building materials, drums and appliances. Illegal dumping however encapsulates a broader range of items including general household waste that would not really be accounted for by the indicator item types, as well as the type of vessel, vehicle and platform dumping described above. Therefore the estimate of 2% may well be an underestimate of the contribution of illegal dumping to marine debris. Data regarding illegal dumping generally are not easy to obtain and it is likely that only a fraction of countries keep records of it. In the UK, local authorities reported 744,000 incidents of illegal dumping in 2011/2012, two-thirds of which involved household waste.[42] 1,885 (0.25%) were recorded in watercourses and 25,255 (3.5%) in the 'other' category, which includes sea-fronts and harbour mouths.[43] However although this shows that this is very likely a pathway for marine debris, making estimates of the relative contribution of illegal dumping to marine debris is very difficult.

- Wind

It is not difficult to imagine why there is little information on wind as a vector for marine debris, given the sheer number and geographical spread of point sources it could be affecting. Wind features in a number of reports about possible vectors for marine debris but there has been no monitoring found.

A few specific wind related litter items deserve a quick mention here. The first is not quite what might come to mind when thinking about wind in its role in moving litter items from source to sink. Weather balloons have recently received recognition as a potentially significant source of marine debris. In Australia, an estimated 68 weather balloons are released every day in coastal regions; if half ended up in the ocean, it would equal 12,410 per year.[44]

In the UK, the RSPCA and the Marine Conservation Society have released statements regarding the danger of balloons (mainly referring to celebratory/promotional balloon releases) to wildlife.[45,46] They point out the scale of the problem – in the US, the

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[40] Kim, L.-H., Kayhanian, M., and Stenstrom, M.K. (2004) Event mean concentration and loading of litter from highways during storms, *Science of The Total Environment*, Vol.330, No.1–3, pp.101–113

[41] NOAA (2013) *Japan Tsunami Debris FAQs*, accessed 5 November 2013, http://marinedebris.noaa.gov/tsunamidebris/faqs.html

[42] Environment Agency (2012) *Official Statistics - Fly-tipping Statistics for England, 2011/12*, Report for DEFRA, 2012

[43] Environment Agency (2009) Flycapture Guidance

[44] O'Shea, O.R., Hamann, M., Smith, W., and Taylor, H. (2014) Predictable pollution: An assessment of weather balloons and associated impacts on the marine environment – An example for the Great Barrier Reef, Australia, *Marine Pollution Bulletin*

[45] RSPCA (2005) Wildlife factsheet: Balloon Releases

largest balloon release was 1.5 million balloons; in the UK, the number of balloons found on beaches has increased three-fold in 10 years. Skylanterns have also been the source of some concern regarding littering, and this waste may also find its way into rivers.[47] Keep Scotland Beautiful and Keep Britain Tidy have released position statements regarding both balloons and skylanterns,[48,49] and there is currently a campaign by the UK National Farmer's Union to ban skylanterns.[50] In several EU countries, such as Austria, Spain and Germany they have already been banned.[51]

Certain types of light weight litter may be particularly vulnerable to being transported by wind, for example, styrofoam, or light weight single-use plastic bags. These items can be targetted for example by bans or economic measures such as levies; the latter have been introduces in several EU countries.

We conclude that there is some disparate data available about pathways, but it is not enough to integrate into a robust, evidence based picture of the ways that debris is reaching the sea at any geographic scale.

A.1.2 Assessment of Local Litter Indicators and Data Availability

A review of the literature was conducted to establish what indicators might be available for assessing potential for litter generation at a local level. This review will provide a basis upon which we can subsequently decide which indicators to use for:

- The assessment of public authorities' potential litter sources and pathways and which to target in subsequent monitoring
- The selection of pilot sites with a high vulnerability to litter

Many of the indicators reviewed provide an indirect estimate of the amount of land based litter from a particular source and pathway. These indicators will correlate, to a greater or lesser extent, with direct measurements of local littering activities. For example, the adequacy of local binfrastructure will, in conjunction with a number of other factors, enable the extent of local littering to be indirectly evaluated. In practice a number of these indicators would need to be considered together to build up a semi-quantitative picture of local littering activities. Indicators falling into this 'indirect' category are all those in Sections A.1.2.1 to A.1.2.6, namely: Public Perceptions and Attitudes, Facilities, Waste and Water Management, Recreational use of waterways and riverbank, Commercial & Industrial activities adjacent to rivers and, General Indirect Indicators (which are relevant to multiple sectors).

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[46] Marine Conservation Society (2006) What happens to balloons after they are released?

[47] http://balloonsblow.org/flaming-litter

[48] http://www.keepscotlandbeautiful.org/media/58556/balloonlanternstatement2013.pdf

[49] http://www2.keepbritaintidy.org/AboutUs/Policy/WhatWeThink/BalloonReleases/Default.aspx

[50] https://www.facebook.com/banchineselanterns/posts/226126034151290

[51] http://balloonsblow.org/flaming-litter

The last category of indicators is called ‘direct indicators’ and describes any indicators which are based on direct or semi-direct measurements of littering activities. A litter survey, i.e. manual counting of the quantity and type of litter in a specific area of land, is an example of a direct measurement which could be used to construct a direct indicator. In the absence of comprehensive data on these things, utilizing indirect indicators represents a refocusing of quantification efforts on factors higher up in the causal chain of an environmental issue, and using them to make an inference about the state of the environment in terms of littering.

We also assessed the extent of available data for constructing these indicators. We limited this assessment to national or regional (e.g. NUTS 2, NUTS 3) data collected by a central body (generally Eurostat). This type of data is required for 7 of the 18 indicators reviewed, while the other indicators require local data, such as litter surveys. As this latter type of data is not collated by a central body, an assessment of data availability for these indicators would require a comprehensive search of country/regional specific reports, and national and regional statistical databases. A review of this kind would take a considerable length of time, and is deemed beyond the scope of this initial data assessment.

Each indicator is reviewed separately below. For each indicator we provide: a description of what it measures; an overview of what a high or low rating means for that indicator and how it relates to litter pressures; and an assessment of what data is required to construct the indicator and whether or not this data is available for Europe.

The indicators are summarised in Table 12. This table includes additional information on the sources (as in sector of society/industry) and pathways (means by which litter reaches the aqueous environment) associated with each indicator. The sources and pathways are based on a condensed list developed from the literature in A.1.1 and presented in Section 2.4. The table also a short summary of the availability and geographical detail of relevant data.

Table 12: Summary of Local Litter Indicators – Data Availability Assessment for National and Regional Indicators Only

Category	Indicator	Geographical Level	Data Availability	Source	Pathway
Public Perceptions and Attitudes	Community	Local		Public – General Littering Public – Smoking Litter Public - Flytipping Commercial (Agriculture and Construction & Demolition) – Flytipping	Directly over land-water junction; Municipal drains.
	Attitudes to Place	Local – Public Attitudes Local/National – Litter Awareness Campaigns	No national datasets		
	Adequacy of Facilities	Local			
Facilities	Infrastructure	Local			
	Binfrastructure	Local			
Waste and Water Management	Collection and Treatment of Municipal Waste	National	Comprehensive dataset available	Waste collection/treatment	Directly over land-water junction; Municipal drains.
	Street Cleansing Provision	Local	Very little data available, unless use proxy (National)[1]	Waste collection/treatment	
	Landfill Located on the Coast or Riverbanks	Local	Better data availability if use proxy (National)[1]	Waste collection/treatment	
	Plastic Packaging Waste Management	National	Comprehensive dataset available	Waste collection/treatment	
	Waste Management of Commercial and	National	Very little data available, unless use proxy[1]	Construction & Demolition Other Commercial &	

	Industrial Waste			Industrial activities	
	Waste Management of Agricultural Plastic Waste	National	Very little data available, unless use proxy[1]	Agriculture	
	Waste Water Treatment	Waste water treatment coverage – NUTS 2 and 3 level Sewer overflow events, number of CSOs, number of misconnections – local/regional data if at all	Waste water treatment coverage – Europe wide data available but with significant data gaps Sewer overflow events – public authority and water company data	Sewerage Public – General littering and smoking litter	Municipal sewerage and CSOs, municipal drains
Recreational use of waterways and riverbank	Tourism and Recreation	Local	Comprehensive dataset available only at NUTS 2 level	Public - Recreational use of waterways and riverbank	Directly over land-water junction
Commercial & Industrial activities adjacent to rivers	Activities at Ports	Port cities/towns	Comprehensive dataset available for large ports	Other Commercial & Industrial Outfall	Directly over land-water junction
	Commercial land use next to rivers; industrial plant next to rivers	Local		Other Commercial & Industrial Outfall	Directly over land-water junction
General Indirect Indicators	Population Density	Resident - NUTS 3 level Tourist – NUTS 2 level Commuter – NUTS 2 level	Comprehensive datasets available at some resolutions	All sources	Directly over land-water junction; Municipal sewerage and CSOs; Municipal drains.
	Litter Generation Areas	Local			
	Prevailing Weather Conditions	Local or national	Some datasets available but may need extensive		

			analysis		
	Heavy Precipitation Events	Local or national	Some datasets available but may need extensive analysis		
Direct Indicators	Disposal Behaviours	Local		Public – General Littering Public – Smoking Litter Public - Recreational use of waterways and riverbank Sewage	Directly over land-water junction; Municipal sewerage and CSOs; Municipal drains.
	Litter Composition	Local			
	Litter Quantity	Local			
	Flytipping incidents (near waterways or coastlines)	National and/or local	Some datasets available	Public - Flytipping Commercial (Agriculture and Construction & Demolition) – Flytipping	Directly over land-water junction; Municipal drains.

Notes:

1. *Comprehensive national dataset available if a proxy indicator is used (municipal waste indicator)*

A.1.2.1 Public Perceptions and Attitudes

A.1.2.1.1 Community

This indicator aims to summarise local community identity and involvement. This could be measured via a survey of local public perceptions, i.e. to what extent do local residents feel a sense of pride, ownership and involvement over local spaces. High levels of identification and involvement in local community spaces will contribute to a lower potential for littering to take place.[52]

A.1.2.1.2 Attitudes to Place

This indicator assesses local public attitudes towards littering. Local surveys are used to understand whether local people are likely to properly dispose of waste.[53] This information can be used to assess the potential local litter pressure in a specific area.[54]

As a proxy indicator for litter awareness in the general public, a quick assessment of local litter prevention awareness campaigns might be informative; making the assumption that long term, high visibility and widely targeted campaigning would be associated with lower littering from the general public.

A.1.2.1.3 Adequacy of Facilities

This indicator summarises local public perceptions about the appropriateness of bins and furniture. A public survey is used to gauge whether facilities are viewed as appropriate and adequate to meet the needs of the local community. If facilities are viewed as appropriate this will decrease the local propensity for littering.[55]

[52] Kernow, R., and Spehr, K. *Leading On Litter: Foundations for Discussion on the Clean Communities Assessment Tool (CCAT)*, Report for Community Change, http://www.communitychange.com.au/insights-and-tools/changing-littering-behaviour/clean-communities-assessment-tool-ccat.html

[53] Kernow, R., and Spehr, K. *Leading On Litter: Foundations for Discussion on the Clean Communities Assessment Tool (CCAT)*, Report for Community Change, http://www.communitychange.com.au/insights-and-tools/changing-littering-behaviour/clean-communities-assessment-tool-ccat.html

[54] Kernow, R., and Spehr, K. *Leading On Litter: Foundations for Discussion on the Clean Communities Assessment Tool (CCAT)*, Report for Community Change, http://www.communitychange.com.au/insights-and-tools/changing-littering-behaviour/clean-communities-assessment-tool-ccat.html

[55] Kernow, R., and Spehr, K. *Leading On Litter: Foundations for Discussion on the Clean Communities Assessment Tool (CCAT)*, Report for Community Change, http://www.communitychange.com.au/insights-and-tools/changing-littering-behaviour/clean-communities-assessment-tool-ccat.html

A.1.2.2 Facilities

A.1.2.2.1 Infrastructure

The infrastructure indicator provides a measurement of the cleanliness, maintenance, and appropriateness of furniture, streetscape and landscaping. In contrast to the 'adequacy of facilities' indicator (discussed in Section A.1.2.1.3), this indicator is measured via on-the-ground surveys of infrastructure rather than surveys of public opinion. A high score on this indicator, i.e. furniture is well maintained, clean and appropriate, means that there is a decreased likelihood of littering in the local area.[56]

A.1.2.2.2 Binfrastructure

The binfrastucture indicator is used to assess the appropriateness of the design, position and maintenance of litter, recycling and butt bins relative to the local area and usage patterns. Adequate local binfrastructure will decrease the opportunity for littering.

The following types of data are required to construct this indicator:

1. Data on the number and specific locations of binfrastructure. Measures such as the density of bins, or number of bins per local household or capita could also be useful;
2. A record of the amount of maintenance of binfrastructure taking place, for example, whether bins kept in full working order and if they are ever allowed to overflow.[57] [58]

A.1.2.3 Waste and Water Management

A.1.2.3.1 Collection and Treatment of Municipal Waste

The relative sophistication of waste management strategies can be used as an indicator of local litter pressures. Regions with more advanced waste management systems are less likely to have significant littering.

The Öko-Institute report (from which this indicator is sourced) suggested that this indicator could be based on the classification of waste management strategies used

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[56] Kernow, R., and Spehr, K. *Leading On Litter: Foundations for Discussion on the Clean Communities Assessment Tool (CCAT)*, Report for Community Change, http://www.communitychange.com.au/insights-and-tools/changing-littering-behaviour/clean-communities-assessment-tool-ccat.html

[57] Kernow, R., and Spehr, K. *Leading On Litter: Foundations for Discussion on the Clean Communities Assessment Tool (CCAT)*, Report for Community Change, http://www.communitychange.com.au/insights-and-tools/changing-littering-behaviour/clean-communities-assessment-tool-ccat.html

[58] Keep Scotland Beautiful (2012) *Keep Scotland Beautiful's Local Environmental Audit and Management System Benchmarking Report 2010/11 for the Scottish Local Authorities*, 2012

by Eurostat.[59] In this classification system, EU member states are categorised into one of three groups depending on the total amount of incineration and material recovery (composting and recycling), as follows:

- **Group 1** - Incineration >25%, material recovery >25%
- **Group 2** - Incineration <25%, material recovery >25%
- **Group 3** - Incineration <25%, material recovery <25%

A fourth group of "even less advanced" countries was also proposed. Municipal waste data from Eurostat can be used to classify all European countries.[60]

This indicator has been used, in combination with other data, to construct other indicators discussed in this literature review, namely: population density (Section A.1.2.6.1); activities at ports (Section A.1.2.5.1); tourism and recreation (Section A.1.2.4); and plastic packaging waste management (Section A.1.2.3.4).[61] This is because litter pressure for each of those sources is considered to be a function of both the source and the adequacy of the general waste management regime.

A.1.2.3.2 Street Cleansing Provision

The better the street cleansing provision, the less litter will be transported to the aquatic environment. One assumes that all localities in Europe have Street Cleansing provision, but it should at least be considered whether there is a gap in provision. Operational measures could be, the number of times a week cleansing is carried out on average, cleansing staff per capita, how much is spent on the service.

However measuring the adequacy of Street Cleansing provision is not straightforward. One thing is because "adequacy" is relative to the litter loads any particular location is subjected to. Land based litter monitoring could help monitor how well Street Cleansing services perform. There is no Europe-wide monitoring effort in this regard, though standardized measures are in development. Some countries do have litter monitoring programs for public authorities to implement (see Section A.1.3.1 for a review of methods), so there will be some local data.

Obviously it cannot always be determined whether litter levels reflect high litter loads or inefficient Street Cleansing, so perhaps, a couple of different indices in conjunction would be needed to assess this. Monitoring might have to be tailored to answer this question in terms of timing of surveys just before and after cleansing times, for this question to be answered.

The proportion of roads outside urban limits, which may have much little or no Street Cleansing provision, may also be a relevant proxy indicator for assessing the ability of

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[59] Eurostat (2011) *Generation and Treatment of Municipal Waste*, 2011, http://epp.eurostat.ec.europa.eu/cache/ITY_OFFPUB/KS-SF-11-031/EN/KS-SF-11-031-EN.PDF

[60] Eurostat (2014) *Municipal Waste [env_wasmun]*, Accessed 4th July 2014, http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=env_wasmun&lang=en

[61] Öko-Institut (2012) *Study on land-sourced litter in the Marine Environment*, 2012

street cleansing services to deal with all public litter generated in a locality. This data would have to be assessed on a local level.

A.1.2.3.3 Littering from Landfill Located Near Riverbanks

This indicator aims to summarise the risk posed by current or historic landfill near rivers. Waste can be mobilised by rainfalls or floods or erosion and discharged into the waterways.

The 2012 Öko Institute report was unable to source specific data for this indicator, proposing instead to use a proxy - the municipal waste indicator (Section A.1.2.3.1). In this case, observational evidence suggests that groups 3 and 4 of the Eurostat classification have the highest potential for this type of littering.

There may be some national datasets for locations of current and historic landfill which may be able to contribute to a locality's assessment of the importance of this source of litter.

A.1.2.3.4 Plastic Packaging Waste Management

This indicator aims to summarise the potential for plastic waste litter. This indicator can be constructed from two types of data, namely:

1. The total amount of 'calculated disposal' of plastic packaging waste. This is the calculated difference between the amount put on the market minus recycling and energy recovery; and
2. The overall level of municipal waste management (see Section A.1.2.3.1 for further details).

Detailed monitoring data are available for packaging materials from Eurostat.[62] 'Calculated disposal' of plastic packaging waste consists of waste that is either incinerated without energy recover or landfilled or littered to the environment.

This indicator assumes that larger amounts of 'calculated disposal' are associated with a higher potential for littering of plastic. Data on the overall sophistication of waste management systems could be used to refine this indicator.

A.1.2.3.5 Waste Management of Commercial and Industrial Waste

This indicator describes local litter pressures from the commercial and industrial (Commercial & Industrial) sectors. The Öko-Institute suggest that the following subsectors might contribute to land sourced litter pressure:

- Industrial or manufacturing outfalls (e.g. by-products, plastic resin pellets);
- Construction or demolition sites;
- Ship-breaking yards;
- On shore fish-processing industry activities; and

62 Eurostat (2013) *Packaging Waste [env_waspac]*, Accessed 4th July 2014, http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=env_waspac&lang=en

- Agricultural activities.

The potential litter pressure from these sources will be determined by the quantity of Commercial & Industrial waste and the quality of waste management of Commercial & Industrial waste. As Eurostat do not publish Commercial & Industrial waste treatment data, this data can instead be sourced directly from Member States' national statistics. However, not all Member States publish this data, and as a result full European coverage will not be possible for this indicator.

If Commercial & Industrial waste generation and treatment data are not available, the Öko-Institute suggest that these effects should be deemed to be considered 'in principal' by the indicator for municipal waste management (Section A.1.2.3.1).

High quantities of waste and rudimentary waste management systems will increase the likelihood of litter from commercial and industrial sources.[63]

A.1.2.3.6 Waste Management of Agricultural Plastic Waste

Agricultural plastic waste has the potential to be a major source of land based litter. This waste could enter the aquatic environment both as agricultural litter, mobilised by flood waters or winds and discharged into rivers, or during the waste management process.

In a similar fashion to plastic packaging waste (Section A.1.2.3.4), this indicator could be constructed from data on both the overall level of municipal waste management (see Section A.1.2.3.1), and the total amount of 'calculated disposal' of agricultural plastic waste. Regarding this latter data, we are not aware of any published statistics for Europe – in this scenario, the municipal waste indicator (Section A.1.2.3.1) could serve as a general proxy for the potential litter pressure from agricultural plastic waste.

