



Rijkswaterstaat
Ministry of Infrastructure
and Water Management

Synthesis of data on riverine macrolitter in OSPAR region II

Paul Vriend, Eric Copius Peereboom, and Lex Oosterbaan,

**Rijkswaterstaat Water,
Verkeer en Leefomgeving**

Griffioenlaan 2
3526 LA UTRECHT
Postbus 2232
3500 GE UTRECHT
T +31 (0) 88 79
www.rijkswaterstaat.nl

Contact

Eric Copius Peereboom,
Lex Oosterbaan,
Paul Vriend,
senior advisors

M +3 16 15 01 79 46
Eric.copiuspeereboom@rws.nl

Date

17 August 2021

1 Abstract

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In this report we provide an overview of the current state of knowledge on macrolitter export by rivers in the OSPAR maritime area. A total of six rivers in the OSPAR regions have been studied for macrolitter pollution these being the Seine, Rhine, Meuse, Ems, Weser and Thames rivers. These rivers all discharge to the sea in OSPAR region II (greater North Sea). By adding the ranges of observed exports for each river we provide a rudimentary estimate of total macrolitter export by these rivers to the greater North Sea area (OSPAR region II) of 10.5 – 220.6 tonnes per year. Plastic is the predominant material type of macrolitter pollution found with all rivers included showing more than 80% of litter found being plastic. Most of the items found in rivers can be linked to consumer consumption. Frequently found items in all rivers include bottles, plastic bags, food wrapping, and sanitary items. However, the most frequently found items are unidentifiable small pieces of plastic (0.5-5 cm). The large presence of smaller pieces of plastic indicate that plastic items already experience breakdown processes within river system. However, it is important to note that data on macrolitter in rivers and the methods used to gather these data are limited. We recommend the setup of long-term, integrated monitoring strategies with standardized methods to provide the data needed to better quantify litter pollution in rivers and to identify possible ways to reduce it.

2 Introduction

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One of the major pathways for litter to enter the marine environment is via terrestrial waterways, i.e. rivers and other tributaries. Action 41 of OSPAR's Regional Action Plan Marine litter (2014) was to exchange experience on best practice to prevent litter entering into water systems and highlight these to River or River basin Commission. Although there has been a lot of work undertaken by OSPAR Contracting Parties to address Action 41, there have also been a number of issues that have prevented progress from being made. These include questions regarding the mandate and competence of OSPAR in terms of addressing issues related to litter in terrestrial riverine environments. Coordinating and collaborating across government agencies and bodies dealing with riverine and marine issues is challenging. Furthermore, the EU Water Framework Directive is a key piece of legislation for the management of water quality in rivers in Europe, and it currently has no reference to litter (macro, meso or micro). This could also explain the fairly passive approach and low level of ambition in relation to addressing riverine litter taken by river commissions to date.

For any future work to address the issue of riverine litter as a source of marine litter in the North-East Atlantic, there must be close cooperation and collaboration with the various river commissions, or the appropriate national responsible bodies. Furthermore, collaboration with work underway at the EU level is essential for the success of any initiative or proposed way forward. With consideration of and discussion on the benefits of a more harmonized approach to riverine litter monitoring.

The new North-East Atlantic Environment Strategy (NEAES) 2020-2030, includes an operational objective on riverine litter:

"By 2025 OSPAR will develop approaches to prevent and reduce riverine marine litter inputs in cooperation with the relevant international river or river basin commissions, and other appropriate authorities and organisations."

In order to support and achieve this objective, a number of riverine litter activities is foreseen in the revised RAP ML, scheduled to be adopted in 2022.

In 2023 OSPAR's Quality Status Report will be adopted. This will include a Thematic Assessment on Marine Litter. In order to support this narrative the contribution of riverine litter should not be forgotten. In this synthesis we provide an overview of the current state of knowledge on macrolitter export by rivers in the OSPAR maritime area. This synthesis has been prepared by Rijkswaterstaat, Ministry of Infrastructure and Water Management, the Netherlands.

3 Rivers included in this study

Reliable and long term monitoring data for macrolitter pollution in rivers in the OSPAR region is limited. Rivers to be included in this overview were chosen based on available literature and provided by Contracting Parties. The selected rivers include the Seine, Rhine, Meuse, Thames, Ems, and Weser (table 1). Litter pollution can reside in different compartments of river systems and require different methods for detection and quantification for each compartment (van Emmerik & Schwarz, 2019). For example, Macrolitter pollution can be mobile through transport on the *river bed*, *floating* on top or within the *water column*, and can be (temporarily) stored on *riverbanks*. To gain a full understanding of macrolitter presence in a river system all compartments should be studied. Studies for riverine microplastic pollution were excluded from this overview since these studies most frequently rely on models instead of field observations.

