SFRA0025: Identification and Assessment of Riverine Input of (Marine) Litter

Final Report for the European Commission DG Environment under Framework Contract No ENV.D.2/FRA/2012/0025

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Summary for Policymakers

This report summarises findings of the project SFRA0025: Identification and Assessment of Riverine Input of (Marine) Litter for the DG Environment of the European Commission. The aim of the project is to investigate the level of pollution in EU rivers from plastic litter and to estimate the level of inputs of plastic litter from the rivers into four European regional seas.

The objectives of the contract are:

1) To monitor litter in suspension in 4 European Rivers;
2) To assess the amount of litter discharged from these rivers into the sea: and
3) To identify the largest sources within the investigated river basins.

This has been broken down according to the description of the tasks in the contract in the following components:

a) Identify existing monitoring programs on riverine litter in the EU and propose and apply a common approach to the monitoring and analysis of plastic particles in different EU rivers;
b) Establish connections and communication with river authorities and include them in the process of monitoring;
c) Assess the amount of small and micro-sized litter transported to the marine environment via rivers, through cost-effective monitoring in four European rivers;
d) Identify the distribution of different fractions of riverine litter, their main sources and associated chemical compounds;
e) Identify the largest sources of riverine litter within the investigated river basins;
f) Disseminate project results to relevant stakeholders and provide them with recommendations for continued monitoring; and
g) Link regional marine litter features with the results from a riverine litter assessment of the river flowing into the regional sea.

E.1.0 Background

Litter is seen as an emerging polluting material on a global level, especially in the marine environment. Within the European Marine Strategy Framework Directive (MSFD), marine litter is therefore included as a separate descriptor, descriptor 10. On a national level, governments have to assess quantities and types of this material in their marine waters as part of the implementation of the MSFD. There are a number of scientific studies that have been conducted by researchers in and outside of Europe showing that litter pollution (especially plastic litter) accumulates in the marine environment and that most marine litter comes from land based sources. Since the Water Framework Directive (2006/60/EC, WFD), does not include litter, plastic litter in freshwater systems is not included in any of the EU freshwater legislation. This also explains why a literature review has revealed that there are no long-term, systematic monitoring programs in place for litter items in the riverine or marine environment. This is the case for the small floating or suspended fraction of plastic litter with the focus on (small plastic particles 5 - 25 mm) and micro plastic particles (300 µm – 5 mm)[1]. We focus on these fractions in this study, since it is expected that these particles significantly contribute to marine litter pollution.

It is anticipated that in the absence of mitigation measures, any region with large rivers can be considered to substantially contribute to marine pollution. However, the scale of such input and the size distribution of these plastic particles remains to be systematically quantified. This quantification will aid in mapping the sources and amounts of litter in river systems and providing an additional knowledge base for the MSFD in terms of plastic litter emissions from river systems into the marine environment. The contribution by rivers to the marine environment are estimates based on an extrapolation of the data gathered during this project.

E.2.0 Process

Four large rivers, discharging into different regional seas (North Sea, Baltic Sea, Mediterranean Sea and Black Sea) were selected for monitoring of meso- to microsized floating litter items. These rivers also belong to the group of important European rivers with respect to discharges. Rivers selected for monitoring were: Rhine, Dalålven, Danube and Po. For each river, a sampling location was chosen on a dominant branch in a river delta, within approximately 50 km of the mouth and, where possible, downstream of the last urban area and sewage treatment plant and downstream of the last tributary. The sampling was done in one two-week sampling period per river, except the Rhine, where sampling was done two times, according to the time and financial constraints of the project. On the Rhine samplings were done only during the outgoing tide, because in this region high tidal differences are present. In accordance with these criteria, the following sampling locations were selected:

- Rhine –Rotterdam (3 times visited, 2 times sampled) - North Sea;
- Dalålven - Ålvkarleby - Bothnic Gulf;
- Po – Ferrara – Mediterranean Sea; and
- Danube – Galati – Black Sea.

[1] It is broadly accepted that macro-litter comprises litter of a size greater than 25mm which is the lower limit of beach litter assessment used by most of the researches, including the TSG ML Guidance document. Micro-litter is a term, based on the definition of microplastics, as plastic particles smaller than 5mm. The size range between 5 and 25 mm is regarded as ‘meso-litter’, which is rarely covered in marine litter monitoring protocols.

Three methods were used for monitoring to test the feasibility of the monitoring approach. Monitoring of floating microlitter was done with:

1) The manta net (mesh size 330 µm), especially modified for monitoring in rivers (Rhine, Danube, Po);
2) The pump-mantanet method (Dalålven and Po), where water was pumped through the manta-net, providing results on litter in suspension; and
3) With the Waste Free Waters (WFW) sampler(all monitored rivers). The sampler contains two metal nets (for surface and suspension sampling) with a mesh size of 3.2 mm.

Altogether 109 samples were collected in series of 7 - 10 successive monitoring days. These samples were analysed to identify the number, weight, chemical composition, type and size and the transported loads to the sea were estimated based on sampling results and on the natural characteristics of each river.

E.2.1 Monitoring Methodology

To monitor riverine litter, a fixed location at the riverbank in the shape of a pontoon, pier or quay wall was used. A temporary mobile crane, a locally available crane or locally available installations were used at these locations to deploy the samplers to collect suspended and floating litter.

It is worth noting that the choice of a specially designed mobile crane was necessitated by the requirement to obtain samples from different rivers. Therefore a mobile crane was constructed and transported in a trailer to different rivers. The result was that samples could be taken at a position in a river a few metres from the bank or the pontoon. Still this was a limitation because it is known from literature that the concentration of plastic litter can vary strongly over the cross-section of a river. The applied method did not allow to quantify this variation. Sampling with a boat would allow to better assess differences in floating litter across the river, however, the size of this boat would have to be considerable taking into account the drag of the samplers during events with high discharge. Since in this project, it was not feasible to carry along a boat to 4 different rivers in Europe, this could not be executed in the project and the choice for a fixed location was made.

Many different phenomena cause this variation in the concentration of plastic litter, for example:

- A tributary may discharge a high concentration of plastic litter and the mixing of this litter may not be ‘complete’ until a considerable distance downstream of the confluence;
- Local sources release plastic litter from a single location in a river (for example a local factory);
- The wind may push all floating litter to one riverbank. As the wind direction changes all accumulated litter might drift in a short period to the opposite riverbank;

- In a harbour basin accumulated floated plastic litter is released when the wind direction changes;
- The lateral mixing of the flow is small in a river in a delta and therefore also the lateral mixing of suspended plastic litter is small; and
- The stratification of fresh water flowing over a salt wedge in the mouth of a river discharging into a sea means that suspended and floating plastic litter accumulates along the curve where fresh and salt water meet each other in the water column and on the surface.

Another aspect is that samplers do not catch all of the plastic litter in front of the opening of a sampler due to the hydrological effect of the presence of the net as an obstruction with a certain resistance in the flow

For future sampling of plastic litter in a river, a survey vessel is strongly recommended to take samples across the entire cross-section and to sample for a longer period. The analysis of these samples will result in better estimates of the plastic litter discharged by a river into a sea, since it 1) allows for the monitoring of the entire cross-section of a river, 2) will be more efficient in terms of setting up of the equipment and can thus be more flexible in monitoring during peak-flow 3) can be better linked to existing monitoring in river systems, which commonly takes place from a moving vessel. The monitoring in the Nieuwe Maas and the Nieuwe Waterweg near Rotterdam showed that monitoring in a boat encounters considerable wash from passing vessels and requires a stable boat.

This leads to the conclusion that monitoring of plastic litter in these circumstances should be part of a general monitoring programme, including also the monitoring of series of different parameters, for example bed levels, salt intrusion and flow fields.

For greatest flexibility in monitoring in different situations and at interesting locations, a transportable survey vessel might be preferable.

E.3.0 Results

Estimates of plastic litter input to the marine environment for all the rivers sampled are provided in Table E. 1

Table E. 1: Estimates of Riverine Inputs of Plastic Litter to the Marine Environment

	Marine Input					
	WFW Sampler				Manta net	
	total				total	
	nr/s	g/s	tonnes/year	nr/year	nr/s	nr/year
Dalalven					1700	5E+10
Rhine 2	19.8	1.29	20	3 E+08	8400	3E+11
Rhine 3	5.1	1.96	31	8 E+07	3100	10E+10
Po	46.3	3.77	120	7 E+08	21500	7E+11
Danube	734.1	16.88	530	1. E+10	68900	2E+12

E.3.1 Number of Plastic Particles

In the Dalålven River, plastics were sampled only with the Manta net used as a sieve to sample 5000 l of water pumped up from the river (pump-manta net method) since sampling with the manta net directly in the water was not possible due to the unsuitable location. On average only 4.5 microparticles per m^3 have been calculated for the Dalålven River.

Estimates based on results from the project show that even this relatively clean river still transports about 50 billion (5E+10) microplastic particles annually. The fact that this river has the the smallest number of particles in comparison with the other rivers is also the result of small number of people that live in the Dalålven River basin (just 250,000). It seems though, that despite this low population density, plastics are still abundantly found in this river. One explanation could be that recreation, especially sport fishing, is well developed in this river basin.

The highest number of microplastic litter particles, 2 trilion (2E+12) microplastic particles are transported annually by the River Danube to the Black Sea. One of the possible reasons for such a high number of particles could be the weather conditions during the sampling period. Because of a thunderstorm in the Siret basin, the Danube carried temporarily a lot of litter resulting from the plastic litter being washed from the floodplains into the river and carried further downstream. An other reason could be the fact that the Danube River basin contains a population of 81 million of people. In the Rhine and the Po the number of transported litter particles lies between these values.

The amount of particles sampled varied per day, depending on the local conditions at that time, therefor these maximum numbers have to be interpreted with care. The maximum values found for the rivers do show a similar pattern as the rivers overall; Danube has the highest values, followed by Po, Rhine and the Dalålven River.

E.3.2 Weight of Plastic Particles

In weight terms, the River Rhine transports 20 to 30 tonnes of plastic litter per year to the North Sea. The Danube is estimated to transport 500 tonnes of plastic litter to the Black Sea annually. The Po transports about 120 tonnes of plastic litter per year to the Mediterranean Sea. For the Dalålven River no results from weights were obtained and could therefor not be extrapolated to estimated total annual values.

E.3.3 Types of Litter

The types of litter found in rivers varies. The most diverse samples were collected in the River Danube, covering 38 different categories under the TSG[2] categorisation. In the River Po 30 different categories of litter were found, and in the River Rhine 33 different categories were present on both sampling occasions.

The analysis of daily variability of litter types shows that in all the daily samples across all rivers, artificial polymer material (plastic) was nearly always the most abundant material. Other materials found in rivers are rubber (with the biggest share in the Rhine 3rd sampling), chemicals (G213, paraffin wax), with the biggest share in the Danube river), metal (Po river), cloth/textile (Rhine 3rd sampling), glass and ceramics, processed and worked wood, and paper and cardboard.

Daily variation of particles quantity (number and mass) was small in the Po and Rhine 3rd sampling day. The variation was much larger in the Danube and Rhine 2nd sampling days, where few high number and weight scores were measured.

Microparticles were placed into five categories, modified from the “Guidance on Monitoring of marine Litter in European Seas” list. These categories were: fragments, pellets, foams, fibres and other (Figure E 1). Fragments were the most abundant category in the Po and the Rhine (2nd and 3rd sampling). Fibres were most abundant in the Danube and Dalålven rivers. However it is worth noting that in the Dalålven River the number of fibres was 8.5 times lower than in the Danube.

For small particle categorisation, the Master List of Categories of Litter Items from the Guidance on Monitoring of marine Litter in European Seas was also used, where artificial polymer material (plastic) items are categorized in 124 different categories. Categories of Shopping bags (G3), food containers (G10), sheets and industrial packaging (G67) and plastic pieces in size 0 – 2.5 cm (G78) (see Annex A.4.0 for a full list) were present in all rivers, in surface and suspension samples. 14 categories, among which different kinds of

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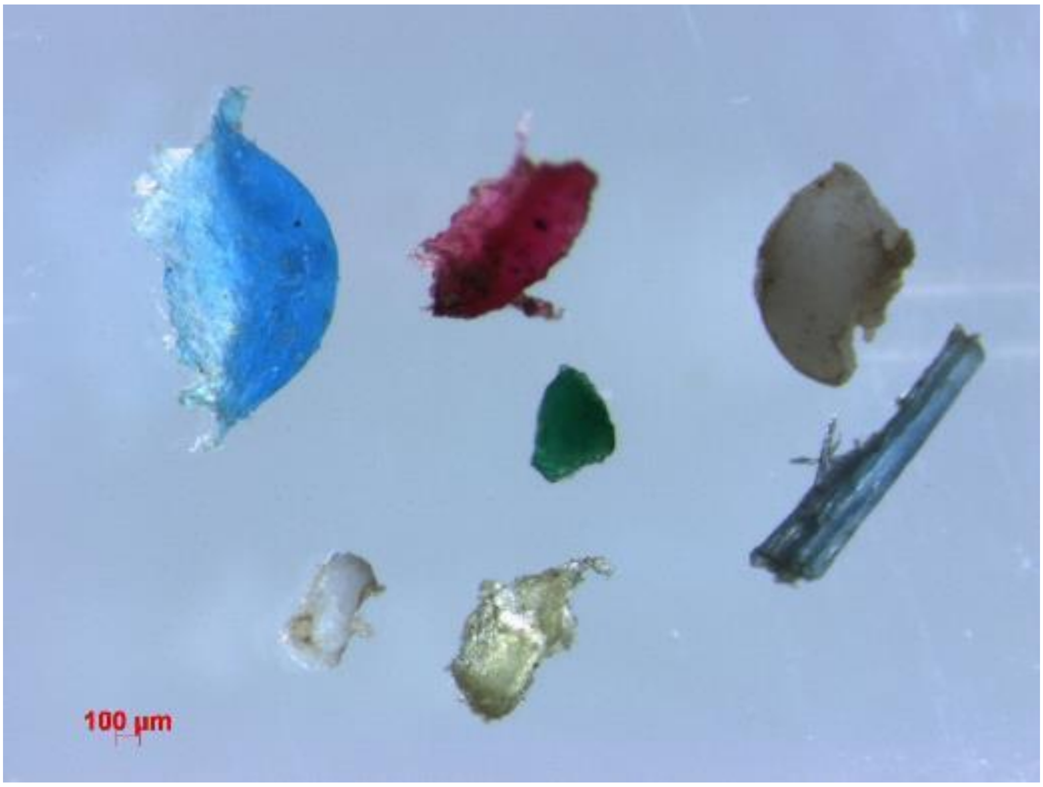
[2] TSG: Technical Sub Group Marine Litter, now renamed as TG-ML: Technical Group Marine Litter

bottles, were present only in surface samples but not in suspension samples. On the other hand only 3 categories (G5 – plastic bag collective role, G66 – strapping bands, G87-masking tape) were seen only in suspension samples, but not in surface.

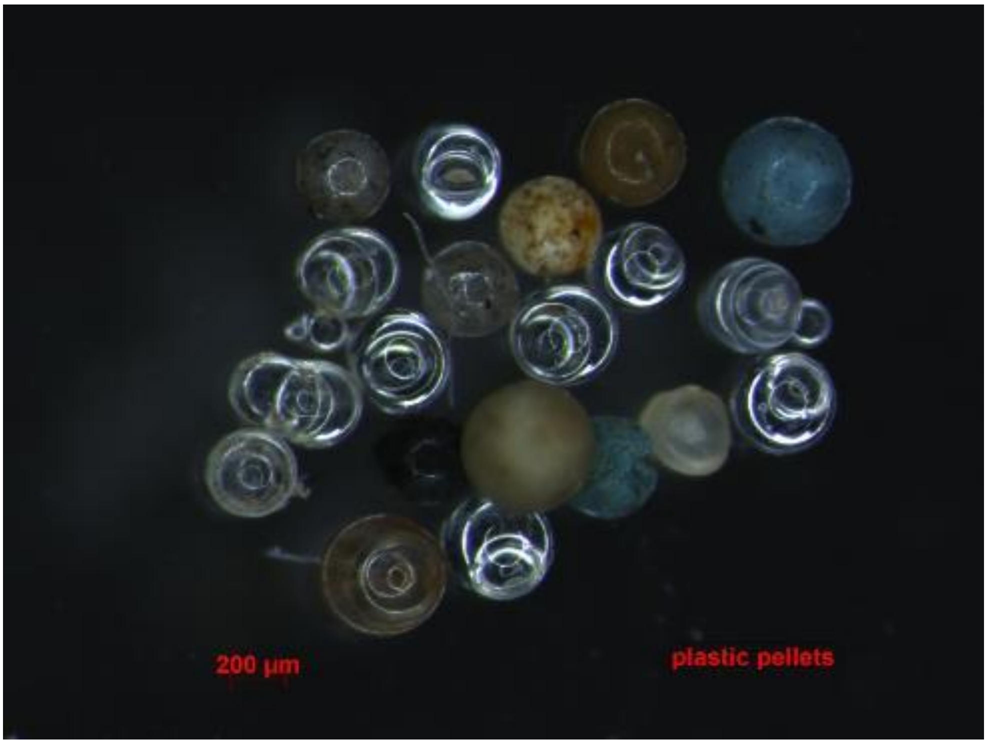
Chemical identification with Near Infrared Spectrometry of small particles (5-25 mm) shows that polyethylene is the most common material among plastic material found in all rivers. Other materials often present are polystyrene, polyamid (Nylon), polypropylene, polyvinylchloride. Chemical composition of microplastic shows mainly polyethylene and polypropylene particles. Overall, plastic represented more than 97 % of all small (5-25 mm) and micro (<5 mm) particles caught in rivers.