A higher litter pressure is indicated when the 'calculated disposal' of agricultural plastic waste is high (i.e. a larger amount of waste is landfilled), combined with less advanced waste management systems.[64]

A.1.2.3.7 Waste Water Treatment

Municipal raw waste water contains litter from a variety of sources and pathways, as follows:

- Hygiene articles from untreated sewage either:
    - Because of lack of adequate sewage treatment,
    - Because of misconnections in the sewage system,
    - Because of storm activity leading to discharge from combined sewage overflows

[63] Öko-Institut (2012) *Study on land-sourced litter in the Marine Environment*, 2012

[64] Öko-Institut (2012) *Study on land-sourced litter in the Marine Environment*, 2012

- Hygiene articles and microplastics (e.g. synthetic material fibres, microbeads) from treated sewage that water treatment is unable to filter; and
- Materials flushed from paved or unpaved surfaces into municipal drains (via surface water sewers (not necessarily treated) or into combined sewers (normally treated, but will not be able to filter all items).

This material is discharged into rivers and taken out to sea.

The types of data that would be useful to assess this are as follows:

1. The level and coverage of waste water collection (sewerage) and treatment;
2. The frequency and magnitude of sewer overflow events,[65] perhaps including a consideration of heavy precipitation events (Section A.1.2.6.4)
3. The number of misconnections
4. The adequacy of street cleansing provision (covered in Section A.1.2.3.2)

This first type of data is published by Eurostat, both at national level and at the NUTS level.[66] [67] However, a review of this dataset demonstrates that recent data is not available for a significant proportion of countries/regions. There may be enough data for some localities to assess their propensity for litter transfer to the aquatic environment because of inadequate waste water treatment. The second type of data is not published centrally and would need to be sourced directly from national/regional statistics. Each locality would have to assess their own data sources for this. Water companies may have access to this type of data.[68] Even an estimate of the number of CSOs might help assess vulnerability (in the UK there are an estimated 30,000 CSOs).[69] Generally, post 1960s housing have separate sewerage systems, so this could even be used to assess how many CSOs there might be in an area. Weather patterns might also give an indication of how much CSO discharge is contributing to litter finding its way into the aquatic environment, with heavy precipitation events associated with more CSO discharge and more litter discharge.

The ideal data to base this indicator on would be measurements of the amount of (mainly plastic) material discharged with untreated waste water, however it is highly unlikely that such data is available, except for perhaps in specific localities. It is

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[65] During heavy rains it is possible for the capacity of wastewater treatment systems to be exceeded. In this scenario a certain amount of sewage and storm water is not treated and is instead directly discharged into rivers and seas.

[66] Eurostat (2014) *Population Connected to Wastewater Treatment Plants [env_ww_con]*, Accessed 4th July 2014, http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=env_ww_con&lang=en

[67] Eurostat (2014) *Population Connected to Wastewater Collection and Treatment Systems by NUTS 2 Regions [env_wwcon_r2]*, Accessed 4th July 2014, http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=env_wwcon_r2&lang=en

[68] http://www.sas.org.uk/safer-seas-service/

[69] http://www.sas.org.uk/campaign/combined-sewage-overflows/

something that localities could look into monitoring however, and such an approach was used in the River Taff some years ago, though not fully quantitatively.[70]

Local authorities might be able to approach water companies for information on the estimated number of misconnections in their area. In the UK, an estimated 300,000 households have misconnections, and are sending greywater and even sewage directly into waterways.[71]

The adequacy of street cleansing provision is addressed in Section A.1.2.3.2.

A low potential litter pressure is associated with a high level of waste water collection and treatment coverage, a low frequency and magnitude of sewer overflow events,[72] a low frequency of misconnections and a highly efficient street cleansing service.

A.1.2.4 Recreational Use of Waterways and Riverbank

A significant share of waste at the coast is generated by leisure activities and tourism, and there will be waste generated in the riverine environment (including lake systems) from recreational activities too. By measuring the amount of tourism in the riverine environment, this indicator provides an estimate of the potential coastal litter pressure.

Data on the number of nights spend in tourist accommodation is used to construct this indicator; this data is available from Eurostat at the NUTS 2 level for most European countries.[73] The indicator would however be most powerful if tourist load in areas adjacent to rivers and lakes could be assessed, which would have to be carried out at a local level. A better indicator would also consider the level of litter mitigation activities, namely, the sophistication of waste management (see Section A.1.2.3.1) and/or the extent of cleaning in the proximity of rivers and lakes.[74]

This indicator is related both to “Litter Generation Areas”, which can include sites for recreation and tourism and “Population Density”, which might involve, rather than residential population assessment alone, the assessment of commuter and tourist influx also, not restricted to lake and riverside areas.

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[70] Williams, A.T., and Simmons, S.L. (1999) Sources of Riverine Litter: The River Taff, South Wales, UK, *Water, Air, and Soil Pollution*, Vol.112, No.1-2, pp.197–216

[71] http://www.water.org.uk/publications/snap/misconnects

[72] Öko-Institut (2012) *Study on land-sourced litter in the Marine Environment*, 2012

[73] Eurostat (2014) *Nights Spent in Tourist Accommodation Establishments by NUTS 2 Regions [tour_occ_nin2]*, Accessed 4th July 2014, http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=tour_occ_nin2&lang=en

[74] Öko-Institut (2012) *Study on land-sourced litter in the Marine Environment*, 2012

A.1.2.5 Commercial & Industrial Activities Adjacent to Rivers

A.1.2.5.1 Activities at Ports

Due to general operations, carelessly discarded waste and wind there is a high risk for land based litter at ports, mainly during loading and unloading activities. This indicator provides an estimate of the amount of such littering that could be expected from port activities.

Direct data on littering and/or lost material at ports in not available. It has been suggested that this indicator could instead be constructed using data on the weight of goods loaded and unloaded in the specific port of interest. This data is available from Eurostat for all major European ports, including inland riverine ports.[75]

A more comprehensive indicator would also include data on mitigation measures (mainly the national level of waste management established, especially for Commercial & Industrial waste). Passenger vessel traffic in different regions might be considered as an additional indirect indicator.[76]

A.1.2.5.2 Commercial Land Use Next to Rivers; Industrial Plant Next to Rivers

Similar in nature to “Litter Generation Areas”, this indicator is considered separately as proximity to the river is a factor that makes it distinct. This indicator is for litter emissions in terms of industrial outfall. There are some regional sources of information regarding potential point sources along river banks (e.g. for the Danube)[77] however this is more tailored towards chemical emissions. Data availability would have to be assessed more closely at the European level and may in fact only be possible at a local level.

A.1.2.6 General Indirect Indicators

A.1.2.6.1 Population Density

Population density can be used as a general indirect indicator for the potential pressure for land based litter. Data for population and the area of regional units (NUTS 3 level) can be sourced from Eurostat, and could be supplemented by data from relevant national population surveys where more local detail is required.[78]

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[75] Eurostat (2014) *Maritime Transport – Goods (Gross Weight) – Annual Data – All Ports – by Direction [mar_go_aa]*, Accessed 4th July 2014, http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=mar_go_aa&lang=en

Eurostat (2014) *Inland waterways transport – Annual Data* [iww_go_atygo], Accessed 4th July 2014 http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=iww_go_atygo&lang=en

[76] Öko-Institut (2012) *Study on land-sourced litter in the Marine Environment*, 2012

[77] http://www.icpdr.org/main/issues/water-pollution

[78] Eurostat (2014) *Population Density – NUTS 3 Regions [demo_r_d3dens]*, Accessed 4th July 2014, http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=demo_r_d3dens&lang=en

The effective impact of this potential pressure depends on a large range of factors, particularly the degree of mitigation measures, for example, the sophistication of waste and water management operations. [79]

In addition, this indicator is only able to provide a very rough picture of the potential for local littering because residential population density is not necessarily proportional to footfall or density of "public space users" whether commuters or tourists. For example, the City of London, an area within London of about 1 square mile, experiences a weekday influx of around 350,000 commuters in comparison to its resident population of around 6,000.[80] Although this is a very localized disparity between residents versus commuters, there may be urban areas where disparity is great enough to mean that it should be taken into account.

Data regard tourist numbers is certainly available (see Section A.1.2.4) at NUTS 2 level, and some data will be available for workplace location; Eurostat has this information, but only at NUTS 2 level, which may not be high enough resolution to be useful.[81] Higher resolution data might be available in national databases.

It was considered whether the demographic by age could be used as a litter indicator, however this was considered only to be useful at an extremely localized level and perhaps better represented by "Litter Generation Areas" such as schools.

A.1.2.6.2 Litter Generation Areas

The extent of litter generation in a specific area of land can be roughly determined by examining land-use maps. Different types of land, for example, commercial, industrial and other areas, will vary in terms of the potential for litter generation. For example, research in Melbourne has found that commercial areas can contribute twice as much stormwater litter as residential areas, and light-industrial areas also produce more than residential areas.[82]

This indicator, when applied to a specific area of land, therefore provides a high-level picture of how much litter may be generated. Land-use categories proposed by Moreland City Council in Australia are listed in Table 13 (these should not be considered a definitive list as they only include types of land found in the specific survey area of this study).

Table 13: Land-Use Categories for Litter Generation Areas

Land-Use	Description	Relative Potential for

[79] Öko-Institut (2012) *Study on land-sourced litter in the Marine Environment*, 2012

[80] http://www.telegraph.co.uk/news/uknews/10417064/Mapped-how-the-countrys-population-changes-during-a-work-day.html

[81] http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=lfst_r_lfe2ecomm&lang=en

[82] CSIRO (1999) *Appendix A: Example of a Litter Trap Action Plan. From Urban Stormwater: Best Practice Environmental Management Guidelines.*, 1999, http://www.publish.csiro.au/?act=view_file&file_id=SA0601229.pdf

Category		Litter Generation
Major Commercial	Large retail outlets (e.g. large shopping centres)	High
Light Industrial	Light industry and associated fast food outlets	Medium
Medium-Sized Commercial	Strip shopping centre (e.g. group of twenty shops or more), often with a supermarket and car parks	Medium
Local Commercial	Small strip shopping areas with between three and ten retail shops	Low

Source: *CSIRO (1999) Appendix A: Example of a Litter Trap Action Plan. From Urban Stormwater: Best Practice Environmental Management Guidelines., 1999, http://www.publish.csiro.au/?act=view_file&file_id=SA0601229.pdf*

The applicability of this indicator to a particular area of land is dependent on the availability of detailed land use data. Eurostat do publish land-use data, however the data is not sufficiently disaggregated to be of use. It is therefore necessary to undertake a review of national and regional data to determine the scope and coverage of land-use data in Europe.

Another mapping approach was implemented for the Irish National Litter Pollution Monitoring System, which created Litter GIS maps pinpointing "Potential Litter Generators" – i.e. areas or activities considered to constitute litter pressures with varying degrees of probability. These are shown in Table 14. Class 1 items were considered to be highly likely to generate litter, Class 2 moderately likely and Class 4 seasonal or occasional potential generators. A range (or particular radius) was associated with each potential litter generator and plotted on local maps. These maps were used to determine a priori litter hotspots for monitoring. However they could also be used to determine likely sources and pathways for litter in a particular local authority.

The maps were created as a one off exercise prior to the monitoring scheme being implemented in around 2000. "Potential Litter Generators" were identified by visual surveys, address databases and commercial listings and public authority records and information (e.g. lists of premises for purposes of licensing). It is not thought that the maps have been updated since. A significant resource was needed to create the maps for each public authority and GIS support was provided by the national local government IT support organisation, as well as the national litter monitoring organising group.

Table 14: Potential Litter Generators, National Litter Pollution Monitoring System

Class	Category	

1	1	Areas where mobile fast-food outlets operate
1	2	Bank ATMs (Both stand-alone and attached to banks)
1	3	Bring Sites and Civic Amenity Sites
1	4	Bus stops close to secondary schools
1	5	Derelict land and buildings
1	6	Illegal camping and halting sites
1	7	Known fly-tipping areas (including areas where 'No Dumping' signs have been erected)
1	8	Known Litter Blackspots (e.g. housing states, Stretches of Road and Canal, open spaces, informal meeting points or particularly problematic commercial premises)
1	9	Landfills
1	10	Litter bins which are habitually overflowing (e.g. those which are illegally used for household and commercial wastes on an ongoing basis)
1	11	Major event locations (with regular schedules)
1	12	Open-air market venues
1	13	Riverside walks, nature trails and similar routes
1	14	Newsagents/corner shops/sweet shops
1	15	Secondary schools
1	16	Shopping malls
1	17	Supermarkets
1	18	Takeaways/ fast-food outlets
1	19	Areas where groups of people gather (other than those cited above)
1	20	Miscellaneous polluting premises/ sites
2	1	Amusement arcades;
2	2	Beaches (public);

2	3	Betting establishments;
2	4	Bus and train stations;
2	5	Cinemas;
2	6	Heavily-used parks;
2	7	Industrial estates;
2	8	Large car parks (stand-alone);
2	9	Lay-bys;
2	10	Major event locations with less frequent event schedules than for Category 11, Class 1 (GAA etc.);
2	11	Primary schools;
2	12	Pubs;
2	13	Quarries;
2	14	Theatres;
2	15	Service station forecourts;
2	16	Third-level educational establishments;
2	17	Tourist attractions (location-specific e.g. monuments and buildings);
2	18	Areas where groups of people gather (other than those cited above); and
2	19	Miscellaneous polluting premises/sites.
3	1	Locations where sporadic events are held (e.g. circuses, fairs and annual events);
3	2	Major construction sites;
3	3	Marts;
3	4	Areas where groups of people gather (other than those cited above); and
4	5	Miscellaneous Polluting Premises/Sites.

We note that this scheme takes into account housing type, where it is known that they are litter hotspots. Housing type may serve as a socioeconomic indicator and may be considered a 'litter indicator'. However the relationship between socioeconomic index and littering is probably not well established and may be controversial to use; hence restricting its use where the area is known to be vulnerable to littering is sensible.

"Potential Litter Generator" mapping also takes into account the scale of commercial activity in an area by mapping retail areas and industrial sites, another useful element for litter pressure assessment.

We also note that riverside walks, nature trails and similar routes are assessed with this method; given that these are a point at which litter can directly transition the land-water boundary, they are particularly important.

Potentially where there are roads/highways near watercourses, or even, lots of larger roads without street cleansing provision, could be assessed with this method.

We have considered the mapping of recreation areas close to rivers, or Commercial & Industrial near rivers separately in Sections A.1.2.4 and A.1.2.5, as we have identified those as particularly important potential pathways for litter to enter the aquatic environment.

Mapping constitutes a particularly resource intensive aspect of data collection; if a simple tally could be produced, and measured per capita of population or per unit area of the locality, this may also be a quicker way of assessing local litter pressures. It would need some calibration however to determine what density of "Potential Litter Generator" would constitute higher risk for a particular source or pathway.

A.1.2.6.3 Prevailing Weather Conditions

Prevailing weather conditions influence tourism and recreational activities and public use of outdoor space. Public authorities might assess how many months of the year have weather clement enough (for example >20˚C) to increase public use of outdoor space; or how many hours of sunshine there are. Such data could be obtained from the European Climate Assessment and Dataset but would need some analysis to provide data of the desired timespan and region as their datasets are disaggregated by weather station and day.[83] Additionally, not all of the data they have is publicly available for every region. Data is available for various cities from Climate Data.[84]

A.1.2.6.4 Heavy Precipitation Events

Heavy precipitation events are associated with discharge from storm drains and combined sewage overflow. Precipitation after long dry spells is also associated with

[83] http://eca.knmi.nl/

[84] www.climatedata.eu

heavy litter loading. Therefore assessing these kinds of weather events can indicate litter pressure. Flooding may also mobilize litter and flytipping adjacent to waterways. Some data on extreme weather events is available from the European Climate Assessment and Dataset.[85] Other data may be available, e.g. from local water companies or environment agencies on flood risk or flashiness of particular waterways.

A.1.2.7 Direct Indicators

A.1.2.7.1 Disposal Behaviours

This indicator measures public disposal behaviours, namely, how much of the time is binfrastructure used, and how much littering takes place. Data could be gathered from observational surveys of local littering activities. While not a direct measurement of the amount of littering, this indicator could be used (assuming a certain composition and weight of litter per littering activity) to estimate the rate of littering in the local area.

This indicator could also target specific disposal activities. Those suggested by previous work are:

- **Recycling activities** – this indicator is based on information recorded about the actions of people in a location disposing of items that are potentially recyclable; and
- **Cigarette Litter** – this indicator uses data collected over an extended period of time on cigarette disposal behaviours, i.e. whether cigarettes are disposed of in designated butt bins or littered.[86]

A.1.2.7.2 Litter Quantity

The litter count indicator is constructed using litter survey data. Two main types of survey technique can be used to gather this data, these are:

1. **Litter Counts** – Detailed surveys in which the amount and type of litter in a designated region is physically counted;[87] [88] [89] and

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[85] http://eca.knmi.nl/events/index.php

[86] Kernow, R., and Spehr, K. *Leading On Litter: Foundations for Discussion on the Clean Communities Assessment Tool (CCAT)*, Report for Community Change, http://www.communitychange.com.au/insights-and-tools/changing-littering-behaviour/clean-communities-assessment-tool-ccat.html

[87] Victorian Litter Action Alliance (2014) *Litter Surveys Made Easy*, 2014, http://www.litter.vic.gov.au/resources/documents/VLAA_Litter_Surveys_Made_Easy_-_2014.pdf

[88] Keep Scotland Beautiful (2012) *Keep Scotland Beautiful's Local Environmental Audit and Management System Benchmarking Report 2010/11 for the Scottish Local Authorities*, 2012

[89] Keep Britain Tidy (2014) *Introduction to LEQ Surveys and LEQs PRO*, http://www2.keepbritaintidy.org/Expertise/LEQSurveysandLEQSPro/Solutions/Default.aspx

2. **Visual Assessments** – Photographs of the survey site are compared to a scaled set of photographs that vary in the extent of littering or illegal dumping.[90]

Once the survey has been conducted, it is common to assign a specific grade to the survey site to provide a standardised indication of the extent of littering. For example, in the UK and Scotland it is common for sites to be given a grading assessment based on a 4-point scale set out in the Code of Practice on Litter and Refuse, ranging from Grade A (clean) to Grade D (heavily affected).[91] The Victorian Litter Action Alliance in Australia assign sites with a rating ranging from 1 (no litter present) to 5 (a very significant amount of litter).[92]

In terms of the relationship of this indicator to land based litter: it is fair to presume that a greater extent of littering on land will correlate with a greater amount of land based litter eventually discharged to waterways.

The main drawback of this indicator is that it is very specific to the survey site, and difficult to extrapolate to wider areas of land. Furthermore, litter survey data across the EU is not easily comparable across different regions due to differences in survey methodology and reporting format.

A.1.2.7.3 Litter Accumulation Rate

This indicator could be considered a sub-category of the litter count indicator (Section A.1.2.7.2). It is in many ways a better indicator as it is constructed from a number of litter count data snapshots conducted over a fixed period of time. Unlike a one-off litter count this enables the rate of accumulation of litter (e.g. 50 pieces of litter per month) in a specific area to be calculated.