Most studies included in this report use visual observations as the monitoring method used to gather data (table 1). Exceptions to this are studies who gather data using different types of nets (Collas et al., 2021; Schöneich-Argent et al., 2020; Morritt et al., 2014). Gathering data using the visual observation method is done in several steps: 1) litter transport is quantified by observing from bridges the amount of macrolitter items floating by per hour, 2) gathering the mass statistics of riverine litter at the specific location 3) combining the flux in items per hour with the mass statistics of the samples to calculate the flux in mass per hour, 4) extrapolating this number to time period of interest (González-Fernández & Hanke, 2017; van Emmerik et al., 2018; González-Fernández et al., 2021). Data in these studies are provided in absolute values in term of mass or items per time unit. To allow for more direct comparison of data it could be considered to normalize these data for the area of the river basin, the human population in the basin, or waste production in the basin.

Monitoring methods used in these studies vary, but are all relatively simple in their design execution. The simplicity makes it easier for more observations to be executed. However, the simplicity also requires the observers to extrapolate their data to provide an indication on mass transport of riverine litter. This extrapolation, in combination with the fact that little is known about the fundamental behaviour of litter in rivers leads to a high degree of uncertainty in the data. This uncertainty leads to large ranges in the estimated macrolitter transport for the rivers included in this report. Research gaps on the fundamental behaviour of litter in rivers include a proper understanding of the influence of (temporary) storage of litter in multiple reservoirs in the river systems including estuaries (van Emmerik et al., 2022a), mechanisms that drive litter transport such as rain and wind (Roebroek et al., 2021), and the process of seasonality in transport of litter (van Emmerik et al., 2019a).

To fill these research gaps it is key to establish cross border standardized monitoring methods for riverine macrolitter and to apply these methods in long-term monitoring strategies. First efforts have been made to guide this development by developing a roadmap for long term macrolitter monitoring (van Emmerik et al., 2022b). Each river is different, it is therefore important to include a certain degree of flexibility in these standardized monitoring methods so they can be adapted to local circumstances.

Table 1 - Overview table studies included in this overview

River name	Place of measurements	River compartment(s) studied	Reference
Seine	France	Floating	van Emmerik et al., 2019b
Seine	France	Floating	Tramoy et al., 2019
Seine	France	Floating, column	Treilles et al., 2021
Rhine	The Netherlands	Riverbank	van Emmerik et al., 2020
Rhine	The Netherlands	Floating	Vriend et al., 2020
Rhine	The Netherlands	Floating	van der Wal et al., 2015
Rhine	The Netherlands	Floating, riverbank	van Emmerik & Lange, 2021
Rhine	The Netherlands	Column	Collas et al., 2021
Meuse	The Netherlands	Riverbank	van Emmerik et al., 2020
Ems	Germany	Floating, column, sediment, riverbank	Schöneich-Argent et al., 2020
Weser	Germany	Floating, column, sediment, riverbank	Schöneich-Argent et al., 2021
Multi basin	Germany	Riverbank	Kiessling et al., 2019
Thames	United Kingdom	Sediment	Morritt et al., 2014
Multi basin	Europe	Floating	González-Fernández et al., 2021

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4 Data per river

4.1 Seine

The Seine River is located in north western France. The Seine is approximately 777 km long, has an average discharge of 350m³/s, and houses 16.7 million inhabitants in its approximate 32.000 km² catchment area (Gasperi et al., 2014; Tramoy et al., 2019). The Seine River drains in the greater North Sea OSPAR region (Region II), and is one of the most frequently studied European river for macroplastic pollution. Most of this research has been done by researchers from the university of Paris-East Créteil.