Figure E 1:Major types of Microplastic Categories (a – fragments, b – pellets, c – foams, d – fibres), source: IWRS

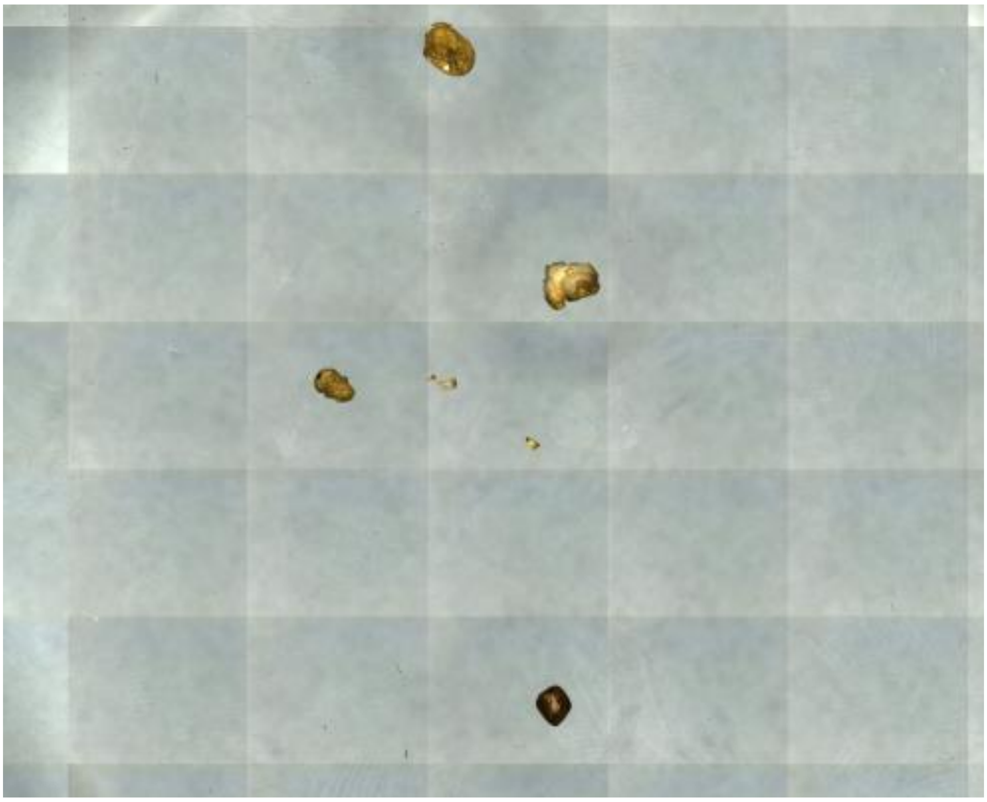
a



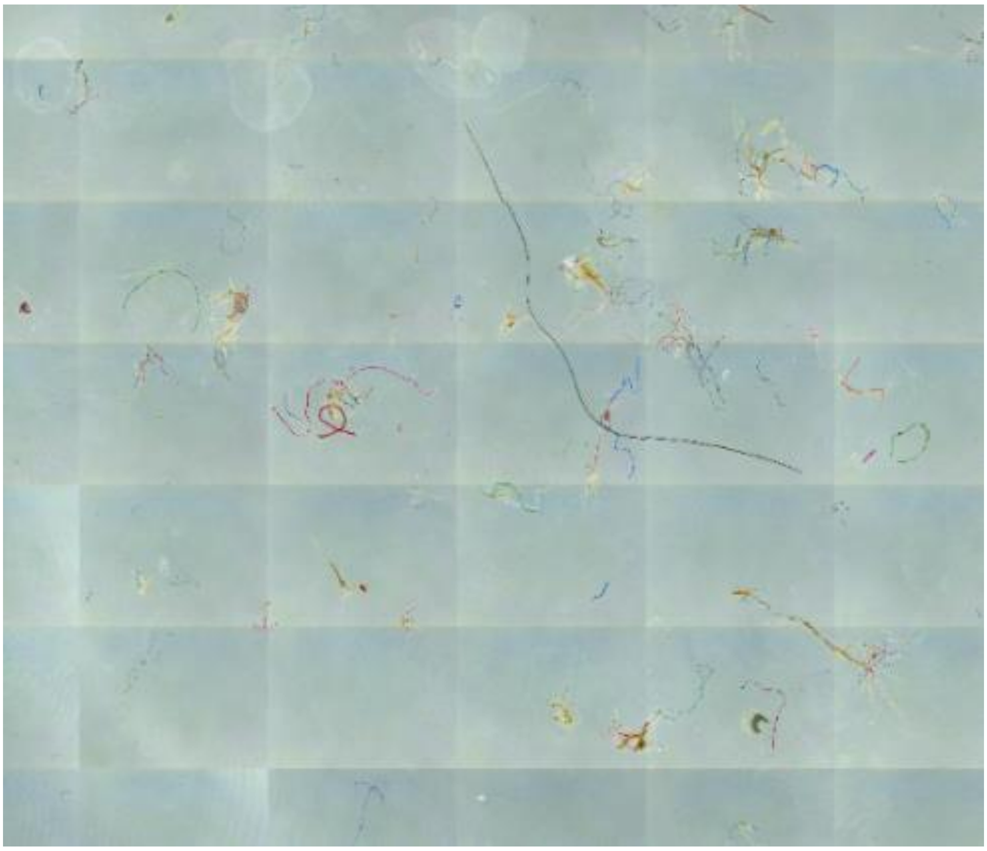
b



c



d



E.3.4 Likely Sources

We were only able to give an indication of sources for 44 % of the particles. Based on our analysis and observation, we could conclude that one quarter of small particles (5-25 mm) most resembles packaging materials used in the industrial sector (most of small particles from industry were attributed to industrial packaging). Urban sources represented 5% of small particles (including wastewater sources). Other identified sources of litter are wastewater treatment plants, agriculture, fisheries, households and medical waste.

E.4.0 Conclusions and Recommendations

This project has provided a quick-scan of the riverine environments in the EU and is one of the first projects that has looked at quantities of microsized litter in multiple rivers and compared them. We have demonstrated that plastic litter is found in all of the rivers sampled, even in the rivers with low population pressure (i.e the Dalålven). Since no threshold values for litter items exist, it is difficult to say whether the concentrations found are a cause for immediate alarm from an environmental perpective, more research is required to assess this. It can, however, be stated that rivers play an important role in transporting all sorts of litter items from the terrestrial to the marine environment, possibly also in the further fragmentation of larger litter items, and that management action is required if this input is to be decreased.

From data that are available it is anticipated that in the absence of additional mitigation measures and improved performance of existing waste management legislation, any region with large rivers entering the sea will see inputs of large amounts of litter into the marine systems, stemming from land based sources. However, the scale of such input remains to be systematically quantified by long term monitoring. One of the main legal instruments to achieve long-term monitoring of litter in freshwater environments is the Water Framework Directive. If real adaptations are to be implemented on a catchment scale, the addition of plastic litter to the monitoring of Good Ecological Status under the WFD should be considered.

E.4.1 Monitoring

For management purposes it is important to know quantities and types of litter in surface waters to enable identification of sources and prioritise management measures, both in the freshwater and marine environment. For more reliable information longer term monitoring and analysis would be recommended on more sampling sites in each river to see if there are seasonal changes (related possibly to different uses throughout the year), whether concentrations differ at different locations throughout the catchment and how this can be related to sources, as well as to see how the variability in weather influences quantities of litter in rivers.

The riverine monitoring programme to be developed should as much as possible connect to the marine monitoring programmes already in place so that the effect of mitigation measures can be monitored , not only on the scale of a Member State, but also on a regional scale. Within the OSPAR region, for example, the Regional Action Plan includes monitoring protocols for beaches and birds, but also on tackling land-based sources. Monitoring in riverine environments should connect to such regional initiatives as much as possible.

A standardized monitoring method that samples the floating plastic litter, the suspended plastic litter in the watercolumn and the transport of plastic litter on the river bed is recommended. In this manner, the three different transport routes for plastic litter from rivers to sea can be quantified. A combination of the applied two methods (Manta net and pump-Manta net) do not completely cover the presence of plastic throughout the water column and thus need to be improved. In particular, monitoring at the time of the rising limb of a hydrograph, when the flood plains become inundated is recommended, because during that period high concentrations of plastic litter in rivers are expected to be transported.

Standard equipment needs to be developed for determining the overall load of riverine input of litter into the marine ecosystem in terms of tonnes/year. The experiences with the Waste Free Waters sampler, as an example of a construction that can be attached to a moving vessel, sampling both the surface and the upper layer of the water column below can be useful for the development of standard sampling equipment. For determining the potential harm of riverine input of microparticles in terms of numbers of particles per year, the Manta net is an appropriate sampler. However, both type of samplers do not provide information about litter close to a river bed and they need to be calibrated. A drawback of sampling from a stationary location is that plastic litter variations over the cross section of a river are not measured. The development of standard equipment for sampling litter in the whole water column is a future challenge.

Methods for analysis, in which samples were cleaned and plastic particles were separated and visually observed prior to gas chromatographic analysis proved to be useful and can be selected based on the aim of the monitoring. There is however, still a need for calibration and harmonization in this analytical step as well; there is a myriad of methods to assess plastic litter in the environment and the manners in which the results are expressed have a very broad range too. To come to a better comparibility of results among EU countries and regions, this calibration and harmonization step is necessary.

From the on-hand experience with monitoring in rivers we conclude that co-operation at a local level should include local organisations, for example, port authorities, fish research stations, NGO’s or (water)sport associations. Good contacts with these organisations is of great importance to facilitate the process of obtaining permission to take samples, which proved difficult in this project.

Results from this project also have implications for the monitoring of marine litter under the MSFD. Due to the large projected quantities of small floating litter from rivers, it is recommended that estuaries and coastal zones are included as part of the monitoring under the MSFD. In reality, the different compartments of the aquatic system are all connected, and insights into the processes driving the transport and accumulation of litter in this system as a whole are paramount in the identification of sources and prioritization of monitoring effort and measures.

E.4.2 Prevention

The most effective environmental protection is preventing plastic litter from entering the environment at source. Recommendations for management are:

- Since the main identified litter source in all sampled rivers appears to be packaging materials that end up in the riverine environment either directly from industries or indirectly through littering, it is recommended to take action in packaging practices by directly addressing packaging producers and users of packaging. Additional sources of packaging litter in rivers might be also bad practices in waste management, therefore public awareness raising is crucial.
- Similarly, urban areas are also an important source in all sampled rivers, therefore waste management in urban areas and wastewater treatment practices should be investigated in order to identify actual causes for emissions of litter from urban areas.
- In the Rhine and Po catchments further investigation should be done to identify which industries are actually directly emitting plastic to surface waters.

- Extensive public awareness raising is recommended to emphasise the importance of changing behaviour which currently contributes to litter entering rivers, including the problem of waste water overflows.
- Agriculture is also an important litter source (by the use of agricultural plastic foils) identified mainly in the Po and Danube rivers. In these two catchments in-depth analysis of litter pollution stemming from agriculture should be performed to identify specific problem areas.
- In the Po and Rhine rivers, recreational fishing was also identified as an important litter source (e,g. net filaments, etc). Awareness raising campaigns are recommended among fishermen in these two catchments.

Contents

Acronyms

ABS - Acrylonitrile butadiene styrene

ATR FTIR – Attenuated total reflection Fourier transform infrared spectroscopy

HDPE – High density polyethylene

iPP/EPR – Polypropylene/ethylene-propylene

NIR – Near Infra-red spectroscopy

PA – Polyamide (Nylon)

PE – Polyethylene

PP – Polypropylene

PO – Polyolefine

PVC – Polyvinyl chloride

PET – Polyethylene terephthalate

PS – Polystyrene

PU – Polyurethane

PVA – Polyvinyl acetate

PVS – Polyvinyl stearate

WOOL + PP = 3 : 2 – Wool + polypropylene mixture

1.0 Introduction

This report describes the results of project SFRA0025: Identification and Assessment of Riverine Input of (Marine) Litter for the DG Environment of the European Commission. The project falls under the framework contract on emerging pressures, human activities and measures in the marine environment (including marine litter) (ENV.D.2/FRA/2012/0025).

The report is structured as follows:

- Project Objectives, Project Tasks, and the Project Team are outlined in Sections 1.1, 1.2 and 1.3 respectively;
- The process by which monitoring sites were selected is explained in Section 2.0;
- The approach to monitoring is outlined in Section 3.0, and fully described in Appendix A.1.0;
- The procedure by which samples were subsequently analysed is briefly described in Section 4.0;
- A brief analysis of the results is presented in Section 5.0, with full results presented in Appendix A.3.0; and
- Conclusions, Discussion and Recommendations are provided in Sections 7.0, 8.0 and 8.0.

1.1 Project Objectives

The main objectives of the contract are:

1) To monitor litter in suspension in 4 European Rivers;
2) To assess the amount of litter discharged from these rivers into the sea: and
3) To identify the largest sources within the investigated river basins.

This has been broken down according to the description of the tasks in the contract in the following components:

a) Identify existing monitoring programs on riverine litter in the EU and propose and apply a common approach to the monitoring and analysis of plastic particles in different EU rivers;
b) Establish connections and communication with river authorities and include them in the process of monitoring;
c) Assess the amount of small and micro-sized litter transported to the marine environment via rivers, through cost-effective monitoring in four European rivers;
d) Identify the distribution of different fractions of riverine litter, their main sources and associated chemical compounds;
e) Identify the largest sources of riverine litter within the investigated river basins;
f) Disseminate project results to relevant stakeholders and provide them with recommendations for continued monitoring; and

g) Link regional marine litter features with the results from a riverine litter assessment of the river flowing into the regional sea.

1.2 Project Tasks

The project requirements as stated in the terms of reference, comprise the following four tasks. These tasks have been slightly adapted, for example to better suit the local conditions necessary for monitoring:

Task 1 - Identification of possible monitoring sites and cooperative river basin authorities

It is essential to identify local partner organisations who are or are becoming aware of the issue of marine litter and the linkage to their river basins and are prepared to cooperate in setting up monitoring. JRC, as co-chair of the MSFD Technical Subgroup (TSG) Litter already has established contacts with the River Danube authorities and the German Federal institute for Hydrology. The sites selected in geographical different catchment areas would preferably also be representative of a number of other aspects related to possible sources of litter. The following steps are identified:

a) Identify existing litter monitoring programmes in river basins in Europe by river authorities or other relevant organisations;
b) Identify river basin authorities willing to cooperate on the (additional) monitoring; a number of them have already shown interest (Danube, Rhine, Elbe, Po, Sweden)
c) Set up criteria to apply the final selection for four monitoring sites based on geographical distribution over river catchments across Europe, proximity of zero salinity location, large cities, outflow of waste water treatment plant, effectiveness of waste management in the area and other source-related criteria
d) Apply the selected criteria and identify four suitable locations in different rivers to monitor critical stretches of each river, taking into consideration possible point sources of smaller particles of litter.

Task 2 - Set up monitoring of litter in 4 European rivers

The focus should be on monitoring microlitter (333µ - 5 mm) and small particles (5 - 25 mm) in suspension in the rivers in those areas identified in Task 1. Use should be made of a standardized trawling net such as Manta net trawls as described in the chapter on microlitter of the draft Monitoring Guidance by the TSG Litter (published in July 2013 at CIRC ABC2).

a) Organize in an efficient and cost-effective way monitoring at the four locations identified in task 1, with the full cooperation of the river authority responsible;
b) Execute the monitoring of riverine litter per selected river (stretch), at intervals enabling the capture of some information on seasonal (water flow and litter-input) variation. This might entail long-term monitoring with a net from a fixed platform.

Task 3 -Analysis of the results

Based on the previous tasks:

a) Analyze the data collected using the standardized categories of the TSG Litter;
b) Estimate for each river the load of litter carried to the sea (quantitative analysis) and assess its relevance in comparison with marine litter data for the relevant sea, i.e. with the load coming from other land-based as well as marine sources;
c) Identify the fractions of plastic type, and their proportion in the monitored litter;
d) Report on which fractions might require special attention due to their potential environmental impacts, for example due to their chemical composition (e.g. presence of plasticisers), by relating the information on their prevalence in the samples to information in literature studies regarding the presence of microplastics or their chemical ingredients in sea life;
e) Identify possible sources/origins of the litter found in each of the rivers including those originating from littering by consumers, and their relevant importance compared to the overall load.

Task 4 -Compile a report and share its results

a) Compile the findings of the tasks above in a comprehensive report accompanied by a summary for policymakers and recommendations for authorities to set up or continue river litter monitoring;
b) Present and discuss the findings in Regional Seas Convention meetings, together with the responsible River Basin Authority;
c) Present in a targeted, user-friendly format the results of the report and discuss the report at a meeting with Member States' representatives under the Common Implementation Strategy for the MSFD and the WFD;
d) Revise the final report based on these discussions.

An overview of the extent to which these tasks have been executed by the project is shown in Table 1.