Similar drawbacks apply to this indicator as for the litter count indicator. Furthermore, the time-series data required to construct this indicator will be less available than standard litter count data.[93]

A.1.2.7.4 Flytipping statistics

Data regarding illegal dumping generally are not easy to obtain and it is likely that only a fraction of countries keep records of it. In the England, there is national database (“Flycapture”) that records flytipping incidents on public land. Reporting to the database is a statutory obligation. Local authorities reported 744,000 incidents of illegal dumping in 2011/2012, two-thirds of which involved household waste.[94] There

[90] Victorian Litter Action Alliance (2014) *Litter Surveys Made Easy*, 2014, http://www.litter.vic.gov.au/resources/documents/VLAA_Litter_Surveys_Made_Easy_-_2014.pdf

[91] Defra (2010) *Cleanliness National Indicator (NI195) Manual*, accessed 8 April 2014, http://cleanliness-indicator.defra.gov.uk/manual.aspx?section=all&print=0#1

[92] Victorian Litter Action Alliance (2014) *Litter Hotshots Rating Tool*, 2014

[93] Victorian Litter Action Alliance (2014) *Litter Surveys Made Easy*, 2014, http://www.litter.vic.gov.au/resources/documents/VLAA_Litter_Surveys_Made_Easy_-_2014.pdf

[94] Environment Agency (2012) *Official Statistics - Fly-tipping Statistics for England, 2011/12*, Report for DEFRA, 2012

is a location based element to the reporting, from which we know that 1,885 (0.25%) incidents were recorded in watercourses and 25,255 (3.5%) in the 'other' category, which includes sea-fronts and harbour mouths.[95]

A app-based flytipping monitoring system, "Flymap" is due to be implemented in Scotland. The system will be for the use of waste operations employees who are likely to come across flytipping in the course of their work. It can also be used to record flytipping incidents reported to the council. It is not currently known whether the location element of the reporting will allow mapping in relation to waterways, however GIS work should be able to determine the number of incidents within a certain distance, if not directly in, waterways, based on this type of dataset.

A.1.3 Monitoring Techniques

In this section, we review litter monitoring techniques, with a specific focus on riverine monitoring. In so far as they are relevant to this project, land based methods are also discussed, though briefly. As the first methods developed for litter monitoring, they provide a useful foundation. The current body of literature specific to riverine litter monitoring is small. Different methodological elements are examined within each section.

A.1.3.1 Land Based

The most established litter monitoring techniques are land based. There are methods in use for inland areas, on river banks or on the coastline, and they have quite a lot in common. Here we look at a few examples.

Urban surveys

In the UK, Keep Britain Tidy developed and help implement Local Environmental Quality Surveys (LEQS). The LEQS framework caters for monitoring of a wide variety of street environmental quality issues, and litter is one of these.[96] Two main types of litter related surveys are possible. The first is for large scale monitoring of local authority street cleansing. This methodology was subsequently adopted for other local authority tools such as the NI195 Cleanliness Performance Indicator.[97] The second is a litter composition survey.[98] The first grades cleanliness on a qualitative scale, for which 7 levels are define – 4 main grades and 3 intermediate between those grades. The composition study counts 35 item types in 6 functional categories.

The two types of survey carried out by the "National Litter Pollution Monitoring System" in Ireland, which have been running since 1999, correspond to some extent

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[95] Environment Agency (2009) Flycapture Guidance

[96] http://www2.keepbritaintidy.org/Expertise/LEQSurveysandLEQSPro/Solutions/Default.aspx

[97] Defra (2010) *Cleanliness National Indicator (NI195) Manual*, accessed 8 April 2014, http://cleanliness-indicator.defra.gov.uk/manual.aspx?section=all&print=0#1

[98] INCPEN, and Keep Britain Tidy (2014) *Litter Composition 2014*, 2014, http://www.incpen.org/docs/KBTINCPENLitterComposition2014.pdf

to those developed by KBT. The first is a "Litter Pollution Survey" which is more qualitative, determining the extent and severity of littering in a public authority's area based on five cleanliness grades; plus a "Litter Quantification Survey", to identify the composition (in terms of type and origin) of litter in an area. Surveys are compared over time to measure progress in tackling litter.[99] However, in contrast to the KBT surveys, the surveys were targetted to some extent to litter hotspots as determined by litter indicator mapping, which was carried out as a one-off exercise before surveys commenced in 2000. There are also survey questions designed to identify the origin of litter, by relating it to the presence of "potential litter generators" (sites or activities).

In Australia, the Victorian Litter Action Alliance (VLAA) has established litter prevention and monitoring programs. Their Local Litter Measurement Toolkit includes a litter count method that categorises litter by item type (46 categories) and largely material based classes (9). It also makes a distinction between recyclable and non-recyclable litter.[100] There is also a method for observing littering behaviour, a tool for logging littering/dumping incidents with an (optional) assessment of source, as well a tool for assessing littering levels in a more qualitative manner.

Table 15: Summary Table of Urban Litter Monitoring Approaches Reviewed

Method	Attribute (no categories) [] = sub category, one-to-one relationship	Micro-plastics/ nurdles/frag ments	Abun-dance*	Comp-osition	Units
LEQSE (Quality)	/	N	N	N	Qualitative scale from A to D, from least to most unclean
KBT/INCPEN (Composition)	Function (6) [Type (35)]	N	N	Y	Counts
NLPMS (Extent and	/	N	N	N	Qualitative scale, scored from 1-5, from least to most

[99] Department of the Environment and Local Government (1999) *National Litter Pollution Monitoring System - Monitoring Manual*, 1999, http://www.litter.ie/monitoring_manual/Monitoring%20Manual.pdf

[100] http://www.litter.vic.gov.au/www/html/20-home-page.asp

severity)					polluted
NLPMS (Composition)	Function (15) [Type (65)] Brand	Y	N	Y	Counts
VLAA	Recyclability (2) [Material (10)] [Type (46)]	Y	?	Y	Counts

Beach/riparian surveys

The Intergovernmental Oceanographic Commission in conjunction with UNEP developed global guidelines on marine debris monitoring.[101] There is one classification scheme for comprehensive analysis to direct abatement measures, and one simpler scheme for rapid surveys more geared towards public communications. The latter is simpler and suitable for visual surveying (rather than surveys that involve collection of items), and does not involve standardising the survey area or timing for comparability between areas. Standard methods were developed for beach surveys, floating litter and sea bed litter surveys, in this section we look at the beach survey method only. The UNEP/IOC methodology, being relatively recently developed, has not yet been utilized extensively, though it is starting to be picked up by research groups.[102] The "comprehensive" survey classifies 77 item types in to 9 material type categories. Many different Regional Seas Program area monitoring programs and NGO monitoring programs were reviewed and compared in developing this method, so we have only picked a few others to review for details regarding method.

The International Coastal Clean-up (ICC), is coordinated internationally by the Ocean Conservancy (a US environmental advocacy group) and is currently undertaken in 97 countries worldwide. The ICC categorizes 43 debris items types into five sources, all of which are of relevance to inland litter sources.[103]

OSPAR has its own guidelines for beach litter monitoring. It is rather more detailed than the ICC method, covering 111 item types. It also categorizes item types into categories by 13 material and functional categories.[104] Some of the item types have,

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[101] UNEP (2009) *UNEP/IOC Guidelines on Survey and Monitoring of Marine Litter*, 2009

[102] Jang, Y.C., Lee, J., Hong, S., Lee, J.S., Shim, W.J., and Song, Y.K. (2014) Sources of plastic marine debris on beaches of Korea: More from the ocean than the land, *Ocean Science Journal*, Vol.49, No.2, pp.151–162

[103] Ocean Conservancy (2012) *The Ocean Trash Index - Results of the International Coastal Cleanup (ICC)*, 2012, http://www.oceanconservancy.org/our-work/marine-debris/2012-icc-data-pdf.pdf

[104] OSPAR, UNEP, and KIMO (2007) *OSPAR Pilot Project on Monitoring Marine Beach Litter: Preventing a Sea of Plastic*, 2007, http://qsr2010.ospar.org/media/assessments/p00306_Litter_Report.pdf

in the past, been used as indicator items for 5 different source categories, mostly orientated around sea based activities.[105] However this form of analysis is not undertaken each year.

In addition, in order to monitor the marine litter "Good Environmental Status" indicators for the Marine Strategy Framework directive, a working group, the Technical Subgroup on Marine Litter (TSG ML) was set up to establish guidelines for litter monitoring.[106] Again, these are recently established but they will probably become more widely used within Europe over time. For example, a DG Environment riverine litter monitoring pilot project has been using the TSG ML litter classification.[107] Arcadis's litter source study (2012) also used the TSG ML litter classification, supplemented with some of OSPAR's higher level categories.

In the United States, the Clean Water Act requires the calculation of maximum amounts of pollution tolerable within water quality standards for impaired water bodies. These permissible amounts are known as Total Maximum Daily Loads (TMDL). In 2007, the state of California's Regional Water Quality Control Board adopted a zero-trash TMDL for at risk waters.[108] Monitoring of progress towards this TMDL is conducted by way of Rapid Trash Assessments, effectively a land based method of assessing the amount of litter in rivers, much like coastal surveys are used to monitor marine litter.[109]

Table 16 Summary Table of Beach Litter Monitoring Approaches Reviewed

Method	Attribute (no categories) [] = sub category, one-to-one relationship	Micro-plastics/ nurdles; large items	Abun-dance*	Comp-osition	Loca-tion	Units
UNEP /IOC	Materials (9)	Y (nurdles, though no	Y	Y	Beach	Count, weight.

[105] OSPAR (2010) Guideline for Monitoring Marine Litter on the Beaches in the OSPAR Maritime Area. Edition 1.0

[106] TSG ML, and JRC (2013) *Guidance on Monitoring Marine Litter in European Seas*, 2013, https://circabc.europa.eu/d/a/workspace/SpacesStore/b627cfb6-cece-45bc-abc1-e4b3297adb91/DRAFT%20MSFD%20Monitoring%20Guidance%20TSG-ML%2011072013.pdf

[107] Tweehuysen, G., Peterlin, M., Van der Meulen, M., Van der Wal, M., and Sherrington, C. (2014) *Identification and Assessment of Riverine Input of (Marine) Litter. Second Progress Report for the European Commission DG Environment under Framework Contract No ENV.D.2/FRA/2012/0025*, 2014

[108] California Regional Water Quality Control Board (2007) *Trash Total Maximum Daily Loads for the Los Angeles River Watershed*, 2007, http://www.epa.gov/waters/tmdldocs/34863-RevisedStaffReport2v2.pdf

[109] California Regional Water Quality Control Board, 2004, *Rapid Trash Assessment Methodology, Version 8* (2004)

	[Types 77]	specific 'fragment' category – through 'other' category;Y (through 'other' category)				
ICC	Sources (5) [Types (43)]	N;N	N	Y	Beach	Count, Weight
OSPAR	Function/Materials(13) [Types (111)] Sources (5) [Types (38 out of 111)]	Y;Y	Y	Y	Beach	Count
TSG ML	Materials (10) [Types (165)]				Beach	
Rapid Trash Assessment	Some indicator item types used to attribute source.	Y;Y	N	N	River-side	Count, plus other qualitative scores

*i.e. standardized temporally and geographically

A.1.3.1.1 Equipment and Location

The equipment for land based monitoring surveys is reasonably standard and generally includes bags, litter pickers, tabards for safety/campaign visibility, gloves, pen paper and clipboard or hand held computer, equipment for measuring length, which might be in the form of GPS capable hardware or tape measures/surveyor's wheels (more common for beach surveys). If scores are based on qualitative levels/grades, photographic guidance may be used to assist; also for item identification photographic guides may also be used. If weight is used as a unit, weighing Often it is recommended that surveyors work in pairs, both for safety, convenience and to help ensure consistency in each other's work.

The UNEP/IOC method suggests that at least one sampling location be chosen per country, but that ideally more should be selected. The ICC method does not specify how many sampling locations are seen as desirable per region, and neither does the OSPAR survey. However, OSPAR does provide some guidelines regarding how to choose beaches; relevant to riverine/riparian monitoring might be that sites are:

- Accessible, not only in terms of access to surveyors but also for litter removal;
- Of minimum transect length (100m and if possible 1km); and
- Not subject to any other litter collection activities.

TSG ML guidelines additionally prefer

- Sites with low to moderate slopes, precluding very shallow tidal mud flats kilometres wide at low tide

It also states that ideally, a large number of pilot surveys should be undertaken for a stretch of coastline and a few reference sites that are representative should be chosen from this set.

These beach methods recommend that fixed locations be chosen, so that sampling occurs in the same sites every year, for better comparability. Physical landmarks such as stakes are considered to be more accurate than GPS, though obviously GPS comes into its own where there are not such landmarks.

In the LEQS NI195 type survey, the transects must cover ten standard land use classes and all quintiles of the index of multiple deprivation. Different monitoring locations are chosen for every survey. Locations are chosen systematically so that over a period of a number of years, every ward will have been surveyed. In LEQs composition studies, it is a subgroup of these sites which chosen for in depth litter monitoring.

For the Irish NLMPS "Litter Pollution Index" survey, locations are chosen in conjunction with a GIS based "Litter Generation Potential) mapping system ("Litter GIS") as well as local knowledge, so that:

- 40% of monitoring sites are in "high risk" areas (town or city centres) as defined by "Litter GIS" maps,
- 40% are in random areas chosen with "Litter GIS", or by public authorities using GIS/maps to choose sites randomly (if resource not available to implement "Litter GIS"); and
- 20% are in locations chosen by local authorities based on local knowledge of litter pollution.

In this way monitoring effort is weighted towards areas most likely to be littered (mostly urban areas), but also there is at the same time coverage of all kinds of locations in a local authority area; local authorities also have some flexibility to tailor monitoring sites to the local situation. Potential Litter Generator is the term given to premises, sites or activities which are likely to give rise to litter pollution such as fast-food outlets, derelict land, tourist attractions and secondary schools; the Litter Generation Potential Maps are maps which identify clusters or 'hotspots' of premises and sites which are, from experience, associated with litter generation.

For the NLMPS Litter Composition survey, of which many fewer are carried out, analyses must, nationally, cover inner cities, urban, suburban and rural areas, and public roads and beaches. The sites chosen are “high risk” areas as defined by “Litter GIS” maps.

For the VLAA survey, areas where there is heavy littering are chosen for monitoring. Fixed infrastructure (bins, benches or signs) can be used to help define the survey area so that it can be returned to. It is also recommended that surveys should be conducted on the most heavily frequented sites, and the number of surveys conducted should be in proportion to the frequentation density.

Standardising and/or measuring the area surveyed in terms of transect length and width is becoming more common practice and features several survey methods. For beach litter, we will also note that buried litter is usually not sampled, though it may be a considerable proportion of beach litter (40% of total in one study).[110]

The UNEP/IOC method recommends transects of anywhere between 100m -1000m depending on the amount of litter generally found on the beach – longer transects being necessary the cleaner the beach. To determine the appropriate length of transect, a curve can be plotted of length sampled versus number of types of litter found. When number of litter types tails off compared to increased transect length, that is the point at which adequate transect length has been determined. Results should be standardized to length of beach surveyed. The survey area is from the beach backline to the water’s edge at low tide, and should be measured for each survey. However it is not recommended that litter quantity be standardized to beach *area* as it was thought that the amount of litter was more proportional to length rather than area.

The OSPAR method was developed for surveying 100m transects in depth and 1km transects with a more rapid method. The width of the beach from beach backline to the water edge is measured. The ICC method does not record or standardize transect length or width.

The TSG ML recommends 2 transects of 100m be taken on moderately to lightly littered beaches, and 2 x 50m transects on heavily littered beaches.

LEQs NI195 type transects are 50m long over the whole width of a street from backline to backline; or if a footpath is going through a recreational area, should cover 2 metres onto grassed or other areas lying either side of the path. In a completely open area, the transect can be 50x50 meters. The NLPMS litter composition survey is for 50m stretches of road or pathway, this covers the either the footpath or 1m of the verge closest to the road and the gulley in the road; plus visible litter within 1m of the survey area, including litter visible on private property. For the VLAA litter survey, a rectangular site of 48m^2 is stipulated, of varying breadth or width as suits the site.

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110 Kusui, T., and Noda, M. (2003) International survey on the distribution of stranded and buried litter on beaches along the Sea of Japan, *Marine Pollution Bulletin*, Vol.47, No.1–6, pp.175–179

Rapid Trash Assessments can be conducted in wadeable streams and shorelines of lakes, beaches and estuaries. Assessment is made of a 100m stretch of stream or shoreline, including the curves of the bank, by teams of assessors. Prominent landscape features can be used to delineate assessment sites so they can be easily returned to. The upper boundary of the bank to be surveyed is based on an evaluation of whether trash can be carried to the water body by wind or water. It is recorded whether litter is above or below the high waterline. Only subsequent surveys after the removal of litter, will be measuring accumulation within a defined timespan.

One study of beach litter found that <1% of litter was being found beneath the strandline and so the researchers felt that there was no need to include this in the survey area.[111] This may be different for rivers, where the distance between the riverbed (perhaps accumulating high levels of litter) and strandline (high water line for a river), are much smaller on a geographic scale. Perhaps this is why the Rapid Trash Assessment method records whether litter is above or below high waterline.

A.1.3.1.2 Sample Timing and Frequency

The timing and frequency of land based survey methods is rather an important aspect, because it affects the level of litter to be quantified and the significance of the data.

It is generally recommended that litter surveys be carried out as long after the last public authority or other cleaning effort as possible. For urban environments and some beach environments, this needs close coordination with public authorities or NGOs/community groups. OSPAR, TSG ML and also the Rapid Trash Assessment methodology recommend that it should be arranged for the survey area to be exempt from other cleaning effort. This is less likely to be easier for beaches and riverbanks than in urban areas.

Most beach surveys recommend that litter counted be removed, so that the next survey represents some measure of accumulation of new litter.

The UNEP/IOC survey recommends surveys be carried out every 3 months, an annually as a minimum. The measurement of accumulation rate is seen to be a fundamental component of their comprehensive survey methodology; so much so that the first time a beach is cleaned, the data gathered should not form a part of the main dataset, and should be used for training teams. Litter can be counted in place or collected, counted and weighed (preferred). Although replicates from the same beach would be desirable, it was recognized that the beach may not be large enough to provide statistically independent samples.

ICC and OSPAR methods do not make recommendations regarding the number of samples per beach. However if more than one transect is sampled per beach, OSPAR recommends they be 50m apart at least. The ICC surveys are carried out annually; while the OSPAR surveys, quarterly. TSG ML also recommends quarterly monitoring.

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[111] Tudor, D.T., Williams, A.T., and Environment Agency (2001) *Investigation of litter problems in the Severn Estuary/Bristol Channel area. R&D Technical Report E1-082/TR*, 2001

These methods do remove monitored litter but actually count it in place, as removing and analysing it afterwards is thought make analysis less robust, with fragmentation of items in transit/entanglement of items making counting more difficult.

However we note that, Tudor and Williams determined that 46% of original beach litter levels were achieved two weeks after clearing.[112] Most surveys are done quarterly or biannually, so litter levels would probably have reached an equilibrium far before then; this probably varies from beach to beach however, and can only be determined by an in depth study.

For urban surveys, litter is often counted in place as street cleansing services will be dealing with the area soon after, if the timing has been chosen to maximize litter accumulation before monitoring. Counts represent accumulation within a delimited timeframe (though often not recorded) as cleaning occurs regularly. If the timeframe was recorded, this would help standardize quantification and perhaps allow better comparison between public authority areas, however this is generally not done. The VLAA survey methodology allows for both options – both a visual and a full survey. The visual survey is a count in place; the full survey is where all litter is picked and removed so it can be sorted and counted in a clean area. A site can then be returned to within a specific timeframe such as a week or a month, to conduct an accumulation count.