- 7.5 – 10.8 t/year plastic flows to the ocean (Gonzalez-Fernandez et al., 2021), and may be significantly higher during moments of peak discharge (van Emmerik et al., 2020). Previous estimates by Tramoy et al. (2019) were much higher.
- Booms already take out a part of the plastic pollution (Tramoy et al., 2019)
- Composition: mostly plastic. Frequently found items include plastic bags or films, crisp or sweet packets, cigarette butts, plastic fragments of unknown origin, garbage bags or garbage bag strings, foil wrappers, tampon applicators, plastic cups, and medical items such as bandages (Treilles et al., 2021)

4.2 Rhine

The Rhine is the main drain of North-Western Europe. Its catchment area encompasses densely populated and heavily industrialized areas such as the Ruhr area and the port of Rotterdam, and drains in OSPAR region II: the greater North Sea (Mani et al., 2015; Vriend et al., 2020). With an average discharge of 2200 m³/s (range of 600-16000 m³/s) it is one of the larger rivers located in the OSPAR region (Helpdesk water, n.d.). The Rhine is the most frequently studied river considered in this report. Most of this research on the Rhine has been undertaken by researchers from the Wageningen University, by the citizen science consortium Schone Rivieren Project, and the university of Kiel & Leibniz.

- Estimations for plastic transport in the Rhine vary greatly:
 - van der Wal et al. (2015): 5.8-58 t/year
 - Vriend et al. (2020): 0.3 – 2.1 t/year
 - van Emmerik & Lange (2021): 59.3 t/year
- The median litter density downstream was 3,990 items per km of riverbank (van Emmerik et al., 2020)
- Riverbank litter in the Rhine mainly consists of plastics (70%, van Emmerik & Lange, 2021; 30.5%, Kiessling et al., 2019). Frequently found items include: foam, hard, and soft plastic fragments (55.8%). Plastic bottles, food wrappings and packaging, caps, lids and cotton swabs were the most abundant specific items (van Emmerik et al., 2020).
- Litter in the water column is mostly plastic, with plastic fragments, food packaging, rope, and sanitary products as most frequently found items (Collas et al., 2021)

4.3 Meuse

The Meuse is approximately 900 km long and flows through France, Belgium, Germany, and the Netherlands (van Emmerik et al., 2020). The Meuse has an average discharge of 200 m³/s (range between 20-3500 m³/s), and discharges in OSPAR region II: the greater North Sea region (Helpdesk water, n.d.). Similar to the Rhine, the Meuse has predominantly been studied for macroplastic presence by the Wageningen University and the Schone Rivieren Project. Additionally, the Meuse river has also been studied by the EU Interreg LIVES project, a transnational

organisation aimed at reducing plastic waste in the river Meuse. This project was successfully finalised in January 2022¹

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- Median transport of 72.5 t/year (range 2.4 – 142.5 t/year) (van Emmerik & Lange, 2021).
- Median litter concentration of 2430 items per km of riverbank (van Emmerik et al., 2020)
- Frequently found items include plastic fragments, food wrapping, caps, lids, food packaging, and other plastics (van Emmerik et al., 2020)

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4.4 Ems

Located in north western Germany, the Ems is the smallest river that is included in this study. The Ems river is approximately 371 km long and houses 2.6 million inhabitants in its 13,200 km² catchment area (Schöneich-Argent et al., 2020). The Ems drains in OSPAR region II (greater North Sea) and has an average annual discharge of 100m³/s, which can range between 20 – 400 m³/s (Winterwerp, 2011). Macroplastic pollution in this river has been quantified by researchers from the Carl von Ossietzky University in Oldenburg.

- Annual export of macroplastic ranging from 0.1 – 1.6 t/year
- Plastic contributed between 87.5-100% of all debris in the river compartments
- Predominantly consumer waste, with industrial waste dominating riverbed transport

4.5 Weser

The Weser river is approximately 432 km long, and has a catchment area of around 46,300 km² which houses 8.5 million inhabitants (Schöneich-Argent et al., 2020). The river is also located in north western Germany, and drains in OSPAR region II: the greater North Sea with an annual average of 327 m³/s (range: 118-1230 m³/s) (Water2Adapt, n.d.). The Weser was also studied for macroplastic pollution by researchers from the Carl von Ossietzky University of Oldenburg.

- Annual export of macroplastic ranging from 0.2 – 6.3 t/year
- Plastic contributed between 87.5-100% of all debris in the river compartments
- Predominantly consumer waste, with industrial waste dominating riverbed transport

4.6 Thames

The Thames is located in the south eastern parts of the United Kingdom, where it flows through the city of London before it drains in the greater North Sea (OSPAR region II). The Thames is some 330 km long, and has an average annual discharge of 53 m³/s which can increase up to 590 m³/s during peak discharge events (Hebbert, n.d.). The river Thames has so far only been studied once for macroplastic pollution, which was done by researchers from the Royal Holloway University of London. This study did not consider the flux or concentration of items.