Table 1: Extent of Sub-Task Completion

Task Number	Subtask	Extent completed	Explanation
Task 1	a. Identify existing litter programs	100 %	Most existing programs deal with sampling litter in a marine environment and only a few are performed in rivers. This lack of data on riverine litter is recognised in the literature and is also the case for the river basins which were the subject of this study. Some riverine litter monitoring is already being undertaken in locations across Europe but the approaches applied would not have met the requirements of this project. In the report a review of the literature with a focus on the monitored river basins is included.
	b. Identify river basin authorities	100 %	For the monitored rivers the competent authorities were identified. However, a problem we encountered was that these authorities were not always competent in the fields that were required for the practical execution of the sampling operation (e.g. ownership of suitable sampling locations or responsibility for safety in harbours). In order to fulfil the assignment local authorities and other organisations such as fishing clubs had to be involved.
	c. Set up criteria for selecting monitoring sites	100 %	Based on practical and logical considerations following the assignment, monitoring locations were defined using criteria including proximity to river mouth, preferable riverbank, location of cities, and safety.
	d. Apply criteria to find suitable	100 %	This was completed taking into account practical constraints. In practice this was very complex. Suitable, available and accessable river bank locations (ideally with a quay wall or accessable pontoon)

	monitoring locations		were far scarcer than expected for a number of reasons, many of which only became clear at the time of the visit itself, including unsuitable currents (e.g. eddies) at the sampling location, interference with other uses (such as fishing, or ships loading and unloading), safety (e.g. not being allowed near flood protection barriers), permission from owners (both public and private) to use the locations, and accessability of the location for sampling equipment.
Task 2	a. Organize cost-effective way of monitoring	100 %	The selected methodology was the most cost-effective and efficient approach within the anticipated time frame of the project. Since we opted for stationary sampling from a fixed location we could use our own equipment (a transportable crane) or we could use the available installations at the location (e.g. a local marina with the equipment already present). If the project had been dependent on the availability of equipment from local authorities, the problems would have been far greater with further time required to undertake monitoring. The selected approach 'only' required the permission to use a location, which as noted asbove was not always easy to obtain. It needs to be recognised that monitoring of plastic litter in rivers is a new activity and that such monitoring is by its nature, exploratory. In undertaking this study the project team has been able to make recommendations about future monitoring activities.
	b. Execute monitoring of river litter	100 %	This was executed, and two samplers were used instead of one sampler (which was all that was requested under the Terms of Reference). Based on our experience of monitoring of marine litter at sea, as well as Waste Free Waters' experience of sampling in riverine

			conditions, we identified that the intended approach of sampling only with a 0.3mm net could lead to problems due to the net clogging up. The WFW sampler (3.2mm) was added to the program in order to be able to sample larger particles for a longer sampling time, both for floating particles and for suspended particles.
Task 3	a. Analyze data based on TSG categories	100 %	All samples were analysed and TSG categories were adapted to the riverine environment, mainly by combining categories in new categories for practical reasons. It appeared very difficult to divide the particles into all the categories provided in the Master List.
	b. Estimate river load carried to sea	75 %	This was estimated through extrapolation of the monitoring data, although this is a methodologically disputable exercise since the samples were taken over a short time period. Ideally the river load carried to the sea would include measurements of a load in which high peaks, over a whole year, are included. Comparing the occurring riverine load during the project with the presence of marine litter is also methodologically disputable, since the result of the sampling activities resulted in a flux (transported load per unit of time) while at sea only the abundance is known of the floating fraction, while the sunk and suspended fraction, and the fraction deposited on beaches is not known. In section 7.10 we have commented on our findings with reference to available data on marine litter quantitities. The recommendations section of the report describes an approach for riverine litter sampling that might deliver better usable data for these types of assessments

			and suggests ways to improve the validity of the measurements.
	c. Identify fractions and proportions	100 %	Undertaken in detail and described extensively in the report.
	d. Additional analysis (chemical)	100%	The chemical analysis undertaken on the particles sampled during the project was mainly aimed at determining the materials that the particles were made of. A separate analysis was performed on some industrial pellets and focused on the presence of other chemicals like additives and POPs. These particles were separately collected.
	e. Identify sources and origins of litter	85 %	There were no ‘finger prints’ of specific sources found, and therefore it was possible only to determine the type of sources. Considering the enourmous surface of the riversheds and the vast amount of activities, it is impossible to determine a specific location of an emission of specific plastic particles. The particles found at the mouth of the river represent all of the emissions of all of the sources in the entire rivershed and can only be categorised by type of litter, combined with a possible use and consequently by possible source (e.g. plastic pellets used by plastic producers or converters, emitted at production locations, transported to the river by sewage systems and delivered to the river in the effluent of a waste water treatment plant).
Task 4	a. Compile findings into report	100%	Completed.
	b. Present and discuss	50 %	It became clear that a meaningful discussion of results would only make

	findings at RSCs		sense after the completion of sampling, characterisation and discussions within the project team. This further compressed the timeframe for discussions with RSCs, and in practice it was not possible to undertake this engagement in the way that we had anticipated at the outset. RSCs also needed considerable time to comment on the report. Some RSC members have responded individually to the report.
	c. Present results at MSs meeting	75 %	Gijsbert presented the project on a number of local TV and radio stations. Presentation of the results at MS meetings has not been possible in the period since the completion of the first draft of report. However, there will be forthcoming opportunities for members of the project team to present the findings. Specifically Monika Peterlin will be able to present at upcoming MSFD meetings and WG Ecostat in the WFD intercalibration framework. In addition Andreja Palatinus will be able to present at the upcoming DEFISHGEAR event being held in Slovenia in May.
	d. Revise final report based on these discussions	100 %	Account has been taken of all received comments in the revision of the final report.
Concluding Remarks			It is important to consider the results of the study in the light of the pioneering nature of the activities that have been reported here. The approach to monitoring of litter in rivers is still under development, so methods used needed to be tested and further developed for the purposes of this project. Working with multiple unknown combinations of ‘entities’ and ‘interfaces’ (land/water, river/sea, surface/suspension,

			microplastics/macroplastics, local/national) and applying the same approach at multiple locations throughout Europe, restricted the opportunities for a succession of successful sampling operations within the anticipated timescale and project budget. This complexity went far beyond the problems that a local organisation encounters when organising a sampling activity in a river with a locally available and well known technical and governmental infrastructure and with good knowledge of the local riverine conditions. Setting up European sampling activities requires the development of a well defined technical, scientific and organisational infrastructure and an innovative combination of dedicated sampling techniques, reporting formats and validation and harmonisation methods to assess the contribution of landbased sources to riverine and marine litter and to identify effective source-oriented mitigation strategies to meet MSFD as well as WFD expectations. The project team has concluded that this aspect of the project was the most meaningful. The project made clear that sampling riverine litter is both complex and challenging and that the state of research, knowledge building and local awareness and organisation with regard to this topic is only in its initial phase.

1.3 Project Team

The project team consists of staff members from Eunomia Research & Consulting Ltd, the Institute of Water of the Republic of Slovenia (IWRS) and Deltares.

Deltares focussed on selection of monitoring sites and monitoring activities and assigned these tasks mainly to a subcontractor, Waste Free Water Foundation (WFW). This foundation has recent experience with monitoring plastic litter in the Meuse River.

IWRS cooperated with WFW to apply methods, used for plastic particles monitoring in the marine environment, and to apply the original WFW approach to monitoring of riverine litter. IWRS undertook the analysis of the samples in cooperation with the National Institute of Chemistry Ljubljana - Laboratory for Polymer Chemistry and Technology. All partners cooperated in communication to river authorities according to their proximity to regional seas.

The National Institute of Chemistry Ljubljana - Laboratory for Polymer Chemistry and Technology contributed to the project by defining and applying the methodology for chemical analysis of collected litter particles, performing a comparison with other results found in the literature and estimating litter sources based on identified types of plastics. The Laboratory performed the analysis of adsorbed pollutants on a selection of the collected litter items.

Eunomia's role is one of internal peer review and quality assurance, retaining overall responsibility for the delivery of the work under the framework contract.

2.0 Task 1: Identification of Possible Monitoring Sites and Co-operative River Basin Authorities

2.1 Introduction

In this section we present findings on:

- Existing litter monitoring programmes in European Rivers (Section 2.2);
- The criteria for identifying river basins (Section 2.3);
- The criteria for selecting monitoring sites (Section 2.4); and
- The application of these criteria to select monitoring sites (Section 2.5).

For readers interested in background details, the following sections, which are attached as appendices, may be of interest.

- Relevant European policies are summarised in Appendix A.8.1;
- Details on the transportation of litter in rivers are provided in Appendix A.8.2; and

- Current litter monitoring methods in rivers and seas are described in Appendix A.8.3.

2.2 Task 1a: Existing Litter Monitoring Programmes in European Rivers

A short literature review has revealed that there are no long-term monitoring programs in place on small litter items in the riverine environment. There are, however, scientific studies conducted by researchers in and outside of Europe.

We observe a shift of focus of the litter problem from the marine environment to the land sources of marine litter, however there appears to be relatively little published literature describing riverine input of plastics to the marine environment[3]. Nevertheless literature recognizes the importance of rivers as a major input of litter into the marine environment. For larger litter items, macrolitter, a study has been conducted in the River Thames, where the amount of litter transported along the river bed was monitored [4].They observed that the locations where the most litter was found were in the vicinity of sewage treatment plants. Significant quantities of litter, especially plastics, are moving down the Thames and are thus providing a major input of such debris to North Sea [5]. Any region with large rivers entering the sea will input large amounts of litter into the coastal system from source but quantification remains to be resolved[6].

There are also some studies on microsized litter in rivers. A recent publication from Austria for example, related the amount of fish larvae caught in the Danube to the amount of microplastics found [7]. One of their main findings was that there are more litter particles observed than fish larvae. A critical note to this paper is that the amount of fish larvae present in river systems is seasonal and dependent on local circumstances, making the relationship with litter items hard to establish. In freshwater lakes in the USA, a study revealed that the highest numbers of microplastic particles were found

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[3] Morritt, D., Stefanoudis, P. V., Pearce, D., Crimmen, O. A., & Clark, P. F. (2014). Plastic in the Thames: A river runs through it. Marine pollution bulletin, 78(1), 196-200.

[4] Morritt, D., Stefanoudis, P. V., Pearce, D., Crimmen, O. A., & Clark, P. F. (2014). Plastic in the Thames: A river runs through it. Marine pollution bulletin, 78(1), 196-200.

[5] Morritt, D., Stefanoudis, P. V., Pearce, D., Crimmen, O. A., & Clark, P. F. (2014). Plastic in the Thames: A river runs through it. Marine pollution bulletin, 78(1), 196-200.

[6] Williams, A. T., & Simmons, S. L. (1996). The degradation of plastic litter in rivers: implications for beaches. Journal of Coastal Conservation, 2(1), 63-72.

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

downstream from large cities. This phenomenon is related to the use of micro beads in consumer products such as cosmetics [8].

There are also more short-term projects taking place in the French river Adour and the Dutch stretch of the Meuse River which build the knowledge base on which monitoring can eventually take place.[9,10,11]

Our findings are in line with the conclusions from Wagner et al., (2014) who conducted a review on state of the art of microplastics in riverine systems, state that the body of data on the presence of microplastcs in freshwater systems for microplastics in the freshwater environment needs to emerge.

Based on interactions with stake holders at the monitored rivers we concluded as follows:

- In Italy no short-term projects or long-term programmes exist to monitor riverine transport of plastic litter;
- In the Danube the transport of litter in the river is monitored in Vienna, Austria, far upstream from the mouth of the river in Romania;
- In the Dalålven a monitoring program of fish species is undertaken regularly, but there is no monitoring of plastic litter.
- In Poland we did not find information concerning regular monitoring of plastic litter in Polish rivers.
- In the Rhine, plastic litter is the subject of sporadic short-term sampling efforts, also in its tributaries. Plastic litter is not a part of the regular monitoring programmes in the river basin.

2.3 Task 1b: Identify Appropriate River Basins

The criteria for the selection of the rivers to be monitored were developed based on a combination of scientific considerations and practical constraints of the sampling of multiple rivers throughout Europe in a relatively short timespan.

The transport of plastic litter in rivers shows similarities with the transport of sediments in rivers. Sediment transport in rivers is measured using different methods. Some of them use a sediment gauging station. For the location of these sediment transport gauging stations various criteria have been formulated. In a recently revised version of the ASCE manual on engineering practice some criteria were mentioned for the location

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[8] Eriksen M., Mason S., Wilson S., Box C., Zellers A., Edwards W., Farley H. and Amato S. (2013). Microplastic pollution in the surface waters of the Laurentian Great Lakes. Mar Poll Bull 77 (1-2): 177-182

[9] Institution Adour, 2003, Le Bassin versant de l'Adour

[10] Tweehuysen, 2013, Onderzoek naar de aanwezigheid van grof en fijn rivierafval in de Maas

[11] Morritt et.al. 2014, Plastic in the Thames: A river runs through it

of a sediment gauging station.[12] In general a reliable measurement of the river discharge and the water level is part of the procedure to estimate the total sediment transport in a river branch. The stability of the banks, a more or less uniform distribution of the discharge in a cross section without return flows in eddies, preferably not in a sharp bend of a river, the presence of an access road to the station, sufficient strength of the subsoil for the foundation of a station are typical criteria for the selection of permanent sediment gauging station. Our criteria for the selection of a temporary monitoring site of plastic litter in a river were derived from that type of criteria for the location of a sediment gauging station.

Since one of the main objectives of the project is to identify floating small plastic litter items in relation to the Marine Strategy Framework Directive (MSFD), assessing the contribution of these rivers to the marine environment, the rivers had to meet several criteria:

The following criteria were applied to select four European rivers in which the plastic litter was sampled:

- The four selected rivers discharge preferably into different regional seas of the European Union (North Sea, Baltic Sea, Mediterranean Sea and Black Sea) so that regional differences could be assessed in relation to plastic litter in the marine environment and the geographical distribution of their river catchments should be representative for the main European rivers;
- Most rivers belong to the group of important European rivers with respect to discharges so that the ‘worst case’ scenario could be calculated;
- These rivers preferably differ in terms of characteristics of the catchment area, so that the effect of these differences could be related to observed differences between rivers;
- Sufficient reliable key hydraulic data is available; such as water levels and discharges, zero salinity point as well as other relevant meta-data like wind speeds, winddirection and precipitation. This was necessary to be able to further support our findings and relate these to environmental factors in the rivers.
- Local authorities should be willing to co-operate with the project in terms of finding suitable monitoring locations, delivering additional services and capacity (for example a safe parking place for our equipment, personnel to learn the applied sampling method of plastic litter, etc.). In terms of obtaining permits for sampling, this criterion was important.

The application of these criteria resulted in four potential rivers (Rhine, Dalålven, Danube and Po River) suitable for monitoring. The Rhine cathment is part of western Europe, sufficient key data of the Rhine are available, the authorities showed interest in the project and the mouth forms a large urbanised area. The Dalålven is very different from the Rhine River. The Dalålven flows in Northern Europe, its cathment is mainly

[12] M.H. Garcia 2007, Sedimentation engineering, New York, Am. Soc. Civil Eng., 1132 p, chapter 5, p 322

woodland and nature reserve, sufficient key data are available. The Danube River flows in Eastern part of Europe and is very long river with a large cathment. The Po River has a relatively small cathment in the Mediterrenean climate zone with some large cities and less nature and the local authorities were interested in the project. The Oder River was also selected, but ultimately no samples were collected from that river mouth for technical and organisational reasons.

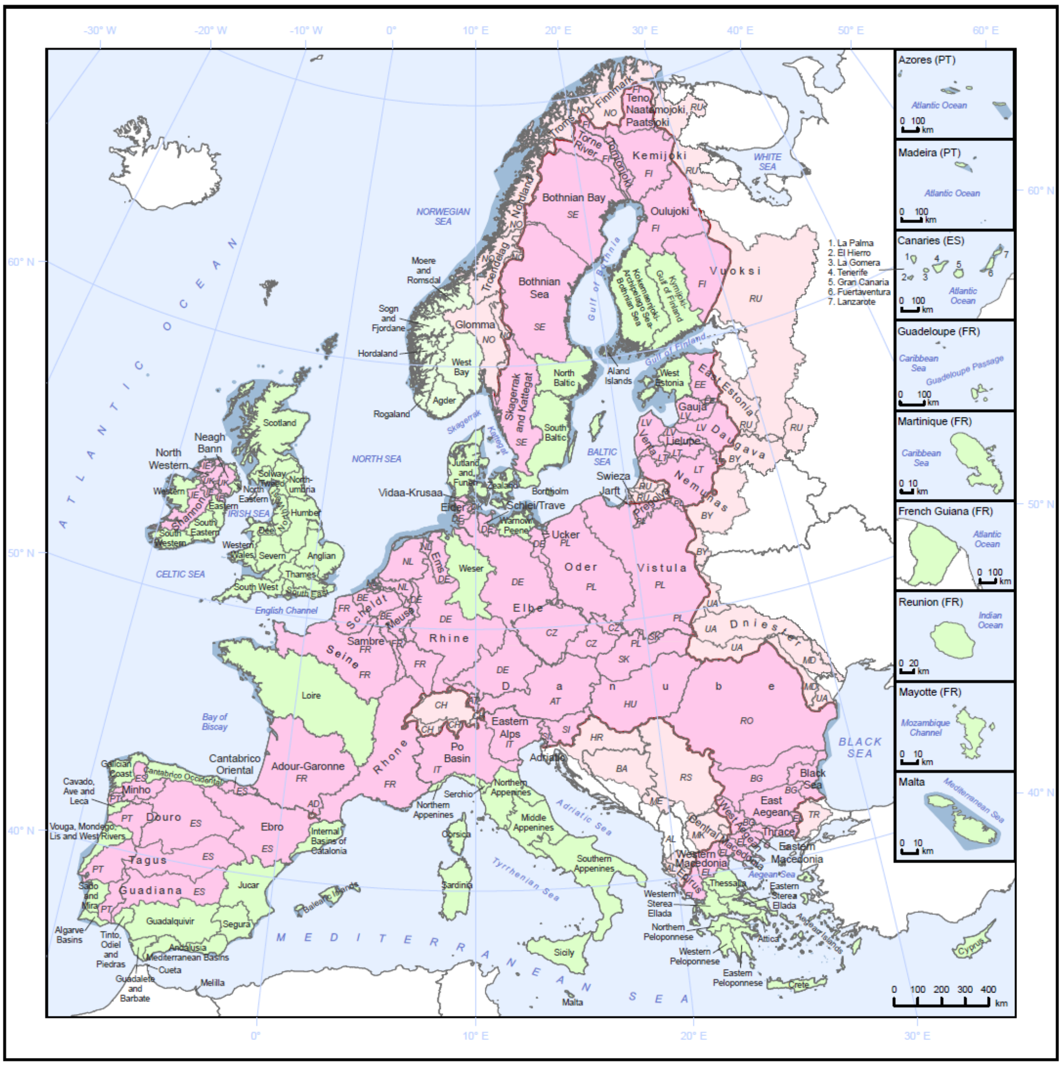
Table 2: Potential European Rivers Suitable for Monitoring

River	Average discharge (m^3/s)	Sea	Catchment area (km^2) characteristics	Reference
Rhine	2378 (1900 Nieuwe Waterweg, en 500 Haring-vliet)	North Sea	200,000, highly urbanised and industrialized catchment	Helpdeskwater.nl Vellinga et al
Dalålven	~380	Baltic Sea	29,000, catchment is a nature reserve	Zinke, P. 2013
Danube	~6500 (6400)	Black Sea	800,000 agricultural catchment of the tributary Siret River	Alexandracotoi.tripod.com
Po	1470	Mediterranean Sea	71,000 moderately urbanized catchment	Montanari

Figure 1: Map of National and International River Basin Districts

Map of National and International River Basin Districts

Version 29 October 2012



National and International River Basin Districts

International River Basin Districts
Compiled from data reported to WISE by EU Member States

Approximate extent of International River Basin Districts outside of the EU
Compiled from data reported to WISE by AD, CH, LI MC and NO, supplemented with CCM2 Seaoutlets and ICPDR data

EU27 extent

National River Basin Districts
Compiled from data reported to WISE by EU Member States

National River Basin Districts outside of the EU
Compiled from data reported to WISE by NO

Coastal waters

Country borders

Map produced by WRc plc on behalf of the European Commission©, DG Environment, 2012

Footnotes

1) The boundaries of the National River Basin Districts are displayed using version 1.5 of the Water Information System for Europe (WISE) River Basin Districts dataset available from the European Environment Agency:
http://www.eea.europa.eu/data-and-maps/data/wise-river-basin-districts-rbds-1.
This dataset is based on data reported to WISE by EU Member States, Andorra, Switzerland, Liechtenstein, Monaco and Norway.