The LEQS NI195 type methodology states that litter monitoring should cover seasonal variations by splitting the year into three survey periods ("tranches"): April-July; August-November and December-March. The survey should cover 300 transects within a local authority, 30 in each land use category and 6 within each ward (5 wards within each land use category). This translates to 900 transects annually. Surveying 300 transects should take around 10 working days. Transects should be taken at a variety of times of day and days of the week. Transects should not be taken directly after cleansing operations, nor directly after refuse collection, to achieve this it was thought that randomly timing transect surveying should be adequate. Surveying immediately after detritus producing periods such as blossom or leaf fall was also to be avoided. For the litter composition work, in 2014, 30 sites were monitored for each participating local authority.

NLPMS states that their litter composition surveys take 20 minutes and should be repeated at least twice for each location type (urban, rural, beach etc). This means that a public authority would be carrying out 12 composition surveys maximum. The survey is undertaken annually, in the summer months. It is noted that the reason given for there being more (around 10 times more) Litter Pollution Index surveys (the qualitative "cleanliness grade" style measure) than composition surveys is that the amount of litter was thought to be far more variable than litter composition. Surveys

[112] Tudor, D.T., Williams, A.T., and Environment Agency (2001) *Investigation of litter problems in the Severn Estuary/Bristol Channel area. R&D Technical Report E1-082/TR*, 2001

are conducted as long as possible after cleansing operations, just before the next operation.

The VLAA survey methodology recommends that three sites be chosen within a litter hotspot for monitoring. Ideally if surveys are being undertaken to monitor litter at the beginning and end of projects, they should be undertaken at the same time of year. Visual surveys are estimated to take around 20 minutes; full surveys where litter is removed to be counted take longer.

The Rapid Trash Assessment Protocol[113] stipulates that sites should be assessed several times a year, in different seasons, in order to determine the variability and persistence of debris in the water being assessed. A survey was estimated as taking 1 to 2 hours depending on litter levels and number of people working on the site.

A.1.3.1.3 Units

Many different parameters of litter can be recorded such as litter count, or weight and items categorized by material, function or assumed source.

NLPMS, LEQs and VLAA urban litter surveys all use litter count as their units. They all do this as a function of item type, often grouped according to various categories, either material type or function. NLPMS also records brands of branded items, as well as number and size of flytipping incidents. LEQs can present data in the form of percentage of sites assayed within a certain land-use category that an item type was observed in. The VLAA litter survey additionally splits items into recyclable and non-recyclable categories.

OSPAR, ICC, and TSG ML survey methods use litter count and type, with material being a common form of categorisation and some attributing item type to source.

UNEP/IOC method suggests that weight is the preferred unit, with both weight and count scored in the ideal scenario. If litter is not collected, then it is accepted that count will be the only unit.

Weighing does take more time than counting and appropriate (potentially covered and wind free) space for carrying out compositional analysis by weight, transport to the space and equipment, are all extra costs. Litter may need drying and cleaning, depending on how wet it is and perhaps contaminated with detritus or mud. Some beach items are too heavy to be weighed. Counting in situ is much more straightforward and cheaper. However recording both weight and count will produce the highest quality data. Many small items (e.g. plastic bags) may be of greater significance than one heavy item (a big roll of polythene sheet); however weighing allows easier comparison spatially and temporally. It is also less biased towards small fragments, if these are included in the methodology, which are always going to be greater in number dispersed in the environment than whole items.

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113 California Regional Water Quality Control Board, 2004, *Rapid Trash Assessment Methodology, Version 8* (2004)

OSPAR recommend that litter be counted in situ as collecting the litter first and identifying it later may alter numbers as collected litter gets more entangled. For this reason, weighing is not carried out, as it is really only practicable in conjunction with collection and sorting.

TSG ML recommend counting be the standard unit, because of the problems mentioned above. They consider volume to be a problematic measure because litter is generally quite compressible.

Rapid Trash Assessments[114] use a standardised monitoring form to assess various aspect of the litter (e.g. number of items, threat to human and aquatic health), with a total score out of 120 ultimately being generated. Scores of 1–20 are assigned across 6 different aspects:

- Level of trash (qualitative first impression);
- Actual number of trash items found;
- Threat to aquatic life (qualitative based on entanglement and ingestion risk or toxicity);
- Threat to human health (medical and sanitary waste);
- Illegal dumping (qualitative assessment); and
- Accumulation of trash (qualitative assessment of presence of old, weathered trash travelling from upstream).

In this way, a total score out of 120 is generated, where 120 is maximally optimal and 0 is maximally poor. For example, if over 100 items are found on the assessed 100m stretch, a score from 0–5 is given. The scoring sheet also includes item type information, categorized by a limited mixture of material type, source, and potential impact.

At this point, it is relevant to note that Gijsbert Tweehuysen (Waste Free Waters) in riverine litter monitoring pilots, found that a substantial part of litter, mostly flexible plastic film, remains suspended in the water as it high surface area to volume ratio means that it is pulled more easily into the water column by any turbulence; and so will not be found on a river bank unless caught in vegetation.[115] So there are some types of litter that land based methods, though focussed on the riverine environment, will be biased against, if they do include a litter type categorisation. That said, the sampling pilot study undertaken on the river Meuse found more items on the surface than in suspension.

A.1.3.1.4 Size Limit

Land based litter monitoring methods have a lower size limit generally imposed by visibility, though there is no empirical definition for this. Beach surveys generally also

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[114] California Regional Water Quality Control Board, 2004, *Rapid Trash Assessment Methodology, Version 8* (2004)

[115] Gijsbert Tweehuysen http://wastefreewaters.wordpress.com/2013/02/

neglect microplastics as for the same reason. However all the methods score cigarette ends (~2.5cm) and so this can give an idea of the lower limit for land based surveys.

The NLPMS has a category specifically for fragments, classed according to material; and the VLAA method also has 'other' categories for each material class which would probably give the flexibility to score fragments of various types. Fragments are not really the focus of LEQs litter counts. The Rapid Trash Assessment suggested that items that have fragmented should be counted as one item if they are made from inert materials such as metal or paper, but multiple items if they are made out of plastic.

Some beach surveys allow no logging of miscellaneous small fragments whatsoever and do not even have an 'other' category (e.g. ICC survey). The UNEP/IOC methodology does not really cater for microplastics either, considering it to be a separate type of analysis altogether, but does monitor nurdles (plastic resin pellets) and does have 'other' categories, allowing more flexibility. The OSPAR methodology caters specifically for unrecognizable fragments according to size class, (0-2.5cm; 2.5-50cm, >50cm). Pellets/nurdles are also scored but only in terms of presence/absence. Recognizable fragments can be scored as a whole item. The TSG ML has a separate methodology for microlitter however it does cater for small plastics within its land based method, with categories for e.g. plastic pieces 0-2.5 cm and for several other material types. In practice however the lower limit in terms of visibility when walking on a beach is thought to be around 0.5cm (like plastic pellets) though it is thought that this is unlikely to be reliably and robustly quantified according to this kind of methods, so in practice, a lower limit of 2.5cm is suggested. No upper size limit is thought necessary.

Regarding large items, there is some variability in terms of what is scored depending on the desired focus of the study. The OSPAR method and has categories for miscellaneous large items (>50cm). Other methods tend to catalogue larger items of waste for the purpose of capturing information about dumping, but do not tend to have a category for miscellaneous large items.

A.1.3.1.5 Attribution to Source and Pathway

Most approaches for assessing the contributions of different sources or pathways to litter in the aquatic environment have relied on an 'indicator item' approach. This is where 'litter count' type data is used to estimate the contribution of different sources/pathways based on the attribution of objects to typical sources/pathways. In its simplest form, one object is attributed 100% to one source or pathway, and the proportions of all items attributed to a particular category of origin are summed to give the contribution of that category to aquatic litter.

For example, in the past OSPAR used an indicator item approach, based on a mapping of a few (3 to 5) commonly found item types within each category, to monitor source according to 5 categories:

- Fishing and Aquaculture,
- Shipping (operational waste),
- Galley waste from ships (i.e. non operational waste),

- Tourism/recreation; and
- Sanitary Waste.

OSPAR states that this approach can only be used to track abundance within source categories over time; and cannot be used to compare the importance of different source categories relative to one another.

The ICC method is an indicator item type approach and is examined extensively in Section A.1.1.1. In contrast to the OSPAR method, it classifies all the litter according to source, and does make comparisons between source categories, because it considers itself to classify 'all litter'. However we consider that some important item types are not covered by the ICC method so understand that between source comparisons are very approximate..

In UNEP/IOC's survey method, the remote litter observation categorisation table classifies 29 litter types into 6 sources and one 'other' category. The larger, comprehensive litter categorisation scheme (77 item types) can be classified according to the that scheme too; each of the 77 item type categories can be nested within the 29 category scheme; and then related to source in this way; most comparable to the ICC method. The sources are defined as:

- Containers,
- Fishing and boating,
- Food and Beverage,
- Packaging,
- Sanitary,
- Smoking; and
- Other.

The TSG ML guidelines say that if this source attribution method is used, source-item type relationships may need to be defined differently for different regions, according to local knowledge.

More sophisticated models estimate the probability that a particular item originates from a range of different known sources/pathways, and these probabilities are used to make a more accurate model of the likely contribution of different sources/pathways. One such example (the DG Env pilot project authored by Arcadis)[116] was examined thoroughly in Sections A.1.1.1 and A.1.1.2. They followed the 'Matrix Score Technique' developed by Tudor and Williams (2001) and Whiting (1998).[117]

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[116] Arcadis (2012) *Case studies on the plastic cycle and its loopholes in the four European regional seas areas*, Report for DG Environment, 2012

[117] Tudor, D.T., Williams, A.T., and Environment Agency (2001) *Investigation of litter problems in the Severn Estuary/Bristol Channel area. R&D Technical Report E1-082/TR*, 2001,Whiting, S.D. (1998)

Indicator item based approaches, while providing a welcome contribution in the absence of other methods, have various shortcomings. Some were discussed directly in Sections A.1.1.1 and A.1.1.2. Because the items recorded in the litter count is necessarily based on simplified scoring sheets, as the variety of items that are found is too great to include all of them, bias is introduced as to the sectors that can be mapped to. For example, industrial plastic pellets, Taprogge balls,[118] and sewage treatment discs, are often omitted in the most common monitoring programme scoring sheets (e.g. ICC, OSPAR, UNEP-IOC) but these items are informative indicator items for 'the industrial sector' as a source and a 'direct discharge to water' pathway, which as a result, is completely omitted for any resulting analysis. Also, a truly representative selection of indicator items would also have to take into account the diversity of items originating from each sector/pathway. This is because of two reasons. Firstly, if a more common item within a particular sector was chosen as an indicator and a relatively rarer item within another sector was chosen as that sector's indicator, bias would be introduced in the calculation of the contribution of the respective sectors to litter, weighted toward that sector for which the indicator item was more common within the sector. Secondly, if the number of different indicator item types chosen for a source/pathway was disproportionate to the relative contribution of the source/pathway, bias would also be introduced towards the sector for which relatively more items types had been chosen. Therefore sampling biases are introduced that could only be overcome by prior knowledge regarding prevalence – a Catch-22 situation.

In addition, the sources or pathways chosen for the attribution of the litter item to source/pathway can introduce bias. Ideally the sources or pathways chosen should represent 100% of the litter stream. However this is rarely the case and the resulting statistics can contain omissions in entire pathways or sources not included in the analytical process, including the complete subsuming of entire categories within others. In this case, they would be misleading with regard to the contributions of included categories relative to the true, total litter stream. Additionally, some analyses conflate source (a particular sector or actor in society) with pathway (physical route) and vector (water/wind/direct deposition), to give a mix of categories which could never account for 100% of the litter stream, but involve an aggregation that is the product of an unknown extent of double-counting on one hand and omission on the other.

The assumptions made in the attribution step determine the resulting statistics on prevalence by source/pathway. However there will always be limitations to the extent to which it is possible to assign items to a source, as many items are attributable to multiple categories. In the absence of empirical data on point sources, the assumptions made are simply guesses, even when validated by surveys of local stakeholders.

Types and sources of marine debris in Fog Bay, Northern Australia, *Marine Pollution Bulletin*, Vol.36, No.11, pp.904–910

[118] Small abrasive sponges used for cleaning pipes in power stations and other industrial systems

Table 17 directly compares the ICC and Arcadis methodologies and demonstrates how different methods make large differences to estimates of source and hence what we assume about the relative importance of different sources. Note for example the large difference between medical/personal hygiene/sewage categories in the two estimates – 1% as opposed to 26%. One reason for this might be that the ICC does not score cotton-bud sticks as a named item type, whereas MAP (Mediterranean Action Plan) surveys do, and this is a key indicator item for that source. The policy choices made on the back of such different data sets would be radically different.

Table 17. A comparison between two indicator item type studies on source. Source categories have been aggregated to provide roughly equivalent groupings to allow comparison.

From International Coastal Clean-up*	**Mediterranean**	**From Report for DG Environment****	**Barcelona**
Shoreline & Recreational Activities (inc smoking related)	93%	Recreation and tourism	41%
Ocean/Waterway Activities	5%	Shipping, fisheries	10%
Dumping Activities	2%	Waste collection, treatment, dumping, household	17%
Medical/Personal Hygiene	1%	Sewage	26%
		Other	6%
Total	100%	Total	100%

*Ocean Conservancy (2012) *The Ocean Trash Index - Results of the International Coastal Cleanup (ICC)*, 2012

**Arcadis (2012) *Case studies on the plastic cycle and its loopholes in the four European regional seas areas*, Report for DG Environment.

Several survey methodologies record supplementary information allowing a qualitative assessment of likely sources within a location, generally for the purpose of guiding management techniques. This can be informative – for example some beaches will better indicate specific sources of debris than others, for example, remote beaches track litter from ships and long-distance drift litter better than urban beaches, which track urban input. TSG ML guidelines say that sites that are far from known sources may better reflect reference values background litter pollution levels, in contrast with sites close to potential sources. Local information is important and has a role to play. However it is difficult to translate this into quantitative assessments of source and pathway.

For example, the UNEP/IOC beach survey forms possess a section on "Source characteristics" where a variety of information regarding sources is collected, as follows:

- Location: Urban/Peri-Urban/Rural,
- Visitors per year,
- Access: vehicular/pedestrian/boat,
- Nearest town (distance),
- Nearest river (distance) (direction),
- River/creek input to beach; and
- Pipes or drains input (distance) (direction).

However it is not really detailed how this information should be used in high level analysis between regions.

The OSPAR method does record information about the survey location such as:

- Access (pedestrian, vehicular, boat),
- Location (metropolitan, peri- urban, rural or remote),
- Beach usage (bathing, fishing, isolated),
- Level of use (light, moderate, heavy) and season,
- Proximity to major rivers or other potential sources (such as food/drink outlets on the beach; shipping lanes, harbours, discharges of waste water, nearest town); and
- Litter collection and disposal facilities

For LEQs surveys, the presence of litter is assigned to one of the following sources:

- General,
- Domestic,
- Clinical,
- Commercial; and
- Faeces.

The percentage of sites for which a particular factor was deemed important was then calculated, in order to give a picture of source.

For the urban NLPMS "Litter Pollution Survey", surveyors must complete a checklist regarding the most likely causes of litter observed in a given area. The "sources/causes" in the checklist are:

- Passing Pedestrians,

- Passing Motorists,
- Retail Outlets,
- Fast Food Outlet,
- Gathering Points,
- Places of Leisure/Entertainment,
- Schools/School Children,
- Bus Stops,
- Fly-tipping/ Dumping,
- Bank/ATM,
- Bring Bank,
- Bus/Train Station,
- Overflowing Bins,
- Major Entertainment Event; and
- Construction Site.

The number of sites at which a particular "Potential Generator" was indicated is used to produce a ranking for "causes of litter" by calculating the percentage of sites for which each item was deemed a causative factor. In the "Litter Quantification Survey" flytipping incidents and their size are also recorded. This information is used to direct public authority litter management plans.

VLAA surveys have some reporting forms for littering incidents reported, found in passing, or during cleaning routines. There is an optional section for "Possible Sources/Cause of litter" as follows:

- Passing Vehicles,
- Passing Pedestrians,
- Gathering point/seats,
- Schools,
- Bank/ATM,
- Transport Stop,
- Retail,
- Food Outlets,
- Outdoor event,
- Tourist site,
- Weather; and
- Other.

Additionally, there is a littering behaviour monitoring form that records bin use by bin type, plus whether an individual threw or dropped litter, left the litter behind, or took litter away with them.

The Rapid Trash Assessment, in its qualitative trash assessment parameters, involves some rough judgements regarding source and pathway – e.g. whether the items derive from dumping, or if they have travelled far upstream, or if they are derived from sewage, based on a few suggested indicator items, or the general physical state of the waste. An assessment of local factors such as public access, proximity to schools etc is also noted in order to provide some information about source.

In conclusion, none of these approaches are able to give an adequate quantitative picture of the relative contribution of different pathways and sources to litter.

A.1.3.1.6 Other Auxiliary Data

The NLPMS, in its "Litter Pollution Survey", expects surveyors to record the weather conditions, whether litter is widespread or associated with any particular premises, where the litter is in the transect (e.g. road, gulley, verge, bushes), the surrounding litter infrastructure and whether it is overflowing, and when the last cleansing sweep was carried out.

The LEQs survey can also monitor bins, their condition and how full they are, in an assessment of bin infrastructure.

VLAA surveys have some reporting forms for littering incidents reported, found in passing, or during cleaning routines. These record location type, whether the incident is considered to be dumping or not, the waste class in terms of residential/domestic, Commercial & Industrial or Construction & Demolition, and volume estimate and number of items in the case of flytipping. They also contain an optional section where bin infrastructure and condition can be assessed. For littering behaviour monitoring forms, bin infrastructure assessment is compulsory.

The UNEP/IOC guidelines recommend a variety of data be collected, recorded in "Beach Characterisation" forms, to ensure better comparability for data analysis. The forms record a variety of information such as prevailing wind, beach slope and aspect, curvature, tidal range, land type at the beach backline (cliff, anthropogenic, dune, etc etc.) Information on any storm activity in the period between surveys is also recorded.

For ICC surveys, little auxiliary data is collected.

For OSPAR methodologies, information is recorded regarding nearby sources and prevailing currents, cleaning regime, beach aspect and slope, plus recent storm activity or container losses. TSG ML recommends that OSPAR Beach characterisation forms be completed for beach sites.

A.1.3.1.7 Statistical Methods

The statistical method required for beach and urban land based litter counts or weights are basic and do not need more elaboration here. The attribution method of the "Matrix Scoring Technique" works by assigning arbitrary scores for different likelihoods of litter deriving from a certain source. The assign a litter fraction to various sources, the score for that particular source is divided by the total score across all sources and multiplied by the total score. (See Table 18 for example).

Table 18. Example of calculation for Matrix Scoring Technique

Litter item	% contribution to total beach litter	Sea Source (Score,* (% contribution to total beach litter))	River Source (Score,* (% contribution to total beach litter))	Beach User (Score,* (% contribution to total beach litter))	Total Score
Food container	2.4%	1 (0.6%)	0 (0%)	3 (1.8%)	4

*Scores from 0 (Extremely unlikely) to 4 (Extremely likely).