- Predominantly plastic
- Most frequently found: sanitary products, tobacco packaging/wrappers, food packaging, plastic cups, plates and cutlery, and plastic bags

¹ For results see: <https://litterfreeriversandstreams.eu/project-results/>

Combining the data from all included studies shows that 10.5 – 220.6 tonnes of macrolitter is exported per year to the greater North Sea area (OSPAR region II) by the rivers included in this report's scope (Seine, Rhine, Meuse, Ems, Weser and Thames). Again, the studies included in this overview all provide their data in absolute values. The data could be standardized in future research (e.g. using population or area of basin) to show relative contributions.

Two main insights can be derived from comparing the observed amounts of macrolitter in rivers within the OSPAR region. First, the export of litter by rivers in the OSPAR region differ greatly (fig. 1). The difference between rivers with lower and higher export of macrolitter can be several orders of magnitude. For example, the Ems exports were observed to be 100 – 1600 kg/year, while the Meuse was observed to be 2400 – 142500 kg/year.

Second, it must be noted that these numbers include a high degree of uncertainty. This uncertainty is indicated by the large ranges for estimated macrolitter transport by rivers, often showing a difference of an order of magnitude or more between the lower and higher estimates. This uncertainty is for example caused by the extrapolation that has to be done in order to calculate annual transport from short term observations. This uncertainty can be reduced by introducing standardized research methods and by applying these methods in long-term monitoring strategies.

Plastic is the most frequently found material type of macrolitter found in the included river systems. All rivers included in this comparison have a >80% share of plastics in the macrolitter found. Most of the items found in rivers can be linked to consumer consumption. Frequently found items in all rivers include bottles, plastic bags, food wrapping, and sanitary items. However, the most frequently found items are unidentifiable small pieces of plastic 0.5-5 cm (González-Fernández et al., 2021). The large presence of smaller pieces of plastic indicate that plastic items already experience breakdown processes within river system. This further underpins the hypothesis that the residence time of macrolitter in river systems is higher than previously thought, and that only a small fraction (1-2%) of all macrolitter that reaches rivers is exported to oceans each year (Meijer et al., 2021; van Emmerik et al., 2022a).

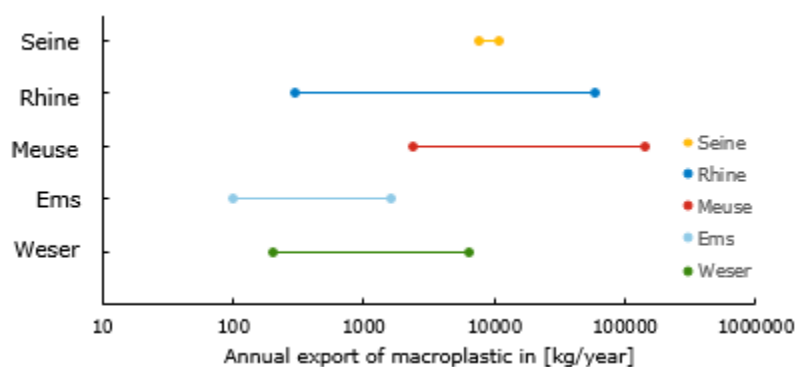


Figure 1 – Overview of floating macroplastic exports of rivers located in the OSPAR region.

6 Future directions

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Data on riverine macrolitter pollution is currently limited. This data scarcity should not be a reason to halt implementation of measures aimed at reducing this pollution. However, to reduce macrolitter pollution more effectively we need to answer “big open questions”, which include how to determine the full mass balance of litter in rivers, determining trends, determining hotspot locations, determining the efficacy of intervention strategies, and defining target values for the reduction of litter pollution. Long-term and integrated monitoring is required in order to provide the data to answer these question. We define integrated as the monitoring of macrolitter in all river compartments (floating, water column, riverbed, riverbank). So far, Schöneich-Argent et al. (2020) are the only ones to quantify macroplastic in all river compartments. Other research is predominantly done on either floating litter or litter deposited on riverbanks. Measurements for one or two river compartments do not give the full picture of litter pollution in a river, and are therefore likely an underestimate.

We define long-term monitoring as the performance of structured measurements over a longer period of time. Current data are often gathered through short-term and temporary research projects. Long-term monitoring is required to provide insights in the efficacy of intervention strategies or to determine overall trends in litter presence in rivers.

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