2) The boundary of the Mayotte RBD (France) is displayed using the country border dataset.

3) The boundaries of the International River Basin Districts are derived from the WISE River Basin Districts dataset.

4) Country border data was provided by Eurostat and is derived from EGM at a scale of 1:3 million.

5) The international river catchments outside of the EU are displayed using data from a number of sources:
- Data reported to WISE by Andorra, Switzerland, Liechtenstein, Monaco and Norway.
- Seaoutlets data from the Catchment Characterisation Modelling (CCM2) database developed by the Joint Research Centre to show the approximate extent of international catchments in Belarus, Moldova, Russia, Ukraine, Macedonia, Albania and Turkey.
- Data provided by the International Commission for the Protection of the Danube River to show the extent of the Danube International River Basin District in the Balkans.

6) Coastal waters are defined in the Water Framework Directive as extending 1 nautical mile from the coastline. Some Member States included a larger part of their coastal waters within their River Basin District boundaries.

2.4 Task 1c: Criteria for Selection of Monitoring Sites

The method used to select a monitoring location close to a river mouth consists of the following two steps:

- Studies are made of aerial photographs (Google Earth) and the following selection criteria applied to identify suitable monitoring locations prior to monitoring on site:
  - The location should be in a stretch within about 50 km of the mouth of the main branch discharging in a sea, in this way there is a reasonable assumption that the results from sampling are in line with the concentrations of litter actually reaching the sea;
  - The location should be on a dominant branch in a river delta to assure that the measurements are representative for the total output into the sea
  - The location should be downstream of the last urban area and sewage treatment plant and preferably downstream of the last tributary, so that the hypothesised influx of litter from urban areas could be taken into account; and
  - The monitoring should not be hampered by extreme tides and waves, since these could disturb the river flow and cause under- or overestimations of the results from sampling.

These criteria were used to rank potential locations.

- For a final selection we checked on site if the following practical conditions were fulfilled:
  - Permission was obtained from the owner of the location and from relevant local organisations;
  - The safety of the site was assessed (for example surrounded by a fence). A safe place is needed in terms of vandalism and theft, since our equipment will remain in place for 2 weeks (day and night) in order to reduce the time for assembly and disassembly each day, especially the crane.
  - Relevant organisations or persons related to a selected river stretch were identified to facilitate making contact regarding awareness-raising, securing permission to monitor (where necessary) and obtaining any other support required.
  - The local flow pattern was checked. Sampling with the available sampling equipment requires unidirectional flow and a minimum flow velocity to keep the net floating. Reversal of the flow direction and periods with flow below a minimum velocity occur often in a tidal estuary. Another aspect is a check on the presence of underwater structures close to the bank of the potential sampling location disturbing the flow pattern by the formation of large eddies.
  - The accessibility of the location was checked for a camper combined with trailer.

These steps were followed for all locations near the selected estuaries, providing different challenges upon arrival at each location.

In practice the complexity of selecting a sampling location proved to be a real challenge. The specially designed crane could only be used in a situation where a relative good quality quay wall was available, which was also accessible with a truck and where camping for some time was allowed. These conditions excluded most of the publicly accessible quays, where camping was not allowed. Where quays were available on private land, permission for camping was not easily obtained. In our experience, it took quite some time (1 to 2 weeks) to select a final location suitable for monitoring from a fixed location at a bank.

2.5 Task 1d: Applying Criteria and Selecting Monitoring Sites

The selection criteria in Section 2.4 were used to select the sites in which the sampling eventually took place.

2.5.1 Rhine River, Netherlands – Three Periods (of which 2 succesful)

The Rhine River has two main branches that discharge in the North Sea. The Nieuwe Waterweg is the most important branch of these two. The first selected monitoring site at the Nieuwe Waterweg was near the village of Rozenburg (Figure 2). However, it was not a suitable location and we were not able to get any sample here. After considering all other potential locations a site at Verkeerspost Stad along the Nieuwe Maas centre of Rotterdam turned out to be the best of all potential locations (Figure 3).

2.5.1.1 Monitoring Site - Rozenburg

Rijkswaterstaat West-Nederland Zuid, part of the Dutch Ministry for Infrastructure and the Environment offered us their station with a quay wall near Rozenburg in the Nieuwe Waterweg (51°54'46.94"N 4°14'23.94"E), see Figure 4. The site fulfilled almost all criteria. However, because of the flow pattern (low flow velocities during the tidal cycle and a big eddy next to the quay wall) the site was unsuitable for monitoring activities.

Figure 2: The Nieuwe Waterweg near Rotterdam with the Sampling Location Rijkswaterstaat Rozenburg

2.5.1.2 Monitoring Site – Verkeerspost Stad

The port authority Havenbedrijf Rotterdam manages three traffic control stations along the Nieuwe Waterweg and the Nieuwe Maas. They gave permission to use one of their traffic control stations - Verkeerspost Stad (51°54'16.27"N; 4°25'47.94"E). That station was a suitable monitoring location (see Figure 3). After the confluence with the Oude Maas the Nieuwe Maas is called Nieuwe Waterweg, which discharges in the North Sea. This location was reasonably well suited with regard to the available current next to the sampling site.

Figure 3: The Nieuwe Maas in Rotterdam with the Sampling Location at Verkeerspost Stad

2.5.2 Monitoring Site – Dalålven River, Sweden

In Sweden the Dalålven discharges in the Baltic Sea (see Figure 4). From aerial photographs several potential sites were identified downstream of a hydropower station. It appeared that none of these locations were suitable for monitoring activities. Several riparian landowners and relevant local organisations were asked permission to carry out monitoring activities from their plots. After an attempt was made to anchor the sampler in the river near the camp site, local salmon anglers objected to what they saw as an obstruction in the river. This was because of their fishing technique where they let their bait float with the current and they feared it could be entangled with the mooring lines. It was a complicated process to get permission to use a suitable location along the Dalålven River, but finally a location was found on a private property (60°36'44.19"N;

17°26'32.78"E) with a private platform. However it was a couple of metres above the water level, limiting the opportunities to use the samplers in the intended way.

Figure 4: The Mouth of the Dalålven River in the Bothnic Gulf (potential sampling locations identified in a first reconnaissance)

2.5.3 Monitoring Site – Po River, Italy

Prior to monitoring on site a study was made of aerial photographs (Google Earth) and some suitable monitoring locations in the mouth of the Po River were identified. However, a different final monitoring location was selected due to practical considerations.

In the Po River no formal water authority was involved in the selection of the sampling site, but contacts were made via the involvement of the Italian Ministry of the Environment, Land and Sea and through Italian environmental organisations. No suitable quays exist along the natural borders of the Po. An environmental organization mediated permission to use a water sport station, Canottieri Ferrara, on the right bank near Ferrara (see Figure 5). That station has pontoons and a crane that was used for getting boats in and out of the water.

The distance of the monitoring site to the sea is a bit far, circa 85 km. It is an advantage that this location (44°53'10.56"N 11°37'26.45"E) is upstream of the bifurcations of several branches discharging in the Mediterranean Sea. The surface flow velocities varied between 0.7 and 0.8 m/s at the monitoring location during the monitoring period of May 28th to June 5th.

Figure 5: Sampling Location in the Po River near Ferrara

2.5.4 Monitoring Site Danube River, Romania

Prior to monitoring on site a study was made of aerial photographs (Google Earth), and initially a potential location was selected near Tulcea. To obtain permission to sample in the Danube was also very difficult and no formal contact was available and emails went unanswered. An attempt was made to get in contact with the Port Authorities in Galati through the involvement of the Damen Shipyard, but due to the vacation period this did not result in contacts with the proper authorities.

However, contact with the Ecological Consulting Centre Galati (ECCG) resulted in the final monitoring location in Galati, about 190 km from the mouth of the main branch of the Danube in the Black Sea. That location is upstream of the large Danube delta with several parallel branches. A marina was selected as the final monitoring site on a left bank of the river (45°25'2.76"N; 28° 2'6.67"E). There was a wastewater treatment plant and the mouth of the Siret tributary just upstream of the monitoring site, but it was not possible to find any other option to install the equipment (see Figure 6 and Figure 7). Using the network of the President of ECCG we obtained a permission from the city authorities to sample at this location.

The location is downstream of the Siret tributary and upstream of the centre of Galati.

Figure 6: The most downstream stretch of the Danube River in Romania

Figure 7: The Marina in Galati

2.5.5 Monitoring Site – Oder River, Poland

The Oder River discharges downstream of Stettin in the Baltic Sea and a large part of the river forms the border between Poland and Germany. The river discharges in a so-called Haf (a laguna or lake) with a small connection (the Swina river) to the sea, see Figure 8 and Figure 9. Świnoujście is a small port that is located at this connection.

It is an interesting mouth, because the hypothesis is that plastic litter transported by the Oder might sink in the laguna before it could be transported to the sea. The trap efficiency of a laguna might depend on the wind conditions.

Selecting a monitoring site near the mouth of the Oder River presented several difficulties. The local authorities in Świnoujście, agreed to sampling at the pier at the harbour entrance (53°55'22.11"N, 14°17'3.88"E), but a permission to sample in the river had to be given by the Ministry in Warsaw. This permission arrived too late to make sampling possible within the timescale of the project.

Figure 8: Aerial photograph of the mouth of the Oder River downstream of Stettin

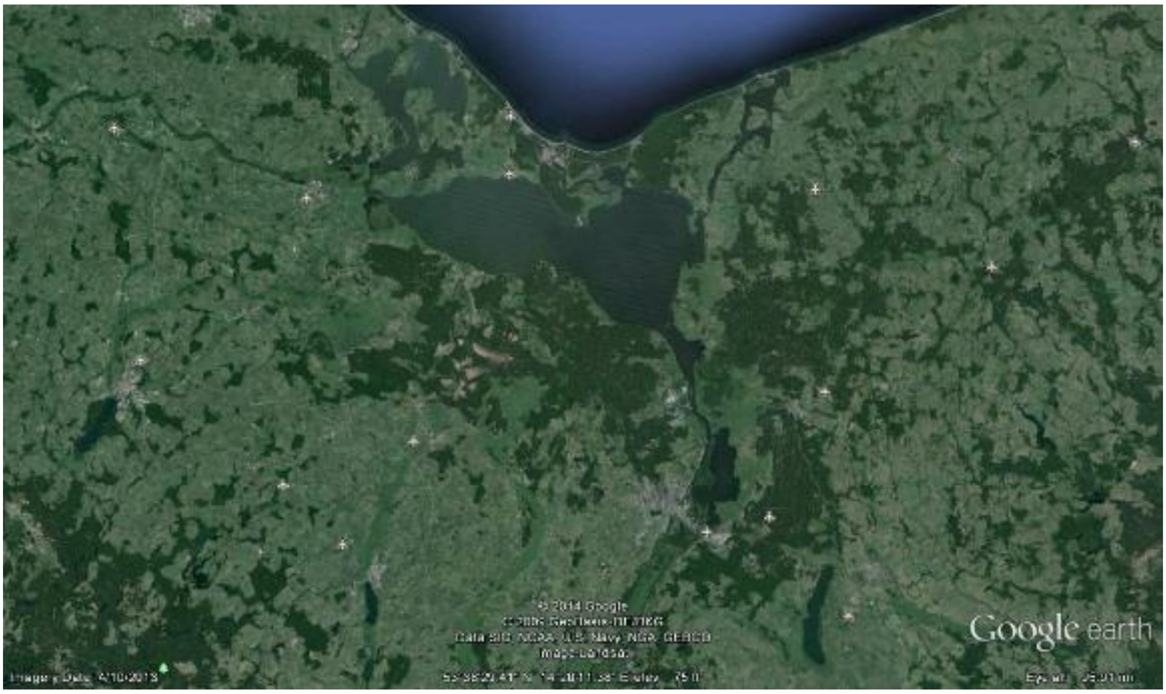
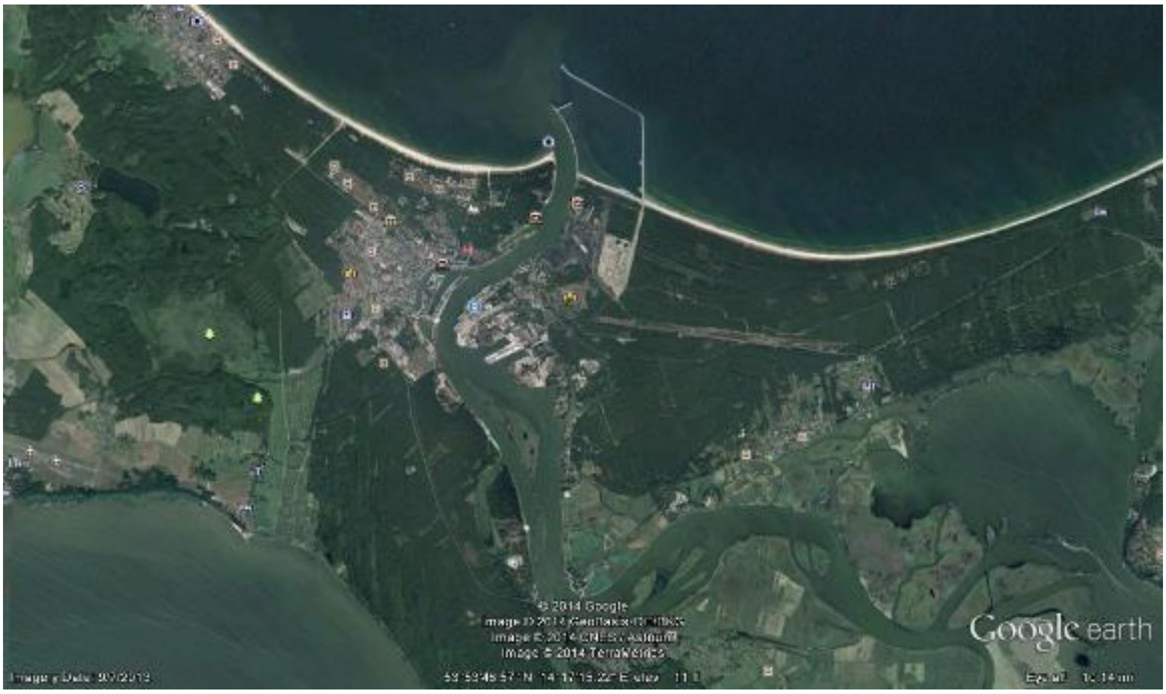


Figure 9: The connection between the laguna and the Baltic Sea and the port of Świnoujście



2.6 River Basin Authorities and Involved Organisations

Co-operation with the local river management authorities was good and they showed interest in the results of the project. However, co-operation had to be extended to include local organisations, for example, port authorities, fish research stations, NGO's or (water)sport associations. Good contacts with these organisations is of great importance in facilitating the process of obtaining permission to take samples.

The project requirement to sample from a fixed location introduced considerable organisational problems because the location could only be defined by inspecting the region at the time we were locally present. Support from a distance by "higher level" organisations like a local river management organisation did not work out smoothly because they were not equipped to deliver support at this very detailed local level. It means that the project had to contact local staff of a river management organisation or other local organisations to obtain permission to take samples.

The necessary time to select a final location and to organise permissions at the sampling location took some time, 2 to 7 days. In the case of Rotterdam, setting up and disassembling the equipment took only 2 days, but at the other locations the time needed for arranging the setup took more time, up to 7 days.

An overview of the most relevant contacted persons to obtain permission per sampling location can be found in Appendix A.6.0.

3.0 Task 2: Set up of Monitoring of Litter in European Rivers

3.1 Tasks 2a & 2b – Organise Cost Effective Monitoring Methods and Execute Monitoring of River Litter

The following monitoring methods have been used in the four selected rivers:

- Dalålven:
  - Pump – manta net method
- Po River:
  - Pump – manta net method
  - Manta net deployed from pontoon
  - WFW sampler with both surface net and suspension net, deployed from pontoon
- Danube River:
  - Manta net, attached to WFW-floater attached to poles in the stream
  - WFW-sampler with both surface net and suspension net
- Rhine River (two sampling periods):
  - Manta net, deployed with crane from a quay wall
  - WFW-sampler with both surface net and suspension net deployed with a crane from a quay wall.

The number of samples collected in each river using these methods is outlined in Table 3.

Applying multiple sampling methods simultanuously reflects the complex nature of the litter itself and the way it is transported by a river.

The manta net is well suited to catch microparticles, but can only sample during short periods (< 30 minutes) due to clogging of the net. In the case of microplastics smaller than 1 mm, where we can assume that a rather homogenious dispersion throughout the water column is present given the turbulent state of a shallow river, the sample might very well be representative for the presence of microplastics in the whole river.

When microplastics between 1 and 5 mm are caught it depends on the compactness of the particle whether or not it can be assumed that it represents the floating fraction or that it represents the suspended fraction of the microplastics.

The WFW sampler is capable of sampling for very long periods, because the net has a greater mesh. The occurrence of larger particles in the river is much lower than that of microparticles, thus a larger covered sampling area or sampled volume is necessary to get statistically significant results. The larger the particles are, the more vertical segregation occurs. This is a result of the lower surface to volume ratio at a given density. Compact, lighter than water particles like closed PET-bottles, EPS foam, PE preproduction pellets, etc., will always be present at the surface, while larger films or fragments will be drawn into the water column while subjected to the turbulence in the current. Sampling both at the surface as well as below the surface is necessary to determine the presence of the whole spectrum of particles in the river.