**Excerpt from Tudor, D.T., Williams, A.T., and Environment Agency (2001) *Investigation of litter problems in the Severn Estuary/Bristol Channel area. R&D Technical Report E1-082/TR*, 2001

UNEP/IOC guidelines suggest a good method for ensuring consistency between data gathering efforts in different places is for a central online database to be made for inputting data; OSPAR apparently have a database that could be modified for this purpose.

A.1.3.2 River Based

Here we look at a number of studies conducted that actually sample the water flowing in rivers. Some techniques may be comparable to the surveying of floating litter at sea, but as there are no standardized methods currently widely implemented, we have not focussed on any individual marine research efforts. There are some standardized at sea methods, developed by UNEP/IOC and also TSG ML for floating and sea floor litter; though not currently widely implemented; we have looked at them briefly for useful elements of methodological design, in the relevant subsections. The TSG ML method is due to be tested and refined in the PERSEUS European project.

Sadri and Thompson[119] undertook a study of the presence of plastic debris in South West England's Tamar Estuary, a typical Northern European estuary in that it is open to riverine litter pathways such discharges from sewerage sites but has no major waste treatment site such as a landfill which would serve as a major polluting source. Estuaries differ from rivers in that debris may also flow back into them from the marine environment as a result of tidal movements. The Tamar has a catchment area

[119] Sadri, S.S., Thompson, R.C. 2014, *On the quantity and composition of floating plastic debris entering and leaving the Tamar Estuary, Southwest England.* Mar. Pollut. Bull. (2014)

of ca. 1700km^2, with relatively clean waters in the upper reaches where land use is predominantly agricultural.

Morritt et al.[120] report on the litter collected as a side effect of a Natural History Museum study on the presence of Chinese mitten crabs in the River Thames. A previous crab study having resulted in the collection of considerable amounts of litter, a riverine litter component was added on to the 2012 study.

The collection methodology was then aimed at capturing crabs, not litter, but placement of nets on the river bed generated a unique litter sampling compared with studies which have focussed on litter either floating or suspended in the water column. The distribution of collection points along the river allowed for comparisons to be made of litter composition and abundance relative to the proximity of anthropogenic impacts points such as towns and sewerage treatment outfalls.

Lechner et al.[121] conducted a study on riverine litter in the Danube, Europe's second largest river and the main tributary of the Black Sea, in a free flowing stretch of the river located in Austria, and within the Danube Alluvial Zone National Park, downstream of Vienna, Given the size and internationality of the Danube (19 countries contribute to the river basin) it is of great importance to Europe's aquatic environmental health.

The Danube study was part of a larger project concerning fish larvae dispersal and riverine fish conversation. Alongside quantifying riverine litter, the study sought to quantify the presence of ichthyoplankton, and compare the two. The rational for the comparison was that riverine litter such as microplastics can be mistaken for the eggs and larvae of fish and ingested.

Williams and Simmons[122] selected the River Taff in Wales for study as it suffers particularly badly from the presence of riverine litter. The study area comprised a stretch of the river within which 4 major tributaries —which cover 56% of its catchment—join the river. There are many Combined Sewer Overflows (CSO) releasing into the Taff catchment, mostly unscreened. Williams and Simmons conducted a study of litter and found the largest quantifiable sources were CSOs and fly tipping.

Moore *et al.* monitored litter discharging into the Los Angeles basin. They categorized litter by size, form and material, using a variety of nets; they also monitoring on a selection of dry and wet days.[123] The study was intended to quantify items <5mm as

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[120] Morritt, D., et al. 2013, *Plastic in the Thames: A river runs through it.* Mar. Pollut. Bull. (2013)

[121] Lechner, A., et al. 2014, *The Danube so colourful: A potpourri of plastic litter outnumbers fish larvae in Europe's second largest river* (2014)

[122] Williams, A. T. and Simmons, S.L., 1999, *Sources of Riverine Litter: The River Taff, South Wales, UK* (1999)

[123] Moore, C.J., Lattin, G.L., and Zellers, A.F. (2011) Quantity and type of plastic debris flowing from two urban rivers to coastal waters and beaches of Southern California, *Journal of Integrated Coastal Zone Management*, Vol.11, No.1, pp.65–73

these are exempt from regulation under the Total Maximum Daily Load regulation framework; though all size ranges were considered.

DG Environment is currently funding a project on the monitoring of riverine input to marine litter.[124] The work is being carried out by a consortium of consultants; the pilot monitoring effort and methodological development is being carried out by Gijsbert Tweehuysen, of Waste Free Waters. The project is currently underway, but the progress reports contain valuable information regarding methodology. The aim is to develop a common approach to monitoring and analysis of debris in EU rivers; and the pilot monitoring is being carried out in four European rivers.

A.1.3.2.1 Equipment and Placement

Sadri and Thompson[125] collected their samples by trawling close to the mouth of the river on with a 0.50m by 0.15m manta net of 300μm mesh. Manta nets sample surface water and their position is maintained by 'wing' like floatation structures extending either side of the net mouth.

The Chinese mitten crab study from which Morritt et al.[126] draw their data used 4 designs of fyke net: one standard eel net and 3 modified nets. Nets were trialled at 7 locations in the Thames from Crossness to Broadness Point (spanning a distance of ~6km). In this stretch of the Thames, the composition of litter was not found to vary a great deal between the seven sites; however the amount of litter did vary significantly. A fleet of nets was placed at each location consisting of three double fykes joined by tying together the closed ends ('cod ends') the nets, with an otter guard in the opening. The fleet was anchored to the river bed at both ends to keep it stationary. The low anchoring of the nets and the diameter of the lead net meant that organisms and litter from the riverbed to 40cm high in the water column were captured; the focus was therefore submerged litter. GPS was used to record the positions of the nets, removing the need for buoys, which can cause net disturbance. They were set sub-tidally, parallel to the shore, and in the direction of the tide. Interference with watercraft was also avoided by not setting the nets in the deep water navigation channel of the river. A grapple was trailed over the fleets to hook the fykes at times of haulage.

Lechner et al.[127] sampled a total of 4 sampling points in the Donau-Auen National Park (the National Park covers 38km of the Danube). Within the studied stretch, the

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[124] Project SFRA0025: Identification and Assessment of Riverine Input of (Marine) Litter , under the framework contract on emerging pressures, human activities and measures in the marine environment (including marine litter) (ENV.D.2/FRA/2012/0025).

[125] Sadri, S.S., Thompson, R.C. 2014, *On the quantity and composition of floating plastic debris entering and leaving the Tamar Estuary, Southwest England.* Mar. Pollut. Bull. (2014), http://dx.doi.org/10.1016/j.marpolbul.2014.02.020

[126] Morritt, D., et al. 2013, *Plastic in the Thames: A river runs through it.* Mar. Pollut. Bull. (2013)

[127] Lechner, A., et al. 2014, *The Danube so colourful: A potpourri of plastic litter outnumbers fish larvae in Europe's second largest river* (2014)

river has an average width of 350m and a discharge at mean flow of 1930m^3 s^{-1}. They used conical driftnets 1.5m long, of 0.5m diameter, and of 500 µm mesh. The nets were stationary, being fixed to the riverbed with iron rods. The nets sampled the top 0.5m of the water column, including the surface,[128] and covered 60% of the water column in 75% of cases. A flow-meter was employed to measure the volume of filtered water, which was collected in a jar attached to the net end. In 2010 duplicate driftnets were exposed at three sampling points along both river margins no more than 1km apart and 25m from the shore. In 2012 triplicate driftnets were used, and at four sampling points.

Williams and Simmons[129] used random number tables to select 50 sites within the Taff and its tributaries which were then classified using the Strahler method, which rates stream based on size from the smallest tributaries with usually no inflow of their own (rated 1) to the largest streams (rated 12). They used COPASACS to collect solids leaving CSO flows. These are sack shaped plastic nets of 4–6mm mesh and 30cm diameter, intended generally for screening use but often used for sampling. Their size meant they could only be fitted to some CSOs and not others. The rest of the site litter was assessed using three 5 metre transects down the river bank. Fly tipping sites were counted and characterised by household or commercial source. Public access to the site was also recorded as well as surrounding land use.

Moore *et al.* chose their monitoring sites such that they could capture all materials travelling from the watershed before they reach the ocean ("mass emission points"). Three sites were selected so that this could be done. Sites were chosen outside of tidal influence, and sites were also chosen for their accessibility. Samples were collected close to the edge of the channel, in the middle of the channel, and at the surface and near the river bed. Surface samples were collected by a manta net, in the middle of the river (0.8x0.15m; 0.333mm mesh size). The manta net was lowered and lifted by crane. Surface samples from the river middle and also the river edge, by two designs of hand net (0.46 x 0.25m and 0.8mm mesh size; and 0.43 x 0.22m and 0.5mm mesh size). To collect samples from the stream bed, a weighted stream bed sampler (0.15x0.15m and 0.333mm mesh size) was lowered into the water by crane in one instance, and a weighted rectangular net (0.46 x 0.25m and 0.333 mesh size) was lowered from a bridge in another instance. Hand nets were used for bottom samples near the side of the river. A flowmeter or timing of a floating object was used to measure flow rate. Samples were removed from the river and analysed in the same lab.

The DG Env riverine litter project has been undertaken in the Rhine (Netherlands), the Dalålven (Sweden), the Po (Italy) and the Danube (Romania). These were chosen for the following reasons:

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[128] Although floating litter was limited to <5cm in size by the height at which of the top bar of the net mouth was fixed above the surface of the water

[129] Williams, A. T. and Simmons, S.L., 1996, *Sources of Riverine Litter: The River Taff, South Wales, UK* (1996)

- To represent rivers discharging into different regional seas of the EU (North East Atlantic, Baltic, Mediterranean and Black Seas),
- They are large rivers and so major inputs into the marine environment; small rivers were excluded,
- The rivers differed in terms of the characteristics of the catchment area
- Data availability for key hydrological parameters is good,
- The location should not be too tidal and should have suitable flow characteristics (minimum velocity, consistent direction); and
- Local authorities were willing to cooperate to help find suitable monitoring locations, deliver additional services and capacity such as electricity/generators.

After the pilot, one river site was not deemed to be optimal because plastic input was so low; however it was suggested that it could be used as a reference (Dalålven, Sweden).

Preliminary pilots were additionally carried out in the Meuse (Netherlands).

Because the objective is to monitor litter discharging into the sea, sample locations were chosen around 50km from the mouth of the main branch discharging into the sea, downstream from the last urban area, sewerage treatment plants or the last tributary. Aerial images (Google Earth), plus the advice of local river management authorities were used to select sites on a local scale. An introductory document was prepared to court the involvement of local authorities, introducing the project and its aims, and how authorities can cooperate with the project. This was policy orientated for contacts at higher organisational levels, and more technical if appeared relevant to the particular contact person; translations were made if it appeared appropriate. Additionally it was found important to make sure that other local stakeholders, like recreational fishing organisations, were on side, in order for obtaining permissions to proceed smoothly. Assessments were made of shortlists of sites for safety and likely influence of prevailing winds, bends in the river and river depth when choosing which side of the bank to survey from. For example, in the Rhein, (sampled in Rozenburg), the sample was taken from the south western bank as this was deepest because of the shape of the river basin so most of the water would be passing on that side. Although prevailing winds (West-Southwest) would push floating litter to the right, north-east facing bank, wind was monitored so that if the wind shifted to a northern origin, more of the floating litter could be captured. Sampling from stationary nets can only occur where there are currents; and sometimes, in large bodies of water, there are places where there may be deep currents underneath an almost stationary layer of surface water.[130] Also, near river mouths, the flow of water is complex and sometimes reverses or becomes stationary in localised areas. Therefore a site should be visited prior to selection to check that flow tends to be consistent over the

[130] Waste Free Waters, 15/04/2014 https://www.facebook.com/pages/Waste-Free-Waters/610036559016085

timeframe of several hours. Use of trawled nets can overcome unpredictable currents.

GPS was used to record the location of sampling points.

Three different types of net have been piloted for the DG Env project, one standard manta net (0.5mm mesh size), and two others, housed within a catamaran shaped pontoon ("Catnet"), one to skim the surface (1m wide and 6.25mm mesh) and a suspension net (1m x 0.5m opening, 3.2mm mesh size) to sample at a depth of 10-60cm. Smaller mesh sizes than 3-4mm become clogged with silt and algae and also collapse under the pressure of turbulent or fast flowing water, which is why the size of 3.2 mm was selected. It was noted that not all litter flowing towards the net mouths could be captured by the nets; an efficiency of around 90% was roughly observed. The nets are either anchored from the riverside by a specially constructed small crane with a boom attachment, or tethered to a bridge. They could also be operated from a mid-river position, anchored to the river bed. The nets are lifted out of the water by the crane which is operated in conjunction with two 24V winches. In the field the winches can be powered with a battery, recharged by a generator. Additionally, a method was trialled where the manta net was simply used to filter quantities of river water pumped out of the river (5000 litres). For each location, just one sample site was operated, close to the river bank.

It was noted that sampling from the side of the river in a stationary location may not fully reflect the heterogeneity of litter quantities caused by local phenomena such as:

- Input from tributaries,
- Input from lakes which can be a significant pathway for waste; some rivers are 1 km wide in points, like the Danube, to further emphasise the issue),
- Input from point sources such as water system discharges,
- Wind pushing floating litter to one side or other of a river; and
- Stratification of river flow because of saline gradients i.e. in estuaries.

Litter may not become homogeneous until quite a distance downstream from these phenomena. Trawling can overcome this, but means that a vessel would needed to be transported or made available for each sampling location or region, increasing potential costs. A dinghy was used to aid monitoring and measurement of river discharge that was transported with the rest of the equipment, and could in theory be used for trawling, though it cannot be used safely near the mouths of rivers where there are tides and waves. In that case, a larger vessel that could not be towed overland easily would be necessary.

A flow meter (Aquadopp doppler current profiler) is used to measure water velocity while sampling. A depth meter determines the depth of the river bed. A laser range finder was used measure the surface dimensions of the river. The collected data are used to calculate the total river discharge. The flow and depth meters are housed in a small floating apparatus. Data is communicated to a laptop where it is saved. The less sophisticated method to measure flow, though also fairly robust, is to measure the time it takes for a tethered float to travel 10 metres in the water.[131] A portable weather station rig (Davis Vantage Vue) was used to record local prevailing wind direction, actual wind direction and wind strength.

The nets were deployed as follows:

- Check condition of the manta net (ruptures, cracks, cleanness, clamps, etc.);
- Check current meter;
- Lower the net in the water, start timing;
- Monitor tension indicator (to prevent sampling with a clogged net);
- Monitor approach of large items;
- When tension > 50%, lift net out of the water;
- Stop timing, collect flow speed data;
- Lower the net slowly into the large container on land, filled with filtered river water and rinse the net;
- The Manta net samples (mostly microplastics) are transported to a lab in 1l containers; the Catnet materials are put in buckets and dried before shipment to the lab in plastic boxes. Shipment is by courier. All samples were analysed by the same lab.

All equipment was designed to be fully transportable in a trailer puller by a camper so that the monitoring team could be on site at all times, also providing maximum flexibility with regard to sampling sites.

The UNEP/IOC floating litter survey (the trawling method) recommends that a net of between 2-4cm mesh size and up to 6m wide be used. The trawl should be carried out directly against the current. Specialist advice should be sort regarding rope length and set up, depending on the width and size of the net used. Side rollers and specialist lifting equipment may be needed to lift the net. “Vessels of Opportunity” can be used to host sampling exercises, to save on costs.

The UNEP/IOC floating litter survey also has a visual method, whereby a reduced item type list is scored for visible litter floating within 50-100m either one or both sides of a vessel. Perhaps this method could be adapted for riverine litter if there are budget constraints. It could be carried out from the river bank or on “vessels of convenience”. A fixed time period can be set (e.g. 2 hours) for litter monitoring so that researchers do not fatigue. The transects can be standardized simply on the basis of time, however a flow monitor could be used to aid this in the case of observation from the river bank. A GPS device on board can achieve this if the survey is carried out from a vessel.

[131] Can be made from a PET bottle tethered with a 10m rope and weighed down with pebbles to keep it upright and visible.

TSG ML has also considered floating litter surveys. It categorisation for floating litter is also much simpler than its beach based survey; it is thought that attributing items to source is just not very feasible for this method; however analysis of litter densities and currents may allow attribution to physical source. Placing the surveys was described as an iterative process, whereby over time, hotspots could be identified and targeted, as well as some relatively cleaner areas, for the production of data suitable for monitoring trends over time. Transect width is to be adjusted according to method, as it will depend on elevation above the sea, the ship speed (2-10 knots) and observation conditions; it was estimated that a transect width of 10m could be expected; the transect width should be chosen such that all items in the transect and in the target size range (2.5-50cm) could be seen. It is noted that an inclinometer can be used to measure distance at sea, to determine transect width. It was though that a sample time of around 1 hr, corresponding to a transect length of a few kilometres, would be a good amount before researcher fatigue causes error. In terms of equipment, this was thought to be minimal, with a tablet PC with GPS, and an inclinometer the bare basics. It was suggested that perhaps a system for visually demarcating the observation area, and a system for training and calibrating size classification could be developed.

A.1.3.2.2 Sample Timing and Frequency

Gijsbert Tweehuysen of Waste Free Waters writes that as sampling results can vary considerably over time due to changes in such variables such as wind conditions, it is imperative that sampling to be undertaken regularly over extended periods of time.[132] River flow in the Meuse, for example, can vary from just 1 or 2km per hour to 15km per hour in the Winter.[133] The number of items can be expected to increase right after floods and when river throughput increases. For example, the faster the river was flowing, the more items were found per unit area surveyed. Samples were taken from April to July, which was considered to give some insight in to seasonal variation. The maximum duration of the sample is determined by the clogging of nets by silt and algae; at 50% of the maximum towing force as measured by a tension indicator, the sampling should be stopped. The sampling time therefore varies; it can be anywhere between one and several hours.[134] Between 5-10 samples were taken with each net type.

In their study of the Tamar, Sadri and Thompson[135] sampled during both spring and neap tides (i.e. representing tides with maximum and minimum tidal ranges respectively, each occurring twice a month) during the months of May and July. Sampling was conducted in triplicate for both flood and ebb tides on three different

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[132] Waste Free Waters, 09/06/2014 https://www.facebook.com/pages/Waste-Free-Waters/610036559016085

[133] Gijsbert Tweehuysen http://wastefreewaters.wordpress.com/2012/04/

[134] Gijsbert Tweehuysen http://wastefreewaters.wordpress.com/2013/02/

[135] Sadri, S.S., Thompson, R.C. 2014, *On the quantity and composition of floating plastic debris entering and leaving the Tamar Estuary, Southwest England.* Mar. Pollut. Bull. (2014), http://dx.doi.org/10.1016/j.marpolbul.2014.02.020

dates for both spring and neap tides. Trawls lasting 30 minutes at a speed of 4 knots were made during periods of maximum-flow-in and maximum-flow-out, which occur approximately 2.5 hours after high and low tides. This was so data on the tidal effects on plastic debris in estuarine environments could be gathered, and the timing gave a greater degree of consistency in terms of tidal flow.

The Chinese mitten crab study reported on by Morritt et al.[136] took place over a period of three months between September and December in 2012, during which 29 hauling trips were made at intervals of 3 days. Individual locales were left for a minimum of 5 days after being fished, and nets were re-set at different localities after being hauled.