Comparing the different methods is difficult, since they are aiming at different materials, forms and shapes and on different transport mecanisms. The presence of floating objects can be expressed per surface unit, while the presence of suspended objects can be expressed per volumetric unit.

The presence of microplastics can best be described as a volumetric concentration for suspended particles or as a surface concentration for floating particles, although the used manta net makes not a proper distinction between these two categories. Here, the pump method might give an additional indication of the presence of microparticles in the watercolumn.

The presence of macroparticles can best be described as a surface concentration in case of floating particles and as a volumetric concentration in case of suspended particles.

In the case we want to describe the riverine input of litter into the sea, then for microplastics the load in terms of numbers per volume or surface might be the most relevant unit, while in the case of macroplastics, the load in terms of mass per volume or surface might be the most relevant unit.

It is advised that this subject requires additional research.

Table 3: Number of Samples collected in Specific Rivers

	Microlitter samples (Manta net sampler)		Small particles samples (WFW-sampler)		
	Manta Trawl samples	Pump-Manta net samples	Surface samples	Suspension samples	**Total**
Dalålven River, Sweden	0	10	1	0	**11**
Po River, Italy	7	8	5	5	**25**
Danube River, Romania	6	0	6	6	**18**
Rhine River I, Netherlands	9	0	8**	8**	**25****
Rhine River II, Netherlands	10	0	10	10*	**30**
Total	**32**	**18**	**30**	**29**	
Total		**50**		**59*,****	**109**

* 3 samples were clean (zero litter particles)

** 1 sample Surface and 1 sample Suspension were not analysed due to severe contamination with lubricating grease

All samples (50 Manta net samples and 59 Waste Free Waters samples (WFW-samples)) were sent to the Institute for Water of the Republic of Slovenia (IWRS) where they were analysed for microlitter and meso litter presence.

Out of 59 WFW samples 2 (1 surface, 1 suspension) were not accepted in the analysis of the results since they were contaminated with lubricating grease (04.08.2014). All valid WFW samples were analysed according to TG ML Master List. All samples were also analysed for microliter and as much as possible categorized according to an agreed protocol for microlitter categorization from the TG ML Master List.

Samples for microlitter analysis were collected with a manta net in three different rivers (trawl samples from the river bank), on four occasions. For the River Dalålven no trawl samples were collected, because the location was not suited to operate the mantanet. Sampling for microlitter with the pump-manta net method was undertaken in two rivers - the Dalålven and Po. From all samples collected via the pump-manta net method microlitter and meso litter a part of samples were separated and categorized according to TSG ML Master List.

3.2 Equipment

Monitoring equipment is described in detail in Appendix A.1.0.

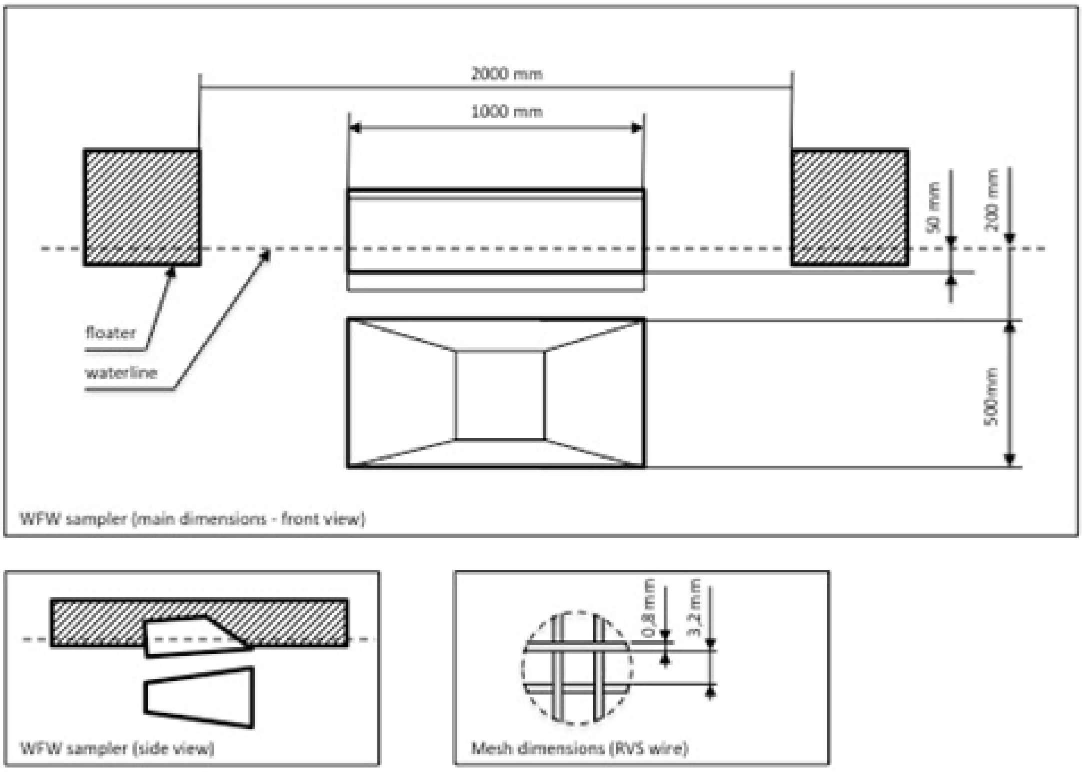
3.3 Sampling

The approach entails monitoring with a sampler from a fixed location on a river bank. The challenge in this project was to have a comparable approach in the four different rivers, whilst retaining a certain level of flexibility to be able to adapt it to the local conditions.

The sampling covered the whole spectrum of litter categories, both microlitter and macrolitter, since these items were caught by the samplers. Restricting the analysis to particles <25 mm would have biased the weight of litter flowing to the seas. Bigger macroplastic, like bottles or larger sheets, fully dominate the weight score compared to the smaller particles. Microlitter was mainly sampled with the manta net, as the larger particles were sampled with the Waste Free Waters (WFW)-sampler.

- The Manta net has an internal width of 60 cm and mainly samples litter floating near and on the surface, skimming the surface to a depth of 10 cm . The sieve size of the net is 0.3 mm. The sampling time was a maximum of 30 minutes, depending of the amount of silt and other organic material (turbidity) in the water, because of the risk of clogging of the net. The trap efficiency of the sampler has not been determined yet, but it is believed it is close to 100 % in calm conditions. The reliability of the Manta net decreases if there are waves, since the amount of water sampled is then difficult to determine.
- The Waste Free Water sampler (WFW-sampler) consists of two floating bodies with two metal nets in between: a surface net and, below the waterline, a suspension net. Both nets have a width of 1m and the suspension net has a height of 50 cm, creating a cross-sectional area of 0.5 m^2. The leading edge of the surface net is 3-5 cm below the water surface. The suspension net collects samples at a depth of 20 to 70 cm below the water surface. However, in conditions with wind and ship-induced waves these figures will change in a complex way. The trap efficiency of the sampler has not been determined yet, but it is believed to be close to 100 %.

Figure 10: Schematic Representation of a WFW-sampler



- A new monitoring method was introduced in the Dalälven River out of necessity, because of the limitations that the banks of that river created for setting up the monitoring equipment. In particular, there are no quay walls present along its banks and the project was unable to obtain permission to sample at other potentially suitable monitoring locations. Therefore the project applied a so called 'pump method' with a manta net, a big 1000 litre liquid container and a pump with a hose and a nozzle. The manta net was placed above the container and acted as a sieve. With the pump in the river a sample of 5000 litres of water was made by filling the container 5 times. The nozzle was 0.3 m below the water surface.
- The methodology is described, in 'step-by-step' detail, in Appendix A.1.0

4.0 Task 2: Methods for Sample Analysis

4.1 Analysis of WFW Surface and WFW Suspension samples (small particles 5-25 mm)

Analysis of WFW samples was performed using visual identification. Each particle was first categorized according to the TSG ML Master List, and after that its size and colour (by TSG ML Master List) was also determined. If possible, the type of suspected source was determined for the particles. All categories for each sample were weighed with analytical laboratory scales (KERN ALJ 310-4A and KERN EMB 5.2KI, KERN & SOHN GmbH, Germany) and photographed separately. On average 5 particles from each sample were sent for chemical identification of particles via Near Infrared Spectroscopy.

4.2 Analysis of manta net and pump method samples (micro-litter 333µm - 5mm)

4.2.1 Cleaning the Sample

Samples were first cleared of the bigger natural and artificial pieces through 5 mm and 0.16 mm sieves. Samples were put into the sieve and cleaned with filtered tap water (300 µm mesh size). After cleaning each sample was rinsed with 70 % ethanol into a plastic bottle and stored in the refrigerator before the analysis.

4.2.2 Microlitter Separation

A sample was divided in cleaned glass Petri dishes and microlitter was first removed from the samples using stereomicroscopes (SteREO Discovery.V8, Carl Zeiss, Germany) and micro tweezers (Aesculap, Germany). The magnification used to visually determine and categorize microlitter was between 12.5x and 100x.

Each particle was separated from a sample using micro tweezers and put in a suitable glass Petri dish (depending on the category of the particle). Particles were dried on the air, but in closed Petri disches to prevent contamination from the air. When they were dry, they were weighted by analytical laboratory scale (KERN ALJ 310-4A), and then the image analysis and chemical analysis were done.

Each particle was photographed under the microscope. From the pictures the size of the particles was measured automaticaly with the picture analysis software. We were using two different microscopes with picture analysis software: 1) Stereomicroscope SteREO Discovery.V8 with AxioVision software (Carl Zeiss, Germany); 2) DMS 1000 with LAS software (Leica, Germany).

4.2.3 Chemical Analysis

Chemical analysis from the categories fragments and pellets of particles was performed using Near infrared spectroscopy (NIR) (SIROGRAN, GUT environmental technologies, GmbH, Germany). We applied a new approach to the identification using a NIR spectrometer with an automated XY scanning facility. A sample plate with 625 set positions each able to contain one particle was used. Identification of polymer type was achieved by comparing collected NIR spectra with a built-in spectral database through an automated chemo metric procedure. Particles from categories foam and fibres were chemically analysed by Fourier transform infrared spectroscopy in ATR mode (FTIR-ATR) (Spectrum One, Perkin Elmer Inc., USA). The Universal ATR sampling accessory was used in transmission mode, in the range between 4000 and 650 cm^{-1} with a spectral resolution of 4 cm^{-1}. Samples were identified by comparing the FTIR spectrum of the sample with spectra in the Hummel spectral database.

The chemical analysis was undertaken in this way for all microplastic particles sampled in the first three sampling days per river, except from the category of fibers, where just 5 fibers per sample sampled in the first three sampling days, were analyzed.

4.2.4 Analysis of Adsorbed Persistent Organic Pollutants (POPs)

The collection of pellets was, due to practical constraints, only carried out on one location in the Netherlands in the river Meuse and followed the Pellet Watch methodology.[13]

4.2.4.1 Extraction Procedure

Pellets were weighed and placed into a 20 ml glass vial. The extraction was done in two steps: first into 20 ml of hexane and then into 20 ml of dichloromethane, following the procedure described in Van et al. (2012). The volume of each extract was reduced to 5 ml under nitrogen flow.

4.2.4.2 Gas Chromatography Analysis

Gas chromatograph Agilent 6890 with mass selective detector Agilent 5973 was used to perform the analysis. The following conditions were used: 2 µl of the extract was injected into the injector heated to 250°C in split less mode (column: DB-35MS, 30 m; length: 0.25 µm diameter). Temperature program was: 5 minutes at 60°C, raised to 300°C with ramp rate 30°/min, 5 minutes at 300°C. Mass spectra were collected in the mass range 33 to 450 amu. Substances were identified by comparing obtained mass spectra with reference spectra from the Wiley spectral library.

4.2.5 Litter categorization according to the TSG Litter Master List (combining categories).

Microlitter was categorised according to the following 5 categories derived from the TSG ML Master List:

- fragments (TSG ML General – codes: G103, G104, G105, G106, G114),
- pellets (TSG ML General – codes: G107, G108, G109, G110, G111, G116),

[13] http://www.pelletwatch.org/

- foam (TSG ML General – codes: G115, G117),
- fibres (TSG ML General – code: G113) and
- other (TSG ML General – code: G217).

Different types of particles from the TSG ML Master List were combined in new categories for practical reasons. Particles were very difficult to divide into all categories provided in the Master List. Different shapes of plastic fragments are suggested as separated categories in TSG Master List (G103 – G106), whereas they are very difficult to distinguish (rounded, subrounded, subangular, angular). The same problem appeared with identifying pellets of different shapes (cylindrical, disks, flat, ovoid, spheruloid). For this reason the TSG ML categories were combined into 5 new categories used for this analysis.

4.2.6 Statistical analysis

Standard deviations were calculated by the classic formula:

$$= \frac{\sqrt{\Sigma(y - \bar{y})^2}}{\sqrt{(n-1)}}$$

y = the absolute number of particles or weight of particles, ȳ = the average of particles number or weight among sampling days, n = number of sampling days included in analysis.

5.0 Task 3: Analysis of the Results

In this section we address:

- Task 3a – Analysing the data collected using the standard categories of the TG Litter (Sections 5.1 to 5.3) ;
- Task 3b – Estimate for each river the load of litter carried to the sea and assess its relevance in comparison with marine litter data for the relevant sea (Section 5.5);
- Task 3c – Identifying the fractions of plastic type, and their proportion in monitored litter (Section 5.6);
- Task 3d – Report on which fractions might require special attention due to their potential environmental impacts (Section 5.4); and
- Task 3e – Identify possible sources/origins of the litter found in each of the rivers including those originating from littering by consumers, and their relative importance compared to the overall load (Section 5.7) .

5.1 Quantity of litter in rivers, according to number of particles and according to weight

5.1.1 Microlitter

Plastic micro particles were counted in samples from 5 consecutive sampling days for each river. The average numbers of micro particles that were caught by manta net in rivers are 100 – 800 (Table 4). The average maximum number of microparticles per km^2 was found in the Po River (≈ 2 million/km^2), followed by the Rhine 2nd sampling (≈ 1.7 million/km^2), Danube (≈ 1 million/km^2) and the Rhine 3rd sampling (≈ 300.000/km^2) (Figure 11).

Overall, the variability in micro particle numbers among sampling days was observed. The smallest differences in micro particle numbers per km^2 between sampling days was observed in samples from the Rhine (3rd sampling) (SD ± 54269.11), followed by the Po River (SD ± 336637.4). The highest variability in micro particle numbers between sampling days was observed for Rhine River (2nd sampling) (SD ± 957726) and the Danube River (SD ± 530066.4) (Table 4, Figure 11).

Comparing the results of the 2nd and 3rd sampling in the Rhine shows the significantly lower numbers (six times lower) of micro particles in the Rhine 3rd sample than in the Rhine 2nd sample (Table 4).

Daily particle numbers per km^2 decreased from the 1st to the 5th sampling day in the Danube River. In the Rhine River 2nd sampling the highest particle numbers were recorded on the 2nd, 3rd and 4th sampling days. On the Po and Rhine (3rd sampling), there were minimal differences between days in the particle numbers per km^2 (Figure A3.29)

The mass of micro particles was analyzed from 3 consecutive sampling days for each river. The average mass per km^2 of micro particles shows a slightly different trend in comparison with the average number per km^2. The biggest mass per km^2 of micro particles was measured for the Rhine (2nd sampling) (2445 g/km^2), followed by the Po (782 g/km^2) and Danube (116 g/km^2). The lowest mass of micro particles was measured for the Rhine (3rd sampling) (39 g/km^2) (Table 4, Figure 12).

The smalllest differences in measured micro particle mass between sampling days was for the Rhine (3rd sampling) (SD ± 11.9) and the greatest difference for the Rhine (2nd sampling) (SD ± 3641). The large SD value for the Rhine (2nd sampling) is the result of a big mass (2.6 g) of particles measured on the 2nd sampling day (Table 4, Figure A3.30).

Table 4: Average number and weight (g) of microparticles collected with manta net per river and normalized values of number (nr) of items and weight (g) per km^2

Manta trawl	Number of particles		Weight of particles (g)		Nr / km^2		g / km^2	
	Average	STDEV	Average	STDEV	Average	STDEV	Average	STDEV
PO	818.4	417.34	0.4145	0.0733	2,043,069.8	336,637.4	782.1	138.23
DANUBE	381.6	245.70	0.0449	0.0529	1,061,126.2	530,066.4	116.2	133.49
RHINE 2	648.8	400.21	0.9513	1.4278*	1,773,392.8	957,726	2,445.5	3,641.046
RHINE 3	142.3	54.20	0.0167	0.0017	311,660.3	54,269.11	39.2	11.90

*On the Rhine River, the second day of sampling, extremely high number of pellets (1-5 mm in diameter) were caught. For this reason the SD is so big.