In 2010 Lechner et al.[137] took samples in two separate years (2010 and 2012). They sampled for 24 hour periods at hourly intervals in 2010. Sampling was done across April and July, so as to encompass the entire larval fish drift season. In 2012, they sampled from 2 hours before sunset to midnight, also at hourly intervals. The rationale for the time spread of sampling did not concern the litter component of the study, but was to ensure capture of a properly representative larvae sample, as larval fish drift is known to peak nocturnally. It is interesting to note that the concentration of plastic in the water was much higher in 2010 than 2012. It was suggested that this could be attributed to sporadic events involving accidental release of material during processing, packaging and transport.

Williams and Simmons[138] conducted two surveys: one winter and one summer. This timing was chosen in order to investigate the possibility of seasonal variation in litter composition. Overall there was not a statistically significant difference between the seasons, though there were trends for particular items. The reasons for particular trends were not obvious and many theories were put forward for each trend. For the CSOs, they monitored the sacs once a week over a twenty week period, and removed them for analysis if overflow had occurred.

Moore et al. took samples both during a dry (at least 2 weeks without 0.6cm of rain) and a wet period (within 24 hours of a 0.6 cm rainfall). The dry period was sampled in Spring and the wet period in Winter. Note that the samples taken in the “wet” period were thought to be underestimating storm water loading of debris as they did not sample the river at its maximum level. Sample size was originally intended to be 15 minutes. However some deployment times were as short as 30s because of fouling by algae and debris in samples taken in Spring. Three samples were taken with each type of net in each position in the river.

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136 Morritt, D., et al. 2013, *Plastic in the Thames: A river runs through it.* Mar. Pollut. Bull. (2013)

137 Lechner, A., et al. 2014, *The Danube so colourful: A potpourri of plastic litter outnumbers fish larvae in Europe’s second largest river* (2014)

138 Williams, A. T. and Simmons, S.L., 1996, *Sources of Riverine Litter: The River Taff, South Wales, UK* (1996)

The UNEP/IOC survey guidelines suggest that trawling transects should be repeated 5 times within three 1km^2 subplots within a 5 km x 5 km sample area. The trawl should sample 800m as a linear dimension and samples should be at least 200m apart. Trawl speeds should not exceed 3-4 knots per hour. They should be carried out at least annually, though quarterly is better.

For rapid visual assessments, quarterly surveys are recommended. Replication is also recommended, and there should be 1 km distance between samples.

TSG ML guidelines for visual assessment of floating litter state that sampling arrangements should be flexible enough so that they can be rescheduled to a time when wind and sea conditions fall within accepted ranges; alternately if there are very regular trips made by a 'vessel of opportunity' such as a coast guard vessel or passenger vessel, this would help standardise conditions. Monitoring should take place only after a period of calm sea. Many samples over a short period might be necessary to understand the variability of samples and therefore how much sampling is needed for samples to be representative. Monitoring could also be targetted to particular sources – e.g. before and after high use levels of coasts in summer; or after heavy rains and heavy expected riverine input.

A.1.3.2.3 Units

Sadri and Thompson[139] categorise their samples by size in millimetres and plastic type and form. The Plastic types occurring in the sampling were:

- Polyethylene,
- Polystyrene,
- Polypropylene,
- Polyvinyl Chloride,
- Polyester; and
- Nylon.

The plastic forms occurring in the sampling were categorised as:

- Fibre,
- Sheet,
- Pellet; and
- Fragment.

Litter was quantified by counting the plastic pieces collected during the whole sampling period using the categorisations of size and material, and size and form (e.g. X number of polypropylene of 1–3mm, and X number of sheets >5mm). Counts were used to calculate percentage composition (a relative measure). The counts were

[139] Sadri, S.S., Thompson, R.C. 2014, *On the quantity and composition of floating plastic debris entering and leaving the Tamar Estuary, Southwest England.* Mar. Pollut. Bull. (2014), http://dx.doi.org/10.1016/j.marpolbul.2014.02.020

also used to compare litter amount between ebb and flow tides (an absolute measure). Additionally, they calculated the mean concentration of plastic in units of count per m^3, calculated based on the distance travelled by the boat at a constant speed and the area of the net mouth submersed in water.

In the study reported by Morritt et al.[140] litter was counted and identified according to 54 categories of rubbish were; this appears to be based on the International Coastal Cleanup schema with some additions especially in the Medical/personal hygiene class; and a category for 'other' items in addition. Counts were used to calculate percentage composition; the method was not fully quantitative in that water throughput was not measured and so the concentration of litter could not be estimated. However tests were applied to determine if the amount of litter at different sites was significantly different (there were some significant differences depending on the item type).

The proportional occurrence of plastics so categorised in the composition of the litter was calculated both for the overall catch and for each of the 7 locations, and represented as a percentage composition.

Lechner et al.[141] counted each plastic particle, categorising them by type, and also classified by size (2-20mm,<2mm), as well as estimating weights based on samples from the size categories. The categories used were:

- Pellets;
- Flakes;
- Spherules; and
- Other

Pellets, flakes and spherules were interpreted as industrial raw materials for plastic production, whereas others represented material from consumer products. The concentration of plastics in the water was represented both as count per unit volume and weight (g) per unit volume. They used data on the flow of the river Danube to estimate total plastic input from the Danube to the Black Sea (4.2 tonnes per day).

Williams and Simmons[142] gathered data in the form of litter counts, weight of COPASAC contents, and % volume. Litter was categorized into about 6 sources, subdivided into 12 subcategories and 36 further, finer, categories. Compositional analyses were performed for the whole Taff catchment, the Taff tributaries, and specifically CSO flow.

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[140] Morritt, D., et al. 2013, *Plastic in the Thames: A river runs through it.* Mar. Pollut. Bull. (2013)

[141] Lechner, A., et al. 2014, *The Danube so colourful: A potpourri of plastic litter outnumbers fish larvae in Europe's second largest river* (2014)

[142] Williams, A. T. and Simmons, S.L., 1996, *Sources of Riverine Litter: The River Taff, South Wales, UK* (1996)

Moore et al. both counted and weighed their items. They categorised them by material, form and size. They did not sort into item type (function). They also monitored flow during monitoring and calculated the quantity of litter per unit water volume by multiplying the area of the sampling device opening, the flow rate and the time of deployment. They used historical data on river discharge rate to calculated daily discharge of litter to the sea in terms of both weight and count.

For the DG Env riverine litter project, items are categorized by the maximum dimension. The focus is microlitter (0.333mm-5mm) and mesolitter (5-25mm), though macro litter is also categorized according to the TSG ML litter list (approx. 169 categories, sorted into material types). Items are also weighed and colour is recorded. Microplastics are sent for further identification by IR spectroscopy. The recording of flow and dimensions of river cross section allowed an estimate of the number of items transported per hour by a river of known dimensions in to the sea.

For the UNEP/IOC trawling survey, the standard list of litter types is to be used, and counts and weight measured. For the visual survey, a reduced list of around 29 items was created, and counts only are recorded, as it is more difficult to score items at a distance.

For TSG ML's visual survey, an item type categorisation based on type and (for plastics) size, was devised, with 43 classes and 8 material types. Data is to be presented as items per square kilometre.

A.1.3.2.4 Size Limit

Sadri and Thompson[143] categorised their collected samples into 4 size groups: >5mm, 3–5mm, 1–3mm, and <1mm. They also used 4 forms of descriptive identification: fragments, sheet, fibre, and pellet. When their samples were analysed, the 1–3mm group was found to be the most prevalent. This differs to other studies cited in the paper where <1mm was the most widely recorded microplastic size. This difference to the fact that glass filter paper was used which would capture smaller particles. The upper size limit is not explicitly stated but as the vertical dimension of the manta net was 15cm, with part of this dimension submerged below water, there will have been some limit less than 15cm.

In the Lechner et al.[144] study, items from a subsample (n=500) of each plastic type were weighed and measured, with weighing being carried out to the nearest 0.01g and measuring to the nearest 0.01mm. Two main size groupings were identified:

- Pellets, flakes and large spherules of 2–20mm (mesodebris); and
- Small spherules of <2mm (microdebris)

[143] Sadri, S.S., Thompson, R.C. 2014, *On the quantity and composition of floating plastic debris entering and leaving the Tamar Estuary, Southwest England.* Mar. Pollut. Bull. (2014), http://dx.doi.org/10.1016/j.marpolbul.2014.02.020

[144] Lechner, A., et al. 2014, *The Danube so colourful: A potpourri of plastic litter outnumbers fish larvae in Europe's second largest river* (2014)

An upper size limit of 5cm for the vertical dimension of *floating* items was imposed by the small gap between driftnet-frame and water surface.

The lower size limit on the Williams and Simmons[145] study was imposed by the 4–6mm mesh size of the COPASACS used for sampling.

The DG Env riverine litter project, litter size classes are

- Micro <1mm
- Meso 1-5mm
- Macro-small 5-25mm and
- Macro-large >25mm

This is consistent with some categorisations of microplastic as being below 5mm. He notes that a major fraction of litter items (by count) found in the Meuse were smaller than 25mm (around 70%).[146] Although the DG Env riverine litter project states as an objective the assessment of the amount of small and micro-sized litter transported to the sea, the methodology in development has not restricted itself to assessing meso/micro litter; it states that by weight, macro litter is the biggest contributor to marine litter and so should not be neglected.

In the Morritt et al study, it appears that the focus was on macro litter; it is not known what lower size limit was imposed or how microplastic was dealt with; however cigarette butts were a monitored category (standardly around 25mm). In terms of upper limits, the otter trap was thought to perhaps have excluded larger plastic bags which were not as prevalent as expected in the samples.[147] Otter guard grills can be in the size range of 7.5- (knot to knot, net) to 9.5 cm (rigid grill) as a maximum, in order to be effective, giving an idea of the upper size limit imposed.[148]

Moore *et al*.'s minimum size limit was that imposed by their net sizes (0.333-0.8mm depending on the net) and they classified litter into 0-4.75mm and >4.75 mm categories. Upper limits are imposed by the net opening sizes.

For the UNEP/IOC survey methods, the trawling data categorization is the same as the comprehensive beach litter assessment – so microplastics are not specifically considered but small plastic items such as nurdles and cigarette butts are included. For the rapid visual assessment of floating litter, the simplified categorization has and "other" category that small fragments could be assessed with but obviously at a distance these will be less visible.

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[145] Williams, A. T. and Simmons, S.L., 1996, *Sources of Riverine Litter: The River Taff, South Wales, UK* (1996)

[146] Gijsbert Tweehuysen http://wastefreewaters.wordpress.com/2013/02/

[147] Morritt, D., Stefanoudis, P.V., Pearce, D., Crimmen, O.A., and Clark, P.F. (2013) Plastic in the Thames: A river runs through it, *Marine Pollution Bulletin*

[148] http://www.otterproject.cf.ac.uk/mitigation.html

For the TSG ML visible floating litter method, a minimum item size was defined as 2.5cm. If the observation conditions could not allow this minimum size limit to be perceived, the method is not deemed valid. A maximum size limit of 50cm was defined.

A.1.3.2.5 Attribution to Source and Pathway

This has not been done in any systematic or extensive way amongst the reviewed riverine studies, as the focus of each tended to be quite narrow.

Sadri and Thompson did not attempt to relate item type with source or pathway beyond some very general suggestions regarding the types of plastic associated with packaging versus sewage outputs.

Morritt et al, although they used an item categorisation list based on the ICC's, where each item is allotted to a specific source, did not use this to make inferences about sources or pathways; however they did make observations that litter levels were higher in the vicinity of sewage treatment plants, using location of potential point sources to make inferences about litter source.

Lechner et al made a very sweeping attribution based simply on item type whereby pellets, flakes and spherules were interpreted as industrial raw materials for plastic production, whereas all others were taken to represent material from consumer products.

Williams and Simmons' study provided some very specific information about litter coming from combined sewage overflows, and their litter categorisation method also attempted some attribution of item type to source. They tested for a relationship between the prevalence according to source with environmental factors such as surrounding land use type and access roads, and found that litter falling into General and MSW categories were significantly affected by this. Their statistical analysis lead them to characterise the major sources of riverine litter as Sewage, Diffuse and Fly-tipping.

Moore et al did not make source attributions in a quantitative manner, however the studies focus on small plastics revealed a considerable proportion of pre-production plastic pellets, indicating an industrial source.

IOC/UNEP's simplified category list for floating visible litter studies is organised according to source categories and could be used to assess source in this way, similarly to beach survey methods reviewed in Section A.1.3.1. The same could be done for trawled litter, by relating the full list to the simpler list. TSG ML's floating litter methodology says that the ability to relate item types to source at sea is much more limited because of the difficulty in identifying the items and for this reason provided a simplified category list.

A.1.3.2.6 Other Auxiliary Data

A variety of data from other sources is important for the establishing comparable datasets and these can help to make attributions for source. In this section, only data from other sources is included, so supplementary data obtained from the monitoring teams' own equipment is not included (see Equipment section for indications of the equipment and all other data produced).

For the DG Environment riverine litter project, the following types of auxiliary data was collected:

- Historical discharges in comparable monitoring periods
- Actual discharge at the sample location, preferably provided by local water management authorities.
- Meteorological conditions (temp, rainfall in the watershed), provided by local meteorological institutes
- Wave height and frequency, water temperature (reflects turbulence of water and this can affect sample composition and abundance)

In Lechner et al, data on discharge at various points in the river Danube were used to calculate total input of litter to the sea.

The UNEP/IOC trawling and visual floating litter surveys collect a variety of supplementary data about the site such as distance and size of nearest town, direction and distance of nearest river and fishery, the wind direction and speed and condition of sea (wave height), and the depth of the sea.

The TSG ML visual floating litter survey method suggests that windspeed be recorded.

A.1.3.2.7 Statistical Methods

Sadri and Thompson[149] tested the differences in size frequency distribution pattern between tidal states with the non-parametric 2 sample Kolmogorov-Smirnov test, which can determine the statistical significance of differences in the shape and range of the empirical cumulative distribution functions of the two samples. They used the non-parametric Mann–Whitney U test to test for differences in the quantities of debris across tidal states. The general benefits of non-parametric tests are that they make fewer assumptions, and are therefore simpler and more robust than parametric tests. However, economy of assumption entails a need for larger sample sizes to reach high levels of confidence in results.

Morritt et al.[150] made comparisons of the number of litter items of recovered at each of the seven locations by way of a Kruskal–Wallis test with post hoc tests carried out to identify significant differences. This is a one-way analysis of variance test. It is non-parametric, and an extension of the Mann–Whitney U test used by Sadri and Thompson.

[149] Sadri, S.S., Thompson, R.C. 2014, *On the quantity and composition of floating plastic debris entering and leaving the Tamar Estuary, Southwest England.* Mar. Pollut. Bull. (2014), http://dx.doi.org/10.1016/j.marpolbul.2014.02.020

[150] Morritt, D., et al. 2013, *Plastic in the Thames: A river runs through it.* Mar. Pollut. Bull. (2013)

Lechner et al.[151] used the Mann–Whitney U test to compare density of fish larvae and plastic.

Williams and Simmons[152] applied Principal Component Analysis (PCA), a pattern recognition tool, to their dataset, in order to establish important sources of litter. They state that PCA was useful for determining underlying trends in the Taff catchment data set. They do however state that it application is limited to data sets with only few zero recordings and therefore it cannot be used for analysis of catchments with low litter recordings.

T-tests were used to assess seasonal variations and analysis of variance (ANOVA) was used to assess differences between source according to surrounding land use.

A.1.3.3 Discussion

General discussion. Main point – lots of variety of methods, standardised not established and only a few studies really done, but can design desired methodology based on these.

Start to form ideas on preferred methods?

A.1.4 Abatement Measures

By monitoring litter in the riverine environment before and after interventions targeted to particular sources or pathways, we hope to be able to both understand which are the most important sources and pathways for a particular locality, but also to provide data for authorities to make decisions regarding the most effective targetted interventions for achieving litter reductions, and potentially, land based litter targets and even (national) marine litter targets in the future. Therefore an important part of the literature review involves making an inventory of abatement measures, and relating them to particular sources or pathways.

A.1.4.1 Inventory

For the inventory of abatement measures, we used the following sources:

- International Conference on Prevention and Management of Marine Litter in European Seas (2013) Toolbox[153]
- The Swiss Federal Environment Ministry Land Based Litter Toolbox[154]

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[151] Lechner, A., et al. 2014, *The Danube so colourful: A potpourri of plastic litter outnumbers fish larvae in Europe's second largest river* (2014)

[152] Williams, A. T. and Simmons, S.L., 1996, *Sources of Riverine Litter: The River Taff, South Wales, UK* (1996)

[153] International Conference on Prevention and Management of Marine Litter in European Seas, Berlin (2013) *Toolbox*, accessed 24 July 2014, http://www.marine-litter-conference-berlin.info/toolbox_show.php

- Marlisco Project Best Practices Database[155]
- Global Marine Litter Information Gateway Examples[156]
- DG Environment Pilot Project, "Case studies on the plastic cycle and its loopholes in the four European Regional Sea Areas", Abatement Measure Database (Annex 20)[157]

Occasionally other disparate sources were used. There was some redundancy and this was removed from the inventory, so that very similar initiatives targeting the same sources and pathways are represented by one entry. Sources and pathways which the abatement techniques are applicable to are based on a condensed list developed from the literature in A.1.1 and presented in Section 2.4. As the scope of this project is the pathways to the freshwater environment, we have not included measures that are only related to coastal or sea based activities.

The abatement measures are categorized according to one or more measure types as follows:

- Collection and Prevention
- Command and Control
- Education and Outreach
- Investment in infrastructure and equipment
- Market based initiatives
- Monitoring
- Administrative
- Research & Development
- Volunteer initiative

The abatement measures are presented in detail in Table 19.