Figure 11: Average numbers of microparticles normalized per km² collected with manta net

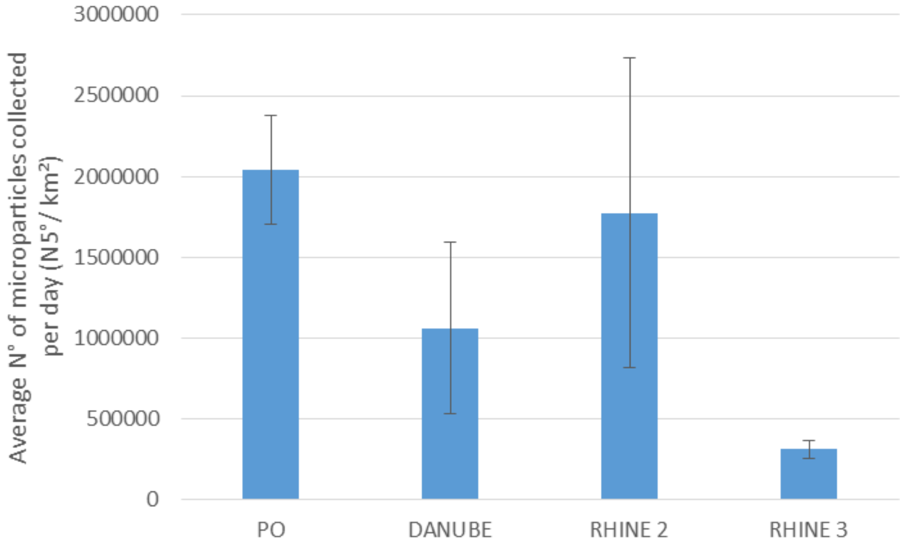
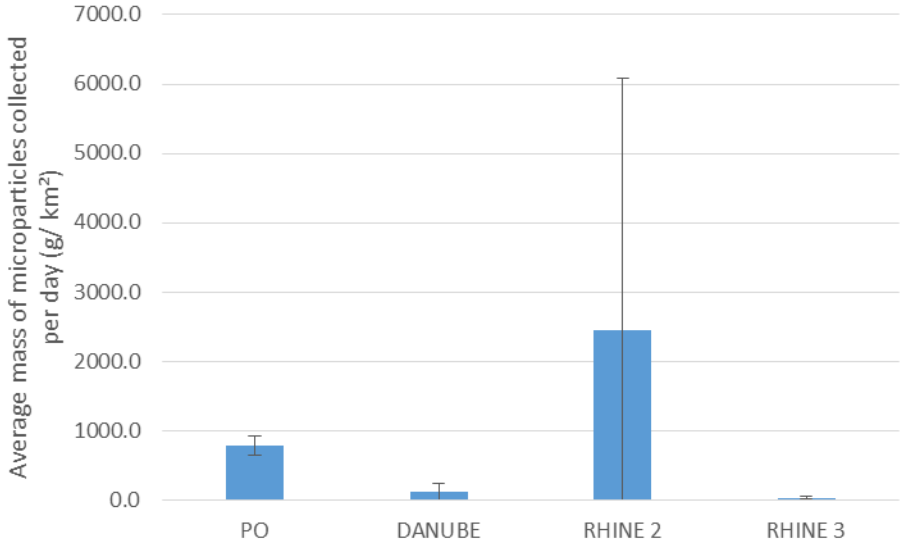


Figure 12: Average mass (g) of microparticles normalized per km² collected with manta net



On the Po and Dalålven rivers, microparticles were sampled with the manta-pump method. In Po River, on average, 5 times more particles were found than in the Dalålven River and for this reason also the average mass of collected microparticles is 5 times bigger. A similar trend was also found for results when normalized per m^3 (by assuming the samping depth of a trawled mantanet is 10 cm) to better relate them to the river discharges, which are also expressed in m^3 (Table 5).

The daily number of microparticles for 5 consecutive sampling days for Po and Dalålven River, sampled by pump-manta method show in all sampling days the biggest values for Po River. As expected, the same trend was found also for results of mass (Figure A3.31).The biggest difference in microparticles number when normalized per m^3 between sampling days was measured for Dalålven River (SD ± 3) and in case of microparticles mass, for the Po River (SD ± 0.001) (Table 5, Figure A3.32).

Table 5: Average number and weight (g) of microparticles collected with manta-pump method per river and normalized values of number of items and weight (g) per m^3

	Number of particles		Weight of particles (g)		Nr / m^3		g / m^3	
	Average	STDEV	Average	STDEV	Average	STDEV	Average	STDEV
Po	101.4	65.85	0.0102	0.0068	20.3	13.17	0.0020	0.0014
Dalålven	22.7	15.06	0.0026	0.0068	4.5	3.01	0.0005	0.0002

5.1.1.1 Comparison between Manta-Trawl Method and Pump Method

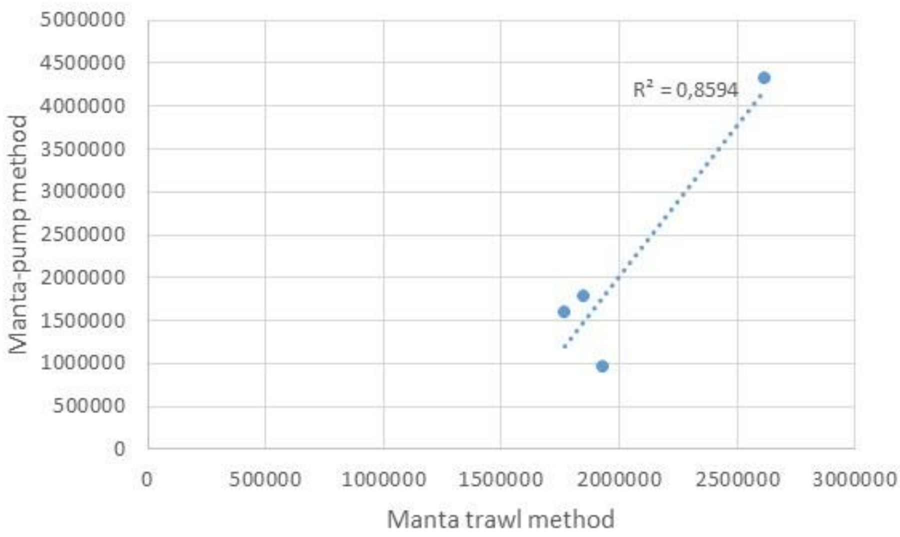
From the Po sampling period we have four samples taken on the same day, enabling a comparison of the results of the two different sampling methods: the manta-trawl method and the pump method (Table 6).

Both data sets are in the same order of magnitude and have a correlation coefficient of 0.86 (Figure 13). This means that the assumption that the samples collected using a manta net, taking samples to a depth of 10 cm, can be compared to the samples collected using the pump-manta net method taking samples to a depth of 10 to 30 cm. Although this correlation looks valid, still a more extensive calibration is needed and additional research of the sampling characteristics of a pump in comparison with a net is advised.

Table 6: Meta data, Po River, Manta trawl method and Manta-pump method sampling

Date	Sample ID	Sampler	Pump (nr/km^2)	Manta (nr/km^2)
27 May 2014	PO2T	manta trawl		2,614,194
27 May 2014	PO2P	pump	4,320,000	
28 May 2014	PO3T	manta trawl		1,847,610
28 May 2014	PO3P	pump	1,780,000	
30 May 2014	PO5T	manta trawl		1,929,293
30 May 2014	PO5P	pump	960,000	
02 June 2014	PO6T	manta trawl		1,767,776
02 June 2014	PO6P	pump	1,600,000	

Figure 13: Correlation between results given by manta trawl method and manta-pump method on the river Po



5.1.2 Mesolitter (Small Particles)

In total 9,412 small particles of size from 5.1 mm to 52.7 mm were counted in all rivers combined. The greatest number of small particles was collected in the Danube River

(8,130 particles). In the Po and Rhine Rivers (2nd and 3rd sampling) the number of small particles found in total were between 292 (Rhine 3rd sampling) and 571 (Po) (Table 7). In the river Dalålven only 4 small particles were found in the sample.

45 % of all collected particles were caught with a surface net, and 55 % of particles were caught with the suspension net of the WFW sampler. All particles weighed in total 1025.67 grams. The average weight of all the analyzed small particles is around 9 gr per particle.

Small particles were analyzed from 5 sampling days from the Po River, 6 days from the Danube River, 7 days from the Rhine, the 2nd sampling and 10 days from the Rhine, the 3rd sampling.

The river where only one sample was collected with WFW nets was the Dalålven. The net was "just laying" in the water for 6 days and no data on sieved water quantity was known, so we do not have daily data for this river or data normalized per km^2.

The average number of small particles collected per day with two different nets (surface and suspension) showed that the biggest number of items per day was collected in the River Danube. More than 1350 small particles were collected in one sample per day. This changes if we look at the average weight (g) of collected small particles per day. Second sampling in the River Rhine gave an average per sampling day of 69.03 g of small particles, which is the highest number of all the rivers.

More than 74,400 small particles were shown to be floating per km2 in an average sample in the River Danube, as suggested by data collected with the WFW surface net (

Table 8,

Figure 14, Figure 15). This number is almost ten times higher than found in rivers Po and Rhine.

The results of small particles caught by the suspension net (Figure 16, Figure 17) show that the most particles were collected in the Danube River ($0.24/m^3$), followed by the Po River ($0.03/m^3$) with the fewest in the Rhine (2^{nd} sampling) ($0.008/m^3$) and the 3^{rd} sampling ($0.002/m^3$) (

Table 8).

Table 7: Absolute number and weight (g) of small particles (> 5 mm) collected per river

	Overall	
	No. of Particles	Weight (g)
DALÅLVEN	4	0.0076
PO	571	50.8
DANUBE	8130	413.2

RHINE 2	415	483.2
RHINE 3	292	75.5

Table 8: Number and weight (g) of small particles (> 5 mm) normalized per km² collected with surface net, and normalized per m³ for small particles collected with suspension net

	SURFACE				SUSPENSION			
	Nr / km²		g / km²		Nr / m³		g / m³	
	Average	STDEV	Average	STDEV	Average	STDEV	Average	STDEV
DALÅLVEN	-	-	-	-	-	-	-	-
PO	6464.8	2584.93	752.2	510.1	0.0309	0.0089	0.0025	0.0028
DANUBE	74464.2	150731.69	7553.6	12299.4	0.2400	0.2668	0.0053	0.0077
RHINE 2	9874.5	11904.88	15859.2	39925.1	0.0077	0.0062	0.0002	0.0004
RHINE 3	8375.4	7938.63	1542.3	1648.7	0.0020	0.0018	0.0008	0.0023

Figure 14: Average number of small particles (> 5 mm) per km² collected with surface net

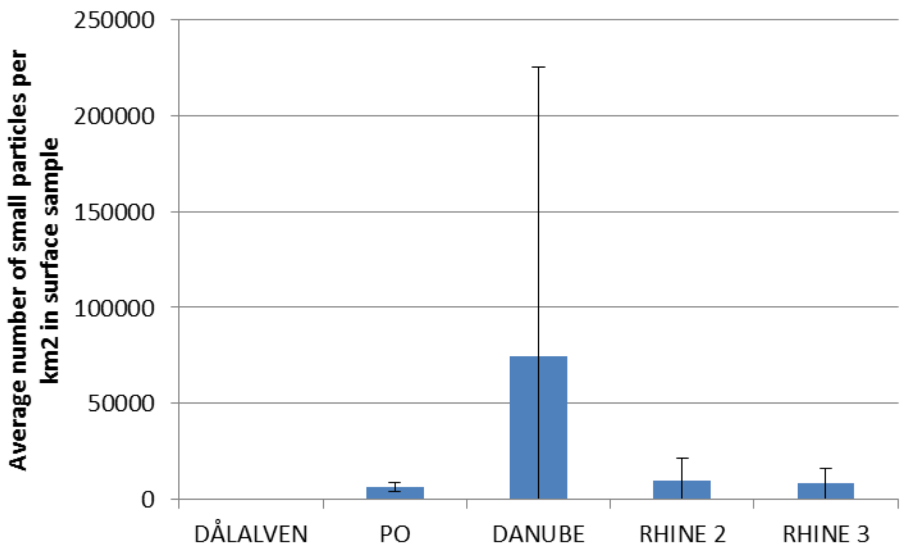


Figure 15: Average mass of small particles (> 5 mm) per km^2 collected with surface net

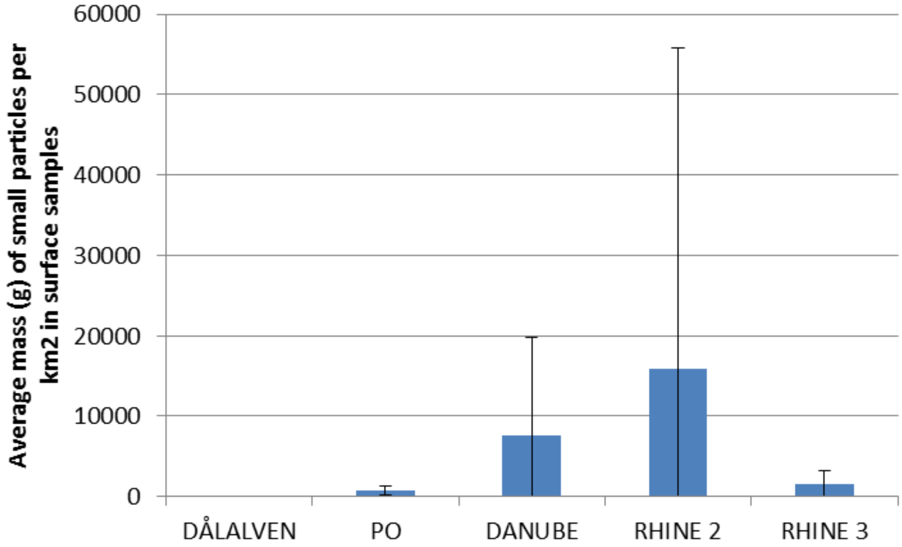


Figure 16: Average number of small particles (> 5 mm) per m^3 collected with suspension net

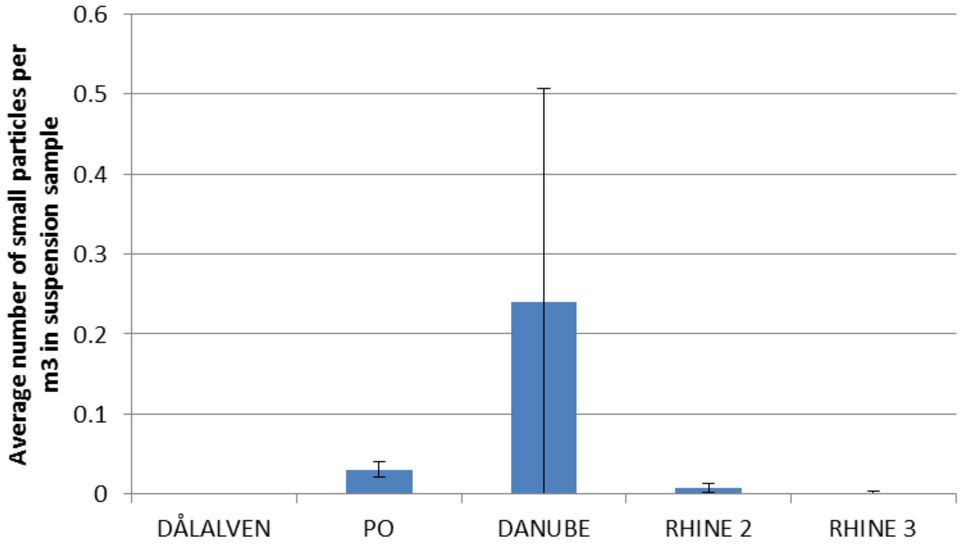
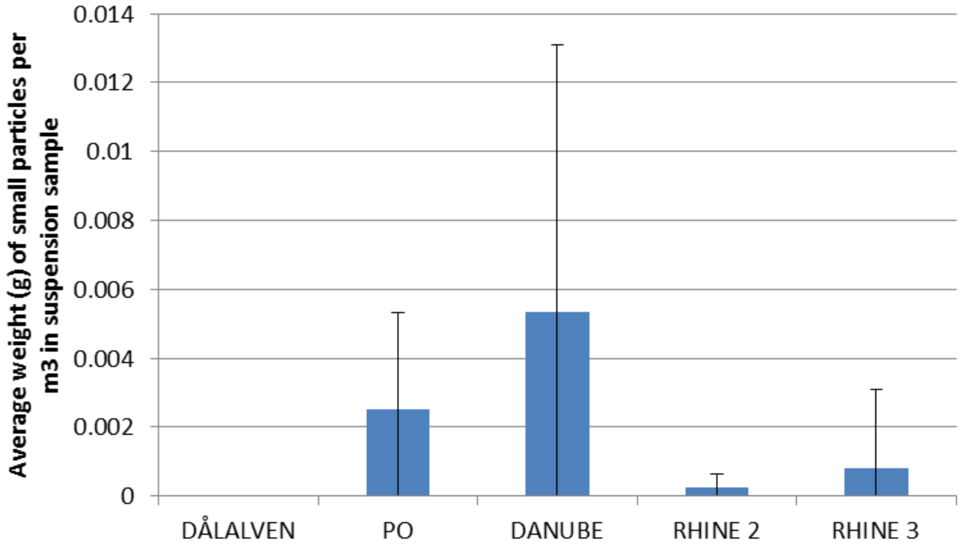


Figure 17: Average mass of small particles (> 5 mm) per m^3 collected with suspension net



5.1.2.1 Surface Net - Daily Changes in Quantity

In the Danube River, the number of small particles per km^2 in an average sample collected with the WFW surface net rose from day 1 (4,386 particles) to day 6 (SD ± 150,732) with a maximum on the 6th day (381,769 particles) (Figure A3.33).

On the Po River the differences in particle numbers per km^2 were much lower (SD ± 2,585) and there was no trend observed. The maximum number of particles per km^2 was 9,515 and the minimum was 3,591 (Figure A3.33).

Results of the Rhine River (2nd sampling) show a large number of collected particles per km^2 on the 8th day of sampling. The number is 7 times greater than on the other sampling days (Figure A3.33) and for this reason the SD is high (SD ± 11905).

Similar conclusions can be drawn from the average mass (g) of small particles collected with the WFW surface net (Figure A3.34) as for the numbers of small particles per km^2. The high mass of the 8th sampling day of the Rhine (2nd sampling) goes off the graph, because of one glass bottle, which was caught on the surface on the 7th of August.

5.1.2.2 Suspension Net - Daily Changes in Quantity

In line with the findings relating to the surface net, for the suspension net the maximum particles per m^3 were found in the Danube River. The results of the Danube suspension net sampling are dominated by the result of the last sampling day, the 6th day, where 0.77 particles per m^3 were caught. There was a big difference in particle numbers per m^3 between the 1st day and the other sampling days. On the first day just 0.02 particles per m^3 were measured. The standard deviation among sampling days was 0.27 (Figure A3.35).

The results of particle numbers per m^3 for the Po River show a small declining trend with a maximum value on the 1st sampling day (0.04 particles per m^3). The lowest value was measured on the 3rd sampling day (0.02 particles per m^3). The differences in particle numbers per m^3 between sampling days was small (SD ± 0.01) (Figure A3.35).