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[154] Schweizerische Eidgenossenschaft: Bundesamt fuer Umwelt BAFU *Littering Toolbox*, accessed 24 July 2014, http://www.littering-toolbox.ch/

[155] MARLISCO - Marine Litter in European Seas - Social Awareness and Co-Responsibility *Best Practices - Listview*, accessed 24 July 2014, http://www.marlisco.eu/best-practices-listview.en.html?af_filter%5B7%5D=&af_filter%5B1%5D=&af_filter%5B8%5D=&af_filter%5B5%5D=&afstype=matchAll

[156] http://marine-litter.gpa.unep.org/cases/cases.htm

[157] Arcadis (2012) *Case studies on the plastic cycle and its loopholes in the four European regional seas areas*, Report for DG Environment, 2012

Table 19: Litter Abatement Measures and Corresponding Sources and Pathways Potentially Targetable

ID	Name (link to original source)	Details/Examples	Type of measure	Source targeted	Pathway targeted
1	Penalties / Enforcement for littering (can target to areas near waterways if desired)		Command and Control	Public - General Littering, Public - Smoking, Public - Waterways Recreation	Direct, Drains
2	Penalties / Enforcement for flytipping (can target to areas near waterways if desired)		Command and Control	Public - Flytipping, Agriculture, Construction & Demolition	Direct, Drains
3	Increase fixed penalty notices for littering and flytipping (can target to areas near waterways if desired)		Command and Control	Public - General Littering, Public - Smoking, Public - Waterways Recreation Public - Flytipping, Agriculture, Construction & Demolition	Direct, Drains
4	Cleaning and maintenance of riverbeds and dry rivers (rieras)	Cleaning up dry riverbeds that attract fly-tipping. Relevant for riverbeds that are often dry.	Volunteer initiative / Collection & Prevention	Public - Flytipping, Agriculture, Construction & Demolition	Direct
5	Updating sewer network	Updating sewers to avoid litter washed from streets and sewage being released during periods of heavy rain. Possibly only relevant to areas with combined drains rather than separate drains between municipal sewage and street run-off. Can either separate sewage (expensive) or increase the capacity of storm tanks. Also can make sure that storm tanks and combined systems are well maintained with no cracks so that if the water table rises, capacity of system to deal with storm water improved.	Investment in infrastructure and equipment	Sewage - Treated/Untreated	Sewage

6	Improving water treatment standards	Increasing tertiary level sewage treatment and implementing better filtration such as membrane filtration systems.	Investment in infrastructure and equipment	Sewage - Treated/Untreated	Sewage
7	Grit chambers (or other filtration system) for unconnected drains	For drains unconnected to WWTP: grit chambers may help collect litter that has been swept into drains by rainwater, however, systems that have some filtration will never be able to get rid of all waste (e.g. microbeads, so prevention is seen by some as far preferable.)	Investment in infrastructure and equipment	Public - General Littering, Public - Smoking, Public - Flytipping	Drains
8	Legislate for higher standards of treatment at treatment plants and reduce the allowed stormwater overflow		Command and Control	Sewage - Treated/Untreated	Sewage
9	Connect unconnected drains to WWTPs	Making this connection to WWTPs will ensure that litter swept into sewer systems by rain will not be discharged to the environment. However, for combined systems, it should be noted that heavy rainfalls can overwhelm UWWT plant capacities. This action could be targeted to urban areas with higher litter levels if necessary.	Investment in infrastructure and equipment	Public - General Littering, Public - Smoking, Public - Flytipping	Drains
10	Connect unconnected sewers to WWTPs	Making sure that all households have access to sewage treatment would decrease the amount of untreated sewage and associated litter being discharged into waterways.	Investment in infrastructure and equipment	Sewage - Treated/Untreated	Sewage
11	Public awareness regarding misconnections	Promote campaigns like http://www.connectright.org.uk/ to encourage householders to check and carry out misconnection correction.	Investment in infrastructure and equipment, Education and Outreach	Sewage - Treated/Untreated	Sewage

12	Action by water authorities and public authorities to identify households with misconnections and make householders fix them	Only rain down the drain, Thames21 project, supported following action: "Thames Water has been checking which homes are sending their wastewater to the Lake, Enfield Council has cleared the drains within the park and has assigned an Enforcement Officer just to deal with the homes that refuse to sort out their misconnected pipes.	Command and Control	Sewage - Treated/Untreated	Sewage
13	Public awareness discouraging waste disposal down municipal drains	Map municipal drains discharging directly to waterways and promote campaigns like the "Yellow fish" campaign https://www.gov.uk/government/publications/avoiding-pollution-yellow-fish-scheme http://www.sepa.org.uk/water/water_publications/yellow_fish.aspx	Education & Outreach	Public - General Littering, Public - Smoking	Drains
14	Public awareness campaigns to persuade the public to change to the solid waste route for the disposal of their domestic sanitary waste	Nationwide / Local information campaigns + information on packaging of products. Example: Bag it and Bin it, Don't flush it: http://www.marlisco.eu/bag-it-and-bin-it-dont-flush-it-uk.en.html?articles=bag-it-and-bin-it-dont-flush-it-uk	Education & Outreach	Sewage - Treated/Untreated	Sewage
15	Specify conditions for the clean-up of construction sites on a contractual basis	A key concern is that plastic waste (especially but not limited to packaging) at construction sites can be blown away by the wind if not properly collected and managed, in particular for construction sites near seashores and rivers. A special clause can be added to the contract specifying that construction companies properly manage their waste flows and in particular prevent litter from being flushed, blown or thrown away. This could be a requirement for obtaining a building permit, or in case of a public client, added directly to the contract. This could	Command and Control / Volunteer initiative	Construction & Demolition	Direct

		also be promoted voluntarily among construction companies.			
16	Provide adequate waste (and recycling) receptacles on the go (can target to areas near waterways if desired)		Investment in infrastructure and equipment	Public - General Littering, Public - Smoking, Public - Waterways Recreation	Drains, Direct
17	Appropriate bin design	To avoid animals (such as birds) or wind moving litter from bins into the environment	Investment in infrastructure and equipment	Public - General Littering, Public - Smoking, Public - Waterways Recreation Waste collection/treatment	Drains, Direct
18	Use of uniform and internationally recognised bin marking system	Encourage people to use bins appropriately with easy to understand markings and signs. Particularly important in areas with many tourists. Including bin signage such as green footprints http://www.walesonline.co.uk/news/local-news/green-footprints-painted-pavements-litter-2505989	Command and Control / Investment in infrastructure	Public - General Littering, Public - Smoking, Public - Waterways Recreation	Drains, Direct
19	Increase capacity of municipal waste services during top season (can target to areas near waterways if desired)		Collection & Prevention	Public - General Littering, Public - Smoking, Public - Waterways Recreation Public - Flytipping	Drains, Direct
20	Improved street cleaning (can target to areas near waterways if desired)	Street cleansing	Collection & Prevention	Public - General Littering, Public - Smoking, Public - Waterways Recreation	Drains, Direct

21	Improved public waste collection (can target to areas near waterways if desired)	Clearing Flytipping	Collection & Prevention	Public - Flytipping	Drains, Direct
22	Regularly cleaning less frequented environments both urban and near waterways (including in winter, when use of the area or traffic may be low)	Port of London Authority operates 2 vessels and 10 litter traps collecting around 250t of floating detritus and rubbish from Thames. Also do riverbank cleanups at low water.	Collection & Prevention	Public - General Littering, Public - Smoking, Public - Waterways Recreation Public - Flytipping	Drains, Direct
23	"Responsible Snack Bars"	Specific voluntary initiative to ask snack bars near beaches to sign up to good environmental practices (presumably encouraging usage of reusable materials, less packaging, etc). The principle of the measure could be extended to any other businesses in or near waterways, particularly food-related businesses; food related businesses anywhere could also be targetted	Volunteer initiative / Education & Outreach	Public - General Littering, Public - Waterways Recreation	Drains, Direct
24	Snack bar vehicle litterer prevention, tagging packaging/receipts with number plates	Allows litterers to be traced and either outreach carried out or prosecution; may act as deterrent to litterers.	Volunteer initiative / Education & Outreach/Command and Control	Public - General Littering,	Drains, Direct
25	BREF (Best Available Techniques Reference Document) in common wastewater and waste gas treatment/management systems in the chemical sector	To avoid release of plastic pellets into the environment from industrial sites - mainly by separating wastewater from rainwater. Not sure whether these are macro- or micro-pellets.	Command and Control	Other Commercial & Industrial activities	Drains, Direct

26	Targeted campaigns at plastic pellet users	Example here: Operation Clean Sweep - provides manual and pledge for all businesses involved in use of plastic pellets. Further example of work in DE/AT/CH (BKV GmbH Platform for Plastics and Recovery): http://www.marine-litter-conference-berlin.info/toolbox2013_detail.php?id=12	Education & Outreach	Other Commercial & Industrial activities	Drains, Direct
27	Involve the retail/tourism sector in actions to improve consumer behaviour in relation to plastic bags/bottles	The tourism sector plays a significant role as regards the behaviour of tourists as it is often the case that tourists tend to change their environmental behaviour when away from home towards less environmentally friendly and aware. The tourism sector should provide information to tourists on ways to reduce their negative environmental prints during the vacation.	Education & Outreach	Public - General Littering, Public - Waterways Recreation	Drains, Direct
28	Awareness campaigning around impact of cigarette butts/filters litter	Awareness and portable ashtray distribution	Education & Outreach	Public - Smoking	Drains, Direct
29	Target interventions at litter hotspots.	Many examples possible (some very specific and much wider ranging than just litter prevention). Could be diversion away from activities that tend to produce litter (i.e. activities for young persons to avoid them sitting in car parks producing food- and drink-related litter, providing permanent bbq grills in parks); prevention of litter being thrown/left on the ground (i.e. patrols of local people at parks/car parks/other hotspots, providing street lighting at river/lake-sides); encouraging litter pick-ups (i.e. by providing rewards to people who collect litter)	Education & Outreach (mainly, others possible as well)	Public - General Littering, Public - Smoking, Public - Waterways Recreation Public - Flytipping Construction & Demolition	Drains, Direct
30	Target interventions at flytipping hotspots	Actions possible include preventing access to secluded areas using fencing and gating, land use change, improving the area e.g. landscaping, planting flowers, adopt a highway or area style schemes, signage RE prohibition and enforcement E.g. ZWS Flytipping Small	Education & Outreach (mainly, others possible as well)	Public - Flytipping Construction & Demolition Agriculture	Drains, Direct

		Grants Scheme			
31	Promote and support implementation of deposit refund system for multi carrier bags of all type by retailers of certain size, including robust plastic bags for multi-use (the amount of deposit to be determined)	The deposit refund system for carrier bags of all types considers that the consumer pays for a bag and gets the money back or a new bag in exchange when returning the old bag to the place of purchase. A deposit refund system has inter alia its benefits in combating generation of the waste "on the go" and littering in the environment after consumption of the products away from home.	Other: administrative / Market-based	Public - General Littering, Public - Waterways Recreation	Drains, Direct
32	Deposit refund system for refillable plastic beverage bottles / other single use beverage packaging		Other: administrative / Market-based / Command and Control	Public - General Littering, Public - Waterways Recreation, Waste Collection and Treatment	Drains, Direct
33	Ban on single-use plastic bags		Command and Control	Public - General Littering, Public - Waterways Recreation	Drains, Direct
34	Plastic bag levy	Example from Portugal: http://www.marlisco.eu/Launch_of_paid_reusable_bags.en.html?articles=Launch_of_paid_reusable_bags	Command and Control / Market-based instrument	Public - General Littering, Public - Waterways Recreation	Drains, Direct

35	Awareness raising and information campaign around the importance of using alternatives to plastic bottles and bags	The measure considers awareness raising campaigns and other informative actions to reduce the negative impacts of plastic bottles and bags entering the marine environment. The target group can be especially tourists and coastal/freshwater lakeside/riverside users. The informative measures shall include risks associated with improper use of bottles and bags (e.g. entanglement of turtles, birds, ...), proper disposal of bottles and bags (e.g. after leaving the coastal recreational sites) and information on alternatives. The information can be spread via billboards on beaches, leaflets in accommodation facilities, etc.	Education & Outreach	Public - General Littering, Public - Waterways Recreation	Drains, Direct
36	Promote consumption of tap water (can be targeted to near waterways if desired)	Could be done by installing hydration stations at locations	Education & Outreach	Public - General Littering, Public - Waterways Recreation	Drains, Direct
37	General anti-littering campaigns and information sharing	Could involve staff working in areas which high amounts of litter or particular vulnerability for aquatic environment - e.g. river/lakeside tourist attractions; train staff and provide t-shirts with messages	Education & Outreach	Public - General Littering, Public - Smoking, Public - Waterways Recreation	Drains, Direct
38	General anti-flytipping campaigns and information sharing		Education & Outreach	Public - Flytipping Construction & Demolition Agriculture	Drains, Direct
39	Tourist tax on activities near vulnerable areas (e.g. near waterways / other vectors)	Tourist tax paid by all who use areas that contribute a lot to litter. Could be on businesses, parking, tourist accommodation, etc. Tax could be spent on clean-up or preventative awareness campaigns, or generate awareness regarding why tax being collected	Market-based initiative / Education & Outreach	Public - General Littering, Public - Smoking, Public - Waterways Recreation Other Commercial & Industrial activities	Drains, Direct

40	Training for waste operators	Provide training to avoid loss of litter to the environment during collection and transport	Education & Outreach	Waste Collection and Treatment	Drains, Direct
41	Appropriately designed collection vehicles	To avoid plastic waste blowing out of vehicles	Investment in infrastructure and equipment	Waste Collection and Treatment	Drains, Direct
42	Collection of litter (and/or analysis of composition and monitoring of river-/lakeside areas), involving the public	Educate public on amounts and types of litter - prevention. Example: Thames21: http://www.marlisco.eu/thames21-river-thames-and-waterways-in-greater-london-uk.en.html?articles=thames21-river-thames-and-waterways-in-greater-london-uk	Education & Outreach	Public - General Littering, Public - Flytipping Public - Smoking, Public - Waterways Recreation	Drains, Direct
43	Control and supervise compliance of waste management companies	Ensure waste management companies are treating waste appropriately through enforcement action; avoid illegal dumping and careless loss	Command and Control	Waste Collection and Treatment	Drains, Direct
44	Appropriate waste management facilities, e.g. bring sites		Investment in infrastructure and equipment	Public - Flytipping Construction & Demolition Agriculture	Direct, Drains
45	"Return to Offender" campaign	This campaign encourages people to send identifiable litter back to the 'offender', assumed to be businesses,	Education & Outreach	Public - General Littering, Public - Smoking,	Drains, Direct,

		i.e. those producing or selling plastic packaging.		Public - Waterways Recreation Sewage	Sewage
46	Waste Management Plan in the river catchment areas contain chapter on (river) litter reduction and prevention		Command and Control	Public - General Littering, Public - Smoking, Public - Waterways Recreation Public - Flytipping Sewage Agriculture Construction & Demolition Other Commercial & Industrial activities Waste Collection and Treatment	Drains, Direct, Sewage
47	Enforce technical requirements on daily cover of the landfills (close to freshwater) and intensify inspections/implement fines		Command and Control	Waste Collection and Treatment	Drains, Direct
48	Identify and close non-compliant landfills and illegal dumpsites close to the freshwater environment		Command and Control	Waste Collection and Treatment	Drains, Direct
49	Formalisation of informal sector in MW/PPW management	Options include: - Create organizational structures that allow and improve collaboration between waste pickers and professional in MW/PPW management - Organise trainings and educational workshops for waste pickers of collection/sorting/recycling techniques, organisational aspects as well as health issues related to the waste - Inform informal sector on the advantages	Education & Outreach / Stakeholder coordination	Waste Collection and Treatment	Drains, Direct

		of formalisation, clarify and simplify formalisation procedures - Inform local authorities on the benefits of integrating informal sector collectors and recyclers in the waste management system - Develop value chains for PPW (and other major waste streams) to create markets and develop business relationships between waste pickers and private/public sector in waste management			
50	Litter Trap at Source	Traps litter at pavement level before it moves into the drains and thus into freshwater.	Investment in infrastructure and equipment	Public - General Littering, Public - Smoking, Public - Flytipping Public - Waterways Recreation Agriculture Construction & Demolition Other Commercial & Industrial activities Waste Collection and Treatment	Drains
51	Litter Trap, riverine	Trap riverine litter with booms - e.g. Bandalong river trap; there are many examples	Investment in infrastructure and equipment	Public - General Littering, Public - Smoking, Public - Waterways Recreation Public - Flytipping Sewage Agriculture Construction & Demolition Other Commercial & Industrial activities Waste Collection and Treatment	Drains, Direct, sewage

52	Increase value of waste by encouraging better recycling and separation of plastics		Research & Development / Investment in infrastructure and equipment	Public - General Littering, Public - Smoking, Public - Waterways Recreation Public - Flytipping Sewage Agriculture Construction & Demolition Other Commercial & Industrial activities	Drains, Direct
53	Strengthen national and municipal/local capacities for managing solid wastes related to planning for natural disasters, such as floods, hurricanes, earthquakes and other events that can produce litter		Investment in infrastructure and equipment	Public - General Littering, Public - Smoking, Public - Waterways Recreation Public - Flytipping Sewage Agriculture Construction & Demolition Other Commercial & Industrial activities Waste Collection and Treatment	Drains, Direct, sewage
54	Sustainable urban drainage systems	Reducing flashiness of rivers and reducing discharge of CSOs. Also reducing 'first flush' of litter during heavy precipitation after dry spells; reducing direct pathways (buffer strips near waterways);	Investment in infrastructure and equipment	Public - General Littering, Public - Smoking, Public - Waterways Recreation Public - Flytipping Sewage Waste Collection and Treatment	Direct, Drains, sewage

55	Educate public about proper presentation of household waste	Minimising time waste left outside by requiring morning presentation of bins with proper lids; insisting on closed lids; use of lids where appropriate or nets for baskets of loose recyclables.	Education & Outreach	Waste collection/treatment	Drains, Direct
56	Implementation of improved and harmonised EU monitoring system for river bank/lakeside litter	Does not on its own result in less litter. Example of specific (marine) monitoring programme: http://www.marine-litter-conference-berlin.info/toolbox_detail.php?id=75	Monitoring	All sources	Drains, Direct, Sewage
57	Apply pressure to manufacturers to minimise material and make products more environmental friendly with aim to reduce the input & impact of sanitary waste into aquatic environment	Does not result in fewer items of litter, but may reduce weight/volume/harmfulness of individual items of litter.	Research & Development / Labelling / Prevention	Sewage - Treated/Untreated	Sewage
58	Establish annual Environmental Award Scheme for the plastic packaging products industry sector to foster innovations in production	To encourage production of thinner plastic bags / bottles + support and promote closed loop business models	Research & Development	Public - General Littering, Public - Smoking, Public - Waterways Recreation Waste collection/treatment	Drains, Direct

59	Support and enforce eco-design of plastic packaging products	E.g. alternatives to expanded polystyrene	Research & Development	Public - General Littering, Public - Smoking, Public - Waterways Recreation Waste collection/treatment	Drains, Direct
60	Apply pressure to manufacturers to minimise material and make products more environmental friendly with aim to reduce the input & impact of sanitary waste into aquatic environment.	Does not result in fewer items of litter, but may reduce weight/volume/harmfulness of individual items of litter.	Research & Development / Labelling / Prevention	Sewage - Treated/Untreated	Sewage
61	Regulation to avoid specific types of litter, e.g. ban plastic particles in exfoliants, require bottle caps to be attached to bottles, require biodegradable cigarette butts, filters on washing machines, require biodegradable packing peanuts etc.		Command and Control	Public - General Littering, Public - Smoking, Public - Waterways Recreation Sewage	Drains, Direct, Sewage
62	Support and promote commitment of retailers to introduce targets on reduction and optimisation of use of plastic packaging		Other: administrative	Public - General Littering, Waste collection/treatment, Other Commercial & Industrial activities	Drains, Direct

	materials				
63	Taxes on specific products that have a high risk of becoming litter, e.g. beverage containers		Command and Control	Public - General Littering, Public - Smoking Public - Waterways Recreation	Drains, Direct, sewage
64	Legal requirements on density of waste management facilities (bins) near freshwater areas		Command and Control / Investment in infrastructure	Waste Collection and Treatment	Direct
65	Awards for municipalities with good recycling rates, particularly for plastic packaging waste	Encourage municipalities to implement measure to reduce littering and dumping by giving awards related to recycling rates	Education & Outreach	Waste Collection and Treatment	Drains, Direct
66	Enforce and improve EPR for plastic packaging waste		Command and Control	Public - General Littering, Public - Smoking, Public - Waterways Recreation Sewage Agriculture Construction & Demolition Other Commercial &	Drains, Direct, Sewage

				Industrial activities Waste Collection and Treatment	
67	National policies to strengthen Regional Strategic Action Plans	To ensure strategic plans to target most damaging litter is backed up by legislation	Command and Control	Public - General Littering, Public - Smoking, Public - Waterways Recreation Public - Flytipping Sewage Agriculture Construction & Demolition Other Commercial & Industrial activities Waste Collection and Treatment	Drains, Direct, Sewage
68	Charge for landfilling waste, to encourage recycling	Avoids waste going to landfill, where it may not be managed properly. On its own, increasing recycling does not lead to less litter.	Market-based initiative	Other Commercial & Industrial activities Waste Collection and Treatment	Drains, Direct

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A.2.0 Annex 2 – Litter Sources and Pathways Checklist

Public authority checklist for assessment of litter sources and pathways.