Of all the rivers, the particle numbers per m^3 were lowest on the Rhine (for both the 2nd and 3rd samplings), with minimal variations in particle numbers per m^3 (2nd sampling, SD ± 0.01; 3rd sampling, SD ± 0.002) (Figure A3.35). Comparison between the 2nd and 3rd samplings on the Rhine River in terms of particle numbers, shows higher numbers in the 2nd sampling.

The results of particle mass per m^3 show a different trend than for particle numbers per m^3. There are a few high weight scores for each river, except the 2nd Rhine sampling. On the Danube river two high weight scores were present, where on the Po and 3rd Rhine sampling one high weight score is present. For this reason also the standard deviations for these three rivers is bigger (Danube: SD ± 0.01; Po: SD ± 0.003; Rhine, 2nd: SD ± 0.0004; Rhine, 3rd: SD ± 0.002) (Figure A3.36).

5.2 Overall Types of Plastic

5.2.1 Microplastics (< 5 mm)

Among four categories (fragments, pellets, foams and fibres) that were used for microparticles categorization, fragments were the most abundant category in the Po and Rhine (2nd and 3rd sampling) rivers and fibres were the most abundant in the Danube and Dalålven rivers. In the Dalålven River the number of fibres was 8.5 times lower than in the Danube River (Figure A3.50,Figure A3.53).

The highest mass by category was of pellets for the Po and Rhine rivers, foams for the Danube River and, fragments in the Dalålven River (Figure A3.50,Figure A3.53).

5.2.2 Small Particles (> 5 mm)

We noticed that in surface samples there were always more categories present than in suspension samples. The biggest difference between the number of categories in surface net and suspension net samples was seen in the River Rhine, second sampling, whereas 73 % of all categories found in Rhine 3rd sampling were missing from suspension net samples.

Categories G3, G10, G67 and G78 were present in all rivers, in surface and suspension samples. 22 categories (G7, G11, G12, G33, G34, G35, G43, G61, G71, G82, G90, G99, G100, G112, G149, G151, G152, G158, G159, G161, G178, G200) were present only in surface samples but not in suspension samples (39 %).

Only 5 categories (G5, G66, G87, G133 and G145) were seen only in suspension samples, but not in surface samples. Further information is presented in Table 9.

Table 9: Presence of categories in different types of samples (surface net (A), suspension net (B) for all rivers (Legend: yellow - artificial polymer material, blue - rubber, orange - cloth/textile, light green - paper/cardboard, dark green - processed/worked wood, grey - metal, light yellow - glass/ceramic, uncoloured – unidentified)

Po		Danube		TSG_ML General-Code	General Name	Rhine 1		Rhine 2	
A	B	A	B			A	B	A	B
✓	✓	✓	✓	G3	Shopping Bags incl. pieces	✓	✓	✓	✓
	✓			G5	Plastic bag collective role; what remains from rip-off plastic bags				
				G7	Drink bottles <=0.5l			✓	
✓	✓	✓	✓	G10	Food containers incl. fast food containers	✓	✓	✓	✓
				G11	Beach use related cosmetic bottles and containers, eg. Sunblocks	✓			
		✓		G12	Other cosmetics bottles & containers				
✓	✓	✓		G20	Plastic caps and lids			✓	
✓		✓		G21	Plastic caps/lids drinks	✓			
		✓		G24	Plastic rings from bottle caps/lids	✓		✓	
	✓	✓	✓	G25	Tobacco pouches / plastic cigarette box packaging	✓	✓		✓
		✓		G27	Cigarette butts and filters	✓	✓	✓	
		✓		G28	Pens and pen lids	✓		✓	
✓	✓	✓	✓	G30	Crisps packets/sweets wrappers	✓		✓	
✓		✓		G32	Toys and party poppers			✓	
				G33	Cups and cup lids	✓			
		✓		G34	Cutlery and trays				
				G35	Straws and stirrers	✓			
		✓	✓	G38	Cover / packaging	✓	✓	✓	
				G43	Tags (fishing and industry)			✓	
	✓	✓		G45	Mussels nets, Oyster nets				
	✓		✓	G50	String and cord (diameter less than 1cm)	✓	✓	✓	✓
✓	✓			G52	Nets and pieces of net				

Po		Danube		TSG_ML General-Code	General Name	Rhine 1		Rhine 2	
A	B	A	B			A	B	A	B
				G61	Other fishing related			✓	
	✓			G66	Strapping bands				
✓	✓	✓	✓	G67	Sheets, industrial packaging, plastic sheeting	✓	✓	✓	✓
		✓		G71	Shoes/sandals				
✓		✓	✓	G74	Foam packaging/insulation/polyurethane	✓	✓	✓	
✓	✓	✓	✓	G78	Plastic pieces 0 - 2.5 cm	✓	✓	✓	✓
✓	✓	✓	✓	G79	Plastic pieces 2.5 cm > < 50cm	✓	✓	✓	
✓		✓	✓	G81	Polystyrene pieces 0 - 2.5 cm	✓		✓	
✓		✓		G82	Polystyrene pieces 2.5 cm > < 50cm	✓		✓	
			✓	G83	Polystyrene pieces > 50 cm				
✓	✓			G87	Masking tape		✓		
		✓	✓	G89	Plastic construction waste	✓		✓	
✓		✓		G90	Plastic flower pots				
✓	✓	✓	✓	G95	Cotton bud sticks	✓			
		✓		G99	Syringes/needles	✓			
✓				G100	Medical/Pharmaceuticals containers/tubes				
✓		✓		G112	Inudstiral pellets				
✓	✓		✓	G124	Other plastic/polystyrene items (identifiable)			✓	✓
	✓			G125	Balloons and balloon sticks	✓		✓	
	✓			G131	Rubber bands (small, for kitchen/household/post use)	✓		✓	
			✓	G133	Condoms (incl. packaging)				
				G134	Other rubber pieces		✓	✓	
			✓	G142	Rope, string and nets			✓	
	✓		✓	G145	Other textiles (incl. rags)		✓		✓
				G149	Paper packaging			✓	
				G151	Cartons/Tetrapack (others)	✓			
		✓		G152	Cigarette packets			✓	

Po		Danube		TSG_ML General-Code	General Name	Rhine 1		Rhine 2	
A	B	A	B			A	B	A	B
✓			✓	G156	Paper fragments	✓	✓	✓	✓
				G158	Other paper items	✓			
		✓		G159	Corks			✓	
				G161	Processed timber	✓			
✓	✓			G177	Foil wrappers, aluminum foil	✓		✓	
		✓		G178	Bottle caps, lids & pull tabs				
		✓		G200	Bottles incl. pieces	✓			
✓	✓	✓	✓	G213	Paraffin/Wax			✓	
		✓		G216	various rubbish (worked wood, metal parts)				
22	21	32	20	SUM		30	14	31	9

The most common item found in nets from the second river Rhine sampling was shopping bags (G3). Also found were food containers including fast food containers (G10), other plastic/polystyrene items (identifiable) (G124), foil wrappers, aluminium foil (G177), cover/packaging (G38), cartons/tetrapack (others) (G151) and plastic flower pots (G90).

5.3 Overall Types of Litter

5.3.1 The Overall Types of Litter coming from each River

In all the rivers and in all the samples the majority of litter was of artificial polymer materials (plastic). Overall, plastic represented more than 97% of all small particles (> 5 mm) by number. In Figure 18 and Table 10 shares by material composition are shown for small particles.

The number of categories present varies between rivers. The most diverse samples were collected in the Danube (38 different categories), and the most homogenous in the River Dalålven (only one category of litter). In the River Po, 30 different categories of litter were found and in the River Rhine 33 on both sampling occasions. Surface samples are more diverse than suspension samples.

Figure 18: Overall types of litter for each river (a – Po; b – Danube; c – Rhine 2nd sampling; d – Rhine 3rd sampling; e – Dålalven) in percentage according to small particles number collected with surface and suspension net combined

Legend

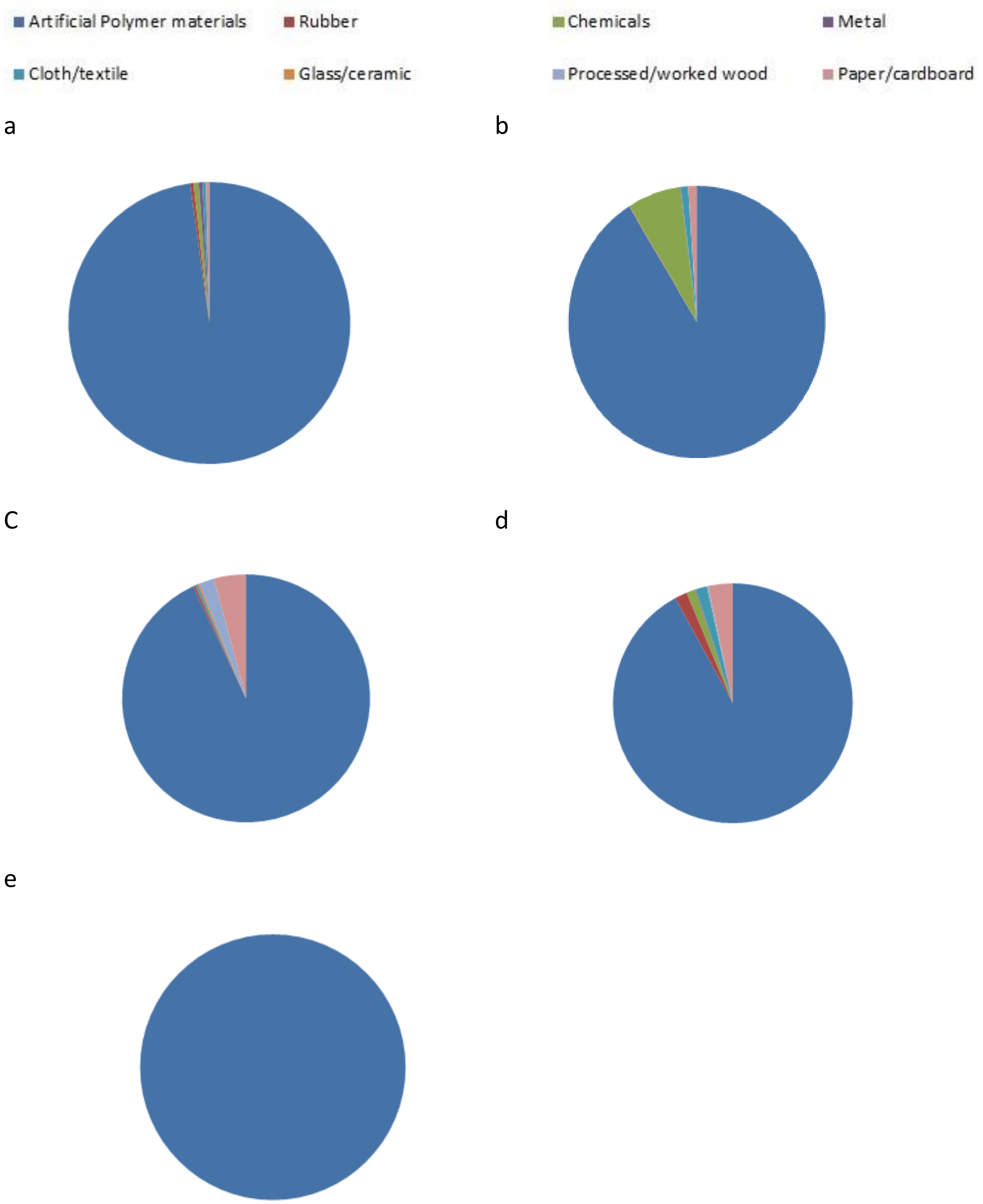


Table 10: Percentage of material composition for each river according to small particles number collected with surface and suspension net combined

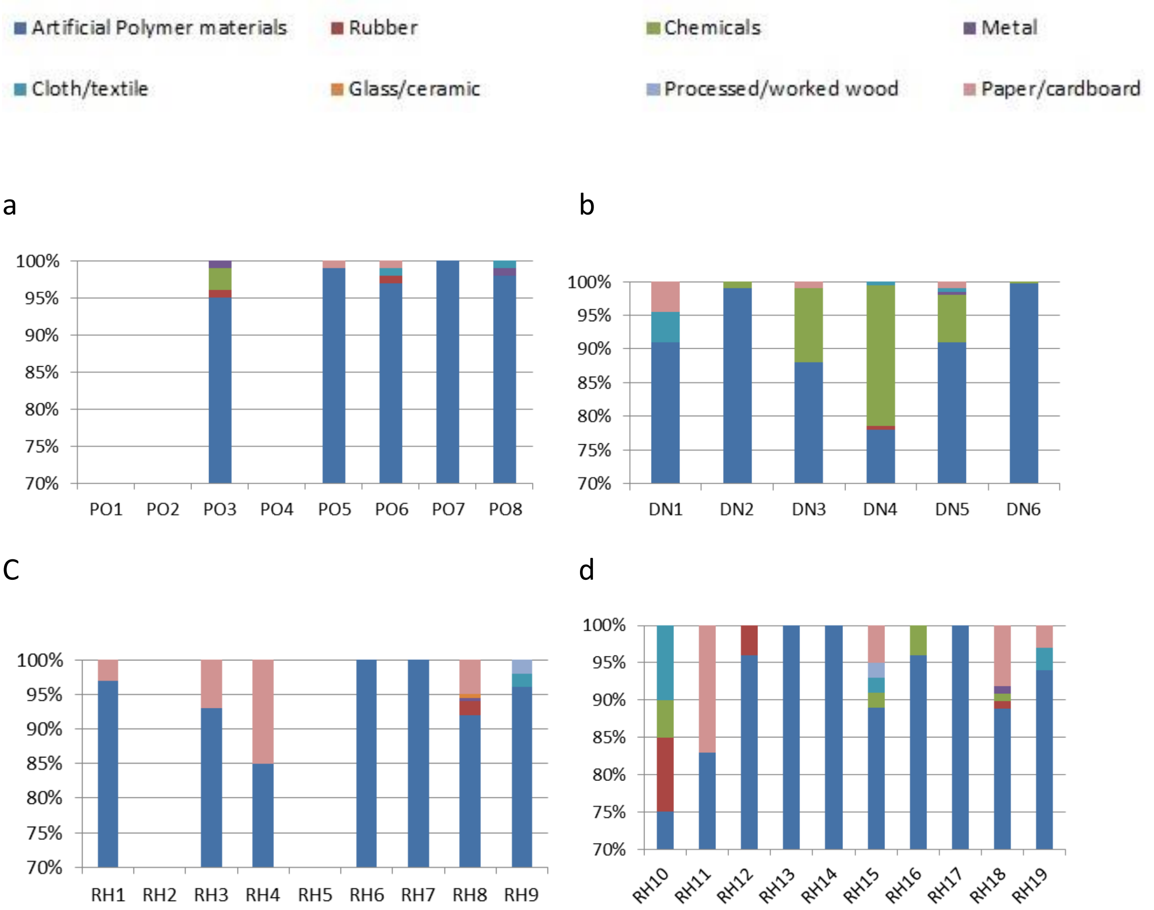
	Artificial Polymer materials	Rubber	Chemicals	Metal	Cloth/ Textiles	Glass/ ceramic	Processed/ worked wood	Paper/ cardboard
Po	97.8	0.4	0.6	0.4	0.4	0.0	0.0	0.4
Danube	91.1	0.1	6.7	0.1	0.9	0.0	0.0	1.1
Rhine 2	94.7	0.3	0.0	0.1	0.3	0.3	2.0	4.3
Rhine 3	92.1	1.7	1.2	0.1	1.5	0.0	0.2	3.3
Dalålven	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

5.3.2 Day to Day Variations in the Types of Litter

From Figure 19 we can see that artificial polymer materials (plastics) represent the majority of all samples in all rivers. The lowest share of polymer material is seen in the first sampling day of the River Rhine 3rd sampling. The highest proportions of polymer material are seen in the River Po, where they represent more than 95% of all small particle items collected with WFW surface and suspension net combined. Other materials found in rivers include rubber (with the biggest share in Rhine 3 samples), chemicals (with the biggest share in the Danube river), metal (Po river), cloth/textile (Rhine 3), glass and ceramics, processed and worked wood and paper and cardboard (Figure 19).

Figure 19: Composition of litter changing from day to day in each river (Dalålven excluded) (a – Po, b – Danube; c – Rhine 2nd sampling; d – Rhine 3rd sampling)

Legend



5.4 Persistent Organic Pollutants

In total 27 pellets, with a total mass of 0.7 g, were collected from the River Meuse in the Netherlands, in order to assess the amount of adsorbed persistent organic pollutants. 52% of all pellets were identified as Polyethylene (PE) and 48 % were identified as Polypropylene (PP) by Near Infra Red (NIR) spectrometry Two main contaminants were identified; di(ethyl)phthalate and isopropyl myristate 2.5.

Since only a limited amount of samples could be taken for chemical analysis in this project, results are difficult to interpret. From a recent study in the Dutch surface waters however, it was estimated that chemical additives (i.e. dibutylftalaat and Bisfenol A) that leach from freshwater plastics waters can reach concentrations of hundreds of kilograms per year for the whole of the Netherlands (Langelaan et al., 2015)[14]. Therefore, it does seem that the chemicals leaching out of plastic fragments in the freshwater environment can contribute to the additional pollution of these systems. This requires further research.

5.5 Estimating River Load and Prelevance

The monitoring data based on the concentration per volume-unit (numbers or weight per m^3) was used to estimate the overall transport of plastic litter in the rivers. This deviates from the monitoring of plastic litter in seas where the concentration per square kilometre is a more common unit to express floating litter. In a sea, litter floats around in deeper water and in a river the plastic litter is transported in the relative shallow riverbed, especially during floods. At sea part of the suspended litter will ultimately sink to the bottom of the seafloor, with marine sediments as a sink (Leslie et al., 2013)[15], but in a river suspended particles will constantly remain in suspension due to the turbulent nature and high velocities of the flow.