Excel file: Source Pathway Checklist FINAL.xls

Preview:

Source	Pathway	Category	Indicator	Geographical Level	Question	Notes	Scoring
Agriculture	Direct, Drains	Public Perceptions and Attitudes	Community	Local	Would you characterise local farmers and workers as being invested in their local community and environs?		Y=0, N=1
Agriculture	Direct, Drains	Public Perceptions and Attitudes	Attitudes to Place (Public attitudes)	Local	Do local farmers and workers report flytipping awareness and knowledge and intention to dispose of waste generated correctly?		Y=0, N=1
Agriculture	Direct, Drains	Public Perceptions and Attitudes	Attitudes to Place (Litter awarenes	Local	Do you have any outreach activities to local farmers and workers on proper waste management with a flytipping component?		Y=0, N=1
Agriculture	Direct, Drains	Public Perceptions and Attitudes	Adequacy of Facilities	Local	Are disposal facilities for waste generated perceived as adequate by local farms and workers?		Y=0, N=1
Agriculture	Direct, Drains	Waste and Water Management	Waste Management of Agricultural Plastic Waste	National	Is a large quantity of agricultural waste generated in this municipality? (Can perhaps work out ' calculated disposal rate').	May need to develop numerical thı	Y=1, N=0
Agriculture	Direct, Drains	Commercial & Industrial activities adjacent to rivers	Agricultural land use near waterways	Local	Is there a large land area adjacent to rivers devoted to agricultural use?	May need to define levels and scores.	Y=1, N=0
Agriculture	Direct, Drains	General Indirect Indicators	Litter Generation Areas/Land use categories	Local	Is there a large percentage of agricultural land use in this locality?	May need to define levels and scores.	Y=1, N=0
Agriculture	Direct, Drains	General Indirect Indicators	Heavy Precipitation Events	Local or national	Is this locality prone to heavy precipitation events, especially after spells without rain? Are the local waterways prone to flashy flow?	May need to define levels and scores.	Y=1, N=0
Agriculture	Direct, drains	Direct Indicators	Flytipping incidents (near waterways or coastlines)	National and/or local	Are there a significant number of flytipping incidents of agricultural waste in the locality? (And near waterways?)	May need to define levels and scores.	Y=1, N=0 - plus one extra point for Y near waterways
Agriculture Total							
Construction & Demolition	Direct, Drains	Public Perceptions and Attitudes	Community	Local	Would you characterise local Construction & Demolition businesses as being invested in their local community and environs?		Y=0, N=1
Construction & Demolition	Direct, Drains	Public Perceptions and Attitudes	Attitudes to Place (Public attitudes)	Local	Do local Construction & Demolition businesses report flytipping awareness and knowledge and intention to dispose of waste generated correctly		Y=0, N=1

A.3.0 Annex 3 – Abatement Measure Database

Abatement measure database and mapping of abatement measures to source and pathway.

Excel file: Litter Abatement Measures FINAL.xls

Preview:

ID	Name (URL)	Name	URL	Details/Examples	Type of measure	Source targeted
1	Penalties / Enforcement for littering (can target to areas near waterways if desired)	Penalties / Enforcement for littering (can target to areas near waterways if desired)	http://w		Command and Control	Public - General Littering, Public - Smoking, Public - Waterways Recreation
2	Penalties / Enforcement for flytipping (can target to areas near waterways if desired)	Penalties / Enforcement for flytipping (can target to areas near waterways if desired)			Command and Control	Public - Flytipping, Agriculture, C&D
3	Increase fixed penalty notices for littering and flytipping (can target to areas near waterways if desired)	Increase fixed penalty notices for littering and flytipping (can target to areas near waterways if desired)	http://ec		Command and Control	Public - General Littering, Public - Smoking, Public - Waterways Recreation Public - Flytipping, Agriculture, C&D
4	Cleaning and maintenance of riverbeds and dry rivers (rieras)	Cleaning and maintenance of riverbeds and dry rivers (rieras)	http://w	Cleaning up dry riverbeds that attract fly-tipping. Relevant for riverbeds that are often dry.	Volunteer initiative / Collection & Prevention	Public - Flytipping, Agriculture, C&D
5	Updating sewer network	Updating sewer network	http://w	Updating sewers to avoid litter washed from streets and sewage being released during periods of heavy rain. Possibly only relevant to areas with combined drains rather than separate drains between municipal sewage and street run-off. Can either separate sewage (expensive) or increase the capacity of storm tanks. Also can make sure that storm tanks and combined systems are well maintained with no cracks so that if the water table rises, capacity of system to deal with storm water improved.	Investment in infrastructure and equipment	Sewage - Treated/Untreated
6	Improving water treatment standards	Improving water treatment standards		Increasing tertiary level sewage treatment and implementing better filtration such as membrane filtration systems.	Investment in infrastructure and equipment	Sewage - Treated/Untreated
7	Grit chambers (or other filtration system) for unconnected drains	Grit chambers (or other filtration system) for unconnected drains	http://w	For drains unconnected to WWTP: grit chambers may help collect litter that has been swept into drains by rainwater, however, systems that have some filtration will never be able to get rid of all waste (e.g. microbeads, so prevention is seen by some as far preferable.)	Investment in infrastructure and equipment	Public - General Littering, Public - Smoking, Public - Flytipping
8	Legislate for higher standards of treatment at treatment plants and reduce the allowed stormwater overflow	Legislate for higher standards of treatment at treatment plants and reduce the allowed stormwater overflow	http://ec		Command and Control	Sewage - Treated/Untreated
				Making this connection to WWTPs will ensure that litter swept into sewer systems by rain will not be discharged to the environment. However, for		

Review / Public - Flytipping / Public - General Littering / Public - Smoking / Public - Waterways recreation / Sewage / Waste Collection Treatment / Agriculture / C&D / Other

A.4.0 Annex 4 – Litter Item Type Categorisation

Table A1: Litter Item Type Categorisation for the Riverine Environment

#	TSG_ML	OSPAR- Code	UNEP- Code	General Name	Riverine	Materials
1	G1	1	PL05	4/6-pack yokes, six-pack rings	x	Artificial polymer materials
2	G3	2	PL07	Shopping Bags incl. pieces	x	Artificial polymer materials
3	G4	3	PL07	Small plastic bags, e.g. freezer bags incl. pieces	x	Artificial polymer materials
4	G5	112		Plastic bag collective role; what remains from rip-off plastic bags	x	Artificial polymer materials
5	G7	4	PL02	Drink bottles <=0.5l	x	Artificial polymer materials
6	G8	4	PL02	Drink bottles >0.5l	x	Artificial polymer materials
7	G9	5	PL02	Cleaner bottles & containers	x	Artificial polymer materials
8	G10	6	PL06	Food containers incl. fast food containers	x	Artificial polymer materials
9	G11	7	PL02	Beach use related cosmetic bottles and containers, e.g. Sunblocks	x	Artificial polymer materials
10	G12	7	PL02	Other cosmetics bottles & containers	x	Artificial polymer materials
11	G13	12	PL02	Other bottles & containers (drums)	x	Artificial polymer materials
12	G14	8		Engine oil bottles & containers <50 cm	x	Artificial polymer materials
13	G15	9	PL03	Engine oil bottles & containers >50 cm	x	Artificial polymer materials
14	G16	10	PL03	Jerry cans (square plastic containers with handle)	x	Artificial polymer materials
15	G17	11		Injection gun containers	x	Artificial polymer materials
16	G18	13	PL13	Crates and containers / baskets	x	Artificial polymer materials
17	G19	14		Car parts	x	Artificial polymer materials
18	G21	15	PL01	Plastic caps/lids drinks	x	Artificial polymer materials
19	G22	15	PL01	Plastic caps/lids chemicals, detergents	x	Artificial polymer materials

				(non-food)		
20	G23	15	PL01	Plastic caps/lids unidentified	x	Artificial polymer materials
21	G24	15	PL01	Plastic rings from bottle caps/lids	x	Artificial polymer materials
22	G25			Tobacco pouches / plastic cigarette box packaging	x	Artificial polymer materials
23	G26	16	PL10	Cigarette lighters	x	Artificial polymer materials
24	G27	64	PL11	Cigarette butts and filters	x	Artificial polymer materials
25	G28	17		Pens and pen lids	x	Artificial polymer materials
26	G29	18		Combs/hair brushes/sunglasses	x	Artificial polymer materials
27	G30	19		Crisps packets/sweets wrappers	x	Artificial polymer materials
28	G31	19		Lolly sticks	x	Artificial polymer materials
29	G32	20	PL08	Toys and party poppers	x	Artificial polymer materials
30	G33	21	PL06	Cups and cup lids	x	Artificial polymer materials
31	G34	22	PL04	Cutlery and trays	x	Artificial polymer materials
32	G35	22	PL04	Straws and stirrers	x	Artificial polymer materials
33	G36	23		Fertiliser/animal feed bags	x	Artificial polymer materials
34	G37	24	PL15	Mesh vegetable bags	x	Artificial polymer materials
35	G40	25	PL09	Gloves (washing up)	x	Artificial polymer materials
36	G41	113	RB03	Gloves (industrial/professional rubber gloves)	x	Artificial polymer materials
37	G42	26	PL17	Crab/lobster pots and tops (Included as crayfish traps very similar)	x	Artificial polymer materials
38	G43	114		Tags (fishing and industry)(used also for freshwater fish)	x	Artificial polymer materials
	G44	27	PL17	Octopus pots	marine	Artificial polymer materials
	G45	28	PL15	Mussels nets, Oyster nets	marine	Artificial polymer materials
	G46	29		Oyster trays (round from oyster cultures)	marine	Artificial polymer materials
	G47	30		Plastic sheeting from mussel culture (Tahitians)	marine	Artificial polymer materials
39	G49	31	PL19	Rope (diameter more than 1cm)	x	Artificial polymer materials
40	G50	32	PL19	String and cord (diameter less than 1cm)	x	Artificial polymer materials
41	G52		PL20	Nets and pieces of net	x	Artificial polymer materials
42	G53	115	PL20	Nets and pieces of net < 50 cm	x	Artificial polymer materials
43	G54	116	PL20	Nets and pieces of net >	x	Artificial polymer materials

				50 cm		
44	G56	33	PL20	Tangled nets/cord	x	Artificial polymer materials
	G57	34	PL17	Fish boxes - plastic	marine	Artificial polymer materials
	G58	34	PL17	Fish boxes - expanded polystyrene	marine	Artificial polymer materials
45	G59	35	PL18	Fishing line/monofilament (angling)	x	Artificial polymer materials
46	G60	36	PL17	Light sticks (tubes with fluid) incl. packaging	x	Artificial polymer materials
47	G62	37	PL14	Floats for fishing nets	x	Artificial polymer materials
48	G63	37	PL14	Buoys	x	Artificial polymer materials
49	G64			Fenders	x	Artificial polymer materials
50	G65	38	PL03	Buckets	x	Artificial polymer materials
51	G66	39	PL21	Strapping bands	x	Artificial polymer materials
52	G67	40	PL16	Sheets, industrial packaging, plastic sheeting	x	Artificial polymer materials
53	G68	41	PL22	Fibre glass/fragments	x	Artificial polymer materials
54	G69	42		Hard hats/Helmets	x	Artificial polymer materials
55	G70	43		Shotgun cartridges	x	Artificial polymer materials
56	G71	44	CL01	Shoes/sandals	x	Artificial polymer materials
57	G72			Traffic cones	x	Artificial polymer materials
58	G73	45	FP01	Foam sponge	x	Artificial polymer materials
59	G75	117		Plastic/polystyrene pieces 0 - 2.5 cm	x	Artificial polymer materials
60	G76	46		Plastic/polystyrene pieces 2.5 cm > < 50cm	x	Artificial polymer materials
	G77	47		Plastic/polystyrene pieces > 50 cm	size/weight exclusion	Artificial polymer materials
61	G78			Plastic pieces 0 - 2.5 cm	x	Artificial polymer materials
62	G79			Plastic pieces 2.5 cm > < 50cm	x	Artificial polymer materials
	G80			Plastic pieces > 50 cm	size/weight exclusion	Artificial polymer materials
63	G81			Polystyrene pieces 0 - 2.5 cm	x	Artificial polymer materials
64	G82			Polystyrene pieces 2.5 cm > < 50cm	x	Artificial polymer materials
	G83			Polystyrene pieces > 50 cm	size/weight exclusion	Artificial polymer materials
65	G84			CD, CD-box	x	Artificial polymer materials
66	G85			Salt packaging	x	Artificial polymer materials
	G86			Fin trees (from fins for scuba diving)	marine	Artificial polymer materials
67	G87			Masking tape	x	Artificial polymer materials
68	G88			Telephone (incl. parts)	x	Artificial polymer materials
69	G89			Plastic construction	x	Artificial polymer materials

				waste		
70	G90			Plastic flower pots	x	Artificial polymer materials
71	G91			Biomass holder from sewage treatment plants	x	Artificial polymer materials
72	G92			Bait containers/packaging	x	Artificial polymer materials
73	G93			Cable ties	x	Artificial polymer materials
74	G95	98	OT02	Cotton bud sticks	x	Artificial polymer materials
75	G96	99	OT02	Sanitary towels/panty liners/backing strips	x	Artificial polymer materials
76	G97	101	OT02	Toilet fresheners	x	Artificial polymer materials
77	G98		OT02	Diapers/nappies	x	Artificial polymer materials
78	G99	104	PL12	Syringes/needles	x	Artificial polymer materials
79	G100	103		Medical/Pharmaceuticals containers/tubes	x	Artificial polymer materials
80	G101	121		Dog faeces bag	x	Artificial polymer materials
81	G102		RB02	Flip-flops	x	Artificial polymer materials
82	G124	48	PL24	Other plastic/polystyrene items (identifiable)	x	Artificial polymer materials
83	G125	49	RB01	Balloons and balloon sticks	x	Rubber
84	G126		RB01	Balls	x	Rubber
85	G127	50		Rubber boots	x	Rubber
86	G128	52	RB04	Tyres and belts	x	Rubber
87	G129		RB05	Inner-tubes and rubber sheet	x	Rubber
	G130			Wheels	size/weight exclusion	Rubber
88	G131		RB06	Rubber bands (small, for kitchen/household/post use)	x	Rubber
89	G132			Bobbins (fishing)	x	Rubber
90	G133	97	RB07	Condoms (incl. packaging)	x	Rubber
91	G134	53	RB08	Other rubber pieces	x	Rubber
92	G137	54	CL01	Clothing / rags (clothing, hats, towels)	x	Cloth/textile
93	G138	57	CL01	Shoes and sandals (e.g. Leather, cloth)	x	Cloth/textile
94	G139		CL02	Backpacks & bags	x	Cloth/textile
95	G140	56	CL03	Sacking (hessian)	x	Cloth/textile
96	G141	55	CL05	Carpet & Furnishing	x	Cloth/textile
97	G142		CL04	Rope, string and nets	x	Cloth/textile
98	G143		CL03	Sails, canvas	x	Cloth/textile
99	G144	100	OT02	Tampons and tampon applicators	x	Cloth/textile
100	G145	59	CL06	Other textiles (incl. rags)	x	Cloth/textile

101	G147	60		Paper bags	x	Paper/Cardboard
102	G148	61	PC02	Cardboard (boxes & fragments)	x	Paper/Cardboard
103	G150	118	PC03	Cartons/Tetrapack Milk	x	Paper/Cardboard
104	G151	62	PC03	Cartons/Tetrapack (others)	x	Paper/Cardboard
105	G152	63	PC03	Cigarette packets	x	Paper/Cardboard
106	G153	65	PC03	Cups, food trays, food wrappers, drink containers	x	Paper/Cardboard
107	G154	66	PC01	Newspapers & magazines	x	Paper/Cardboard
108	G155		PC04	Tubes for fireworks	x	Paper/Cardboard
109	G156			Paper fragments	x	Paper/Cardboard
110	G158	67	PC05	Other paper items	x	Paper/Cardboard
111	G159	68	WD01	Corks	x	Processed/worked wood
112	G160	69	WD04	Pallets	x	Processed/worked wood
113	G161	69	WD04	Processed timber	x	Processed/worked wood
114	G162	70	WD04	Crates	x	Processed/worked wood
115	G163	71	WD02	Crab/lobster pots (included as crayfish traps very similar)	x	Processed/worked wood
	G164	119		Fish boxes	marine	Processed/worked wood
116	G165	72	WD03	Ice-cream sticks, chip forks, chopsticks, toothpicks	x	Processed/worked wood
117	G166	73		Paint brushes	x	Processed/worked wood
118	G167		WD05	Matches & fireworks	x	Processed/worked wood
119	G171	74	WD06	Other wood < 50 cm	x	Processed/worked wood
	G172	75	WD06	Other wood > 50 cm	size/weight exclusion	Processed/worked wood
120	G174	76		Aerosol/Spray cans industry	x	Metal
121	G175	78	ME03	Cans (beverage)	x	Metal
122	G176	82	ME04	Cans (food)	x	Metal
123	G177	81	ME06	Foil wrappers, aluminium foil	x	Metal
124	G178	77	ME02	Bottle caps, lids & pull tabs	x	Metal
125	G179	120		Disposable BBQ's	x	Metal
	G180	79	ME10	Appliances (refrigerators, washers, etc.)	size/weight exclusion	Metal
126	G181		ME01	Tableware (plates, cups & cutlery)	x	Metal
127	G182	80	ME07	Fishing related (weights, sinkers, lures, hooks)	x	Metal
128	G184	87	ME07	Lobster/crab pots	x	Metal

				(included as crayfish traps very similar)		
	G186	83	ME10	Industrial scrap	size/weight exclusion	Metal
	G187	84	ME05	Drums, e.g. oil	size/weight exclusion	Metal
129	G188		ME04	Other cans (< 4 L)	x	Metal
	G189		ME05	Gas bottles, drums & buckets (> 4 L)	size/weight exclusion	Metal
130	G190	86	ME05	Paint tins	x	Metal
131	G191	88	ME09	Wire, wire mesh, barbed wire	x	Metal
	G193			Car parts / batteries	size/weight exclusion	Metal
132	G194			Cables	x	Metal
133	G195		OT04	Household Batteries	x	Metal
134	G198	89	ME10	Other metal pieces < 50 cm	x	Metal
	G199	90	ME10	Other metal pieces > 50 cm	size/weight exclusion	Metal
135	G200	91	GC02	Bottles incl. pieces	x	Glass/ceramics
136	G201		GC02	Jars incl. pieces	x	Glass/ceramics
137	G202	92	GC04	Light bulbs	x	Glass/ceramics
138	G203		GC03	Tableware (plates & cups)	x	Glass/ceramics
	G204	94	GC01	Construction material (brick, cement, pipes)	size/weight exclusion	Glass/ceramics
139	G205	92	GC05	Fluorescent light tubes	x	Glass/ceramics
140	G206		GC06	Glass buoys	x	Glass/ceramics
	G207	95		Octopus pots	marine	Glass/ceramics
141	G208		GC07	Glass or ceramic fragments >2.5cm	x	Glass/ceramics
142	G210	96	GC08	Other glass items	x	Glass/ceramics
143	G211	105	OT05	Other medical items (swabs, bandaging, adhesive plaster etc.)	x	unidentified
144	G213	181, 109, 110	OT01	Paraffin/Wax	x	Chemicals

A.5.0 Annex 5 – Cost Assessment

Costing of pilot projects

Excel File: CEN CW3 Pilots Costs FINAL.xlsx