The averaged data on amounts of plastic litter was multiplied by the average river discharge during the monitoring period for each of the four rivers. In the Dalålven and the Rhine the discharge measured during sampling was close to the annual average discharge. In the Po the discharge reduced during the monitoring period after a small flood. Also the monitoring in the Danube, or more precisely the discharge from the Siret River was after a local flood.

The width of the river was measured locally near the monitoring site or measured from aerial photographs. The difference between the bottom of a river and the water level was taken as the depth. The trapezoidal cross section of a river is the difference between the water level and the bottom multiplied by the depth averaged width. Only in the Dalålven a rectangular cross section was a better approximation of the cross section of the river near the monitoring site. The average discharge is the cross-sectional area multiplied by the average current velocity. The hydraulic parameters are shown in Table 11.

In sampling locations with a dominant tidal action the samples were taken during the ebb phase only. In all locations fresh water or a mixture of fresh and salt water was present during the monitoring periods without the complex phenomena of a salt wedge at the bottom and fresh water layer flowing at the surface.

The flow was fully turbulent in all monitored rivers. Laminar flow does not occur in alluvial rivers. For example in canals with a smooth concrete lining a laminar sublayer exists with about a millimeter thickness. In practise its influence is often neglected.

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[14] Langelaan et al, 2015, Microplastics in Nederlands zoete wateren

[15] Leslie, van Velzen and Vethaak, 2013, Microplastic survey of the Dutch environment

Table 11: Characteristics of the riverine input of plastic litter to the local seas

	Surface Sampling				Suspension Sampling		Hydraulic Parameters						
	Manta Net		WFW	WFW	WFW	WFW							
	concentration	weight	concentration	weight	concentration	weight	current velocity	width	water level	depth	cross sectional area	sampling discharge	average discharge
	nr/m³	g/m³	nr/m³	g/m³	nr/m³	g/m³	m/s	m	m	m	m²	m³/s	m³/s
Dalalven	4.54						0.3	91	0	20	1820	546	380
Rhine 2	4.92		0.05	0.079	0.008	0.00024	0.44	410	0.2	15.2	5500	2420	1700
Rhine 3	1.85		0.042	0.0077	0.002	0.0008	0.43	410	0.2	15.2	5500	2365	1700
Po	14.6		0.032	0.0038	0.031	0.0025	1.17	530	0	2.3	1250	1462.5	1470
Danube	10.6		0.372	0.038	0.24	0.0053	0.42	1070	0	6.7	7200	3024	6500

The estimates of marine input are shown in Table 12.

Table 12: Estimates of the Marine Input

	Marine Input					
	WFW Sampler **)				Manta net *)	
	total				total	
	nr/s	g/s	tonnes/year	nr/year	nr/s	nr/year
Dalalven					1725.2	5.44E+10
Rhine 2	19.8	1.29	20.4	3.12E+08	8364	2.64E+11
Rhine 3	5.1	1.96	30.9	8.04E+07	3145	9.92E+10
Po	46.3	3.77	119.0	7.31E+08	21462	6.77E+11
Danube	734.1	16.88	532.4	1.16E+10	68900	2.17E+12

These estimates of marine input are based on the following formulas.

***) Manta-net (mostly) microplastics < 5 mm:**

In a non-tidal river:

Transported number of plastic litter particles as sampled in a Manta-net per year [nr/year] =

> concentration of particles caught in a Manta-net [nr/m^3] * average discharge [m^3/s] *discharge ratio [-] * 3600 * 24 *365

in which:

average discharge = discharge at the sampling location during the monitoring period [m^3/s],

discharge ratio = yearly average discharge devided by the discharge during the monitoring period [-]

In the formula it is assumed that the concentration of caught particles in the Manta-net is representative for the concentration in the river cross section. The flow with a high turbulence intensity in the river causes a complete mixing of the suspended plastic litter particles in a cross section and therefore a rather constant concentration of these particles.

Further a discharge ratio as defined in this report is based on the assumption of a linear relationship between the discharge and the concentration of litter. During floods this relationship is exponential, but the deviations from the linear relationship are acceptable close to a discharge ratio of 1. It means that these formulas are recommended if this averaged flow velocity during the monitoring period is close to the yearly average flow velocity. The discharge ratio varied between 0.7 and 2 in the monitoring campaigns see Table 10 last two columns.

In a tidal river:

Transported number of plastic litter particles as sampled in a Manta-net per year [nr/year]=

> concentration of particles caught in a Manta-net [nr/m^3] * yearly average discharge [m^3/s] * 3600 * 24 *365 / 2[16]

****) WFW-sampler (small particles > 5 mm):**

With the WFW sampler a combination of floating and suspended plastic litter can be made:

The yearly transport in a riverine **surface** layer with a depth of 0.05 m is equal to:

> Concentration in surface net [nr/m^3] * Width river [m] * depth [0.05m] * Average flow velocity during monitoring period [m/s] *. Flow velocity ratio [-]* 3600 * 24 * 365 [seconds/year] =.

In which the flow velocity ratio = the average flow velocity during the monitoring period divided by the yearly average flow velocity [-]. It is assumed that the average flow velocity is the cross-section averaged flow velocity. And it is assumed that the litter concentration in the surface layer is constant over the width and the depth of this layer. The layer thickness of 0.05 m is a fair estimate based on visual observations. Further a flow velocity ratio as defined in this report is based on the assumption of a linear relationship between the flow velocity and the concentration litter. During floods this relationship is exponential, but the deviations from the linear relationship are acceptable close to a flow velocity ratio of 1. It means that these formulas are recommended if the the averga flow velocity during the monitoring period is close to the yearly average flow velocity.

The yearly transport in the riverine **watercolumn** can be calculated as:

> Concentration in suspension net [nr/m^3] * yearly average discharge [m^3/s] * 3600 * 24* 365 [seconds/year]

The total annual riverine transport is **the sum of both values**. The transport of plastic litter near the river bed is neglected because of the absence of data and measurements of that transport.

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[16] This ‘2’ is because of the fact that this is a tidal river, meaning that only half the time the tide is pushing litter out into the marine environment.

For an estimate of the transported weight the same formulas are used, but the grammes-values are used instead of the numbers.

In case of a tidal river, it is assumed that the annual transport is based on half the amounts of caught litter in the samplers (the sample are only taken in the outgoing tide).

The data in table 11 concerning the riverine input are assessed from a very limited amount of monitoring data. For a better assessment of the yearly riverine input from rivers into the seas more monitoring data is a necessity and a better understanding of the transport fenomena with regard to the behaviour of different sizes, shapes and materials of litter in turbulent riverine conditions.

5.6 Identification of Plastic Type and Production

5.6.1 Microparticles

Comparison of the content of plastic materials among rivers for all plastic categories together shows that polyethylene (PE) is the most prevalant material in all rivers. In the Danube River the second most prevalent material is polystyrene (PS) and the third Nylon-PA. In the Po River the second most prevalent material is polypropylene (PP) and the third polyurethane (PU). The first and second samplings on the River Rhine have the same content of plastic material, which show that the second most populated material is PP and the third is PS. In the Dalålven River almost 40% of particles were not identified as plastic material. The most prevalent material PE is followed by Nylon-PA and PS (Figure 20 to Figure 24).

Figure 20: Content of Plastic Material in Danube River

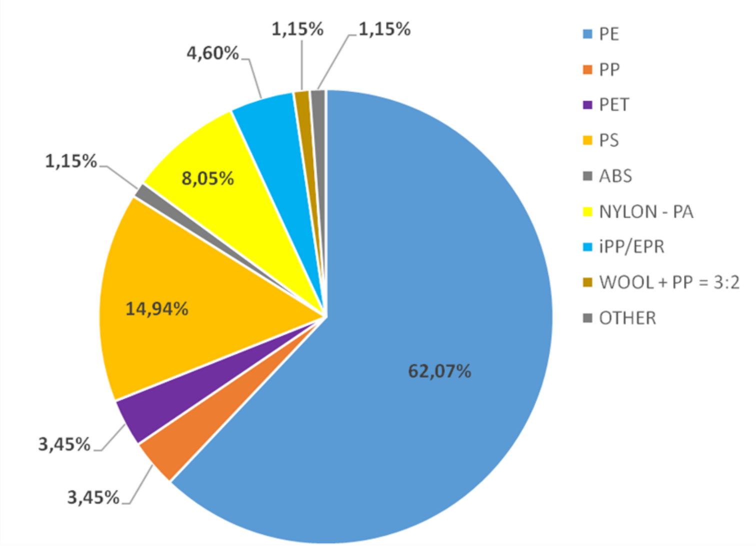


Figure 21: Content of Plastic Material in Po River

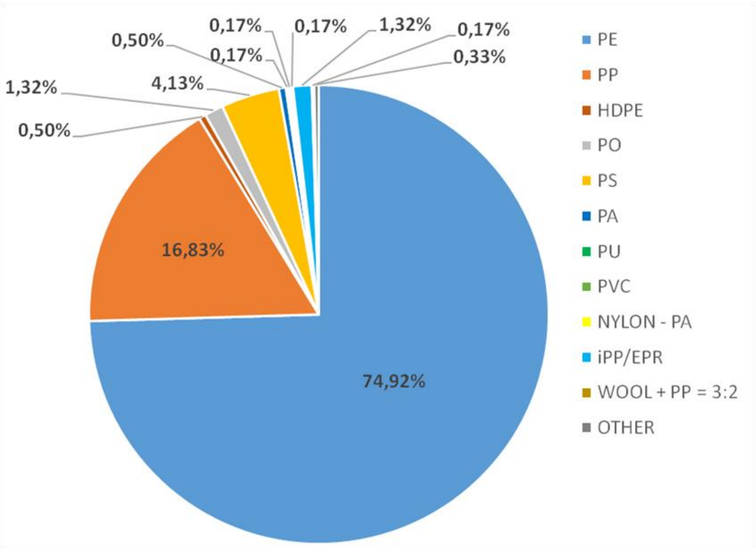


Figure 22: Content of Plastic Material in Rhine River, the 2nd sampling

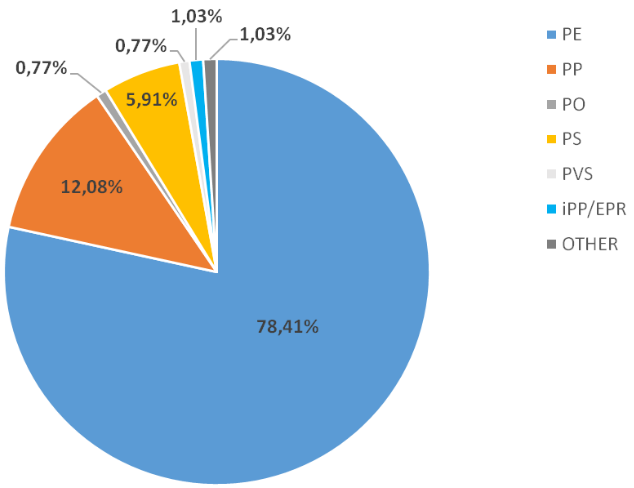


Figure 23: Content of plastic material in Rhine River, the 3rd sampling

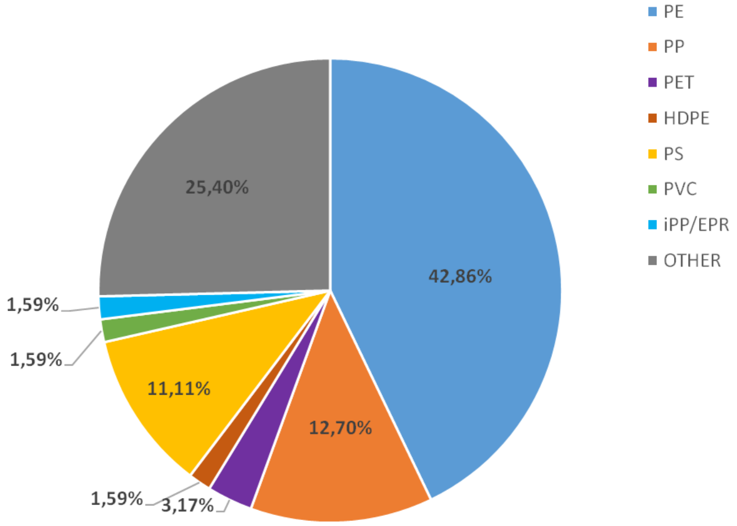
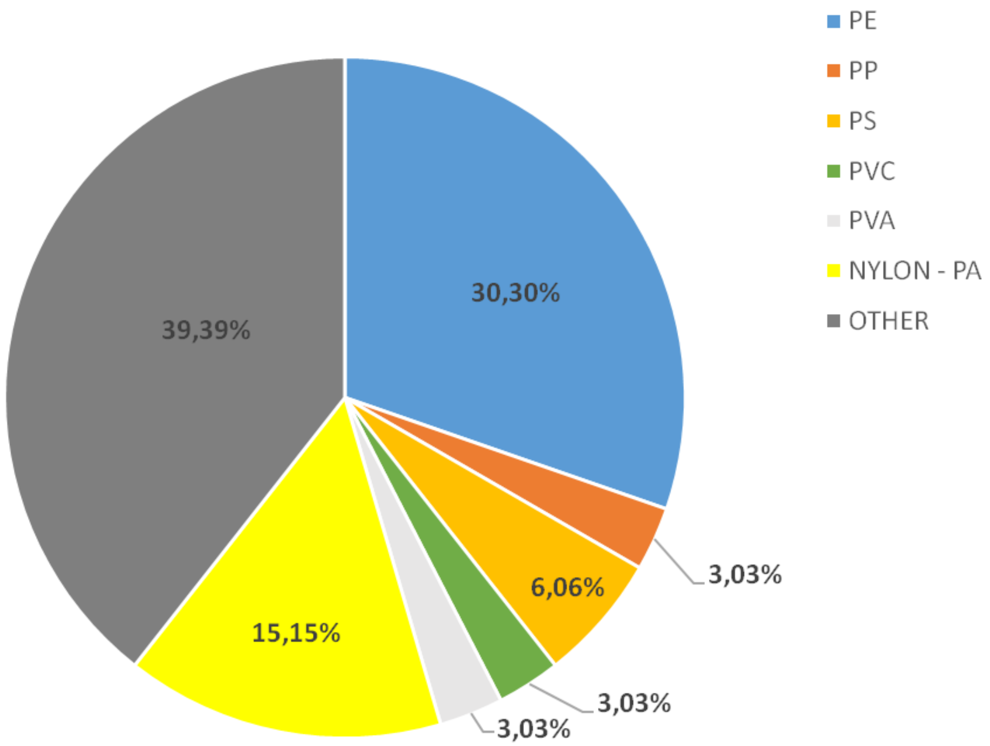


Figure 24: Content of plastic material in Dalålven River

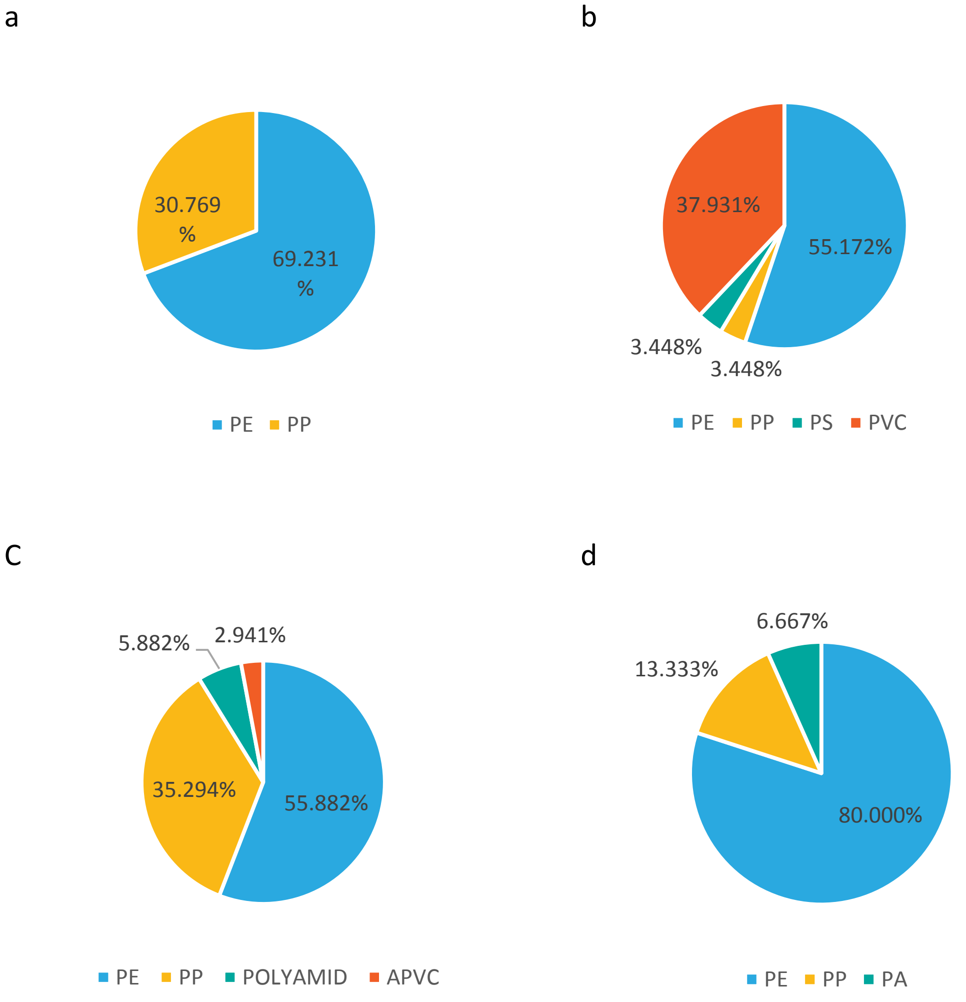


5.6.2 Small Particles (> 5 mm)

WFW Surface

Chemical analysis of 8.39 % of all particles sampled by the WFW surface net was performed. Results show that the most common material in the rivers Po, Danube, Rhine 2 (2nd sampling, August 2014) and Rhine 3 (3rd sampling, September 2014) is polyethylene (PE) and the second is polypropylene (PP). In the Danube River, polystyrene (PS) and polyvinyl chloride (PVC) were also present. In the Rhine River, polyamid (PA) was also found (Figure 27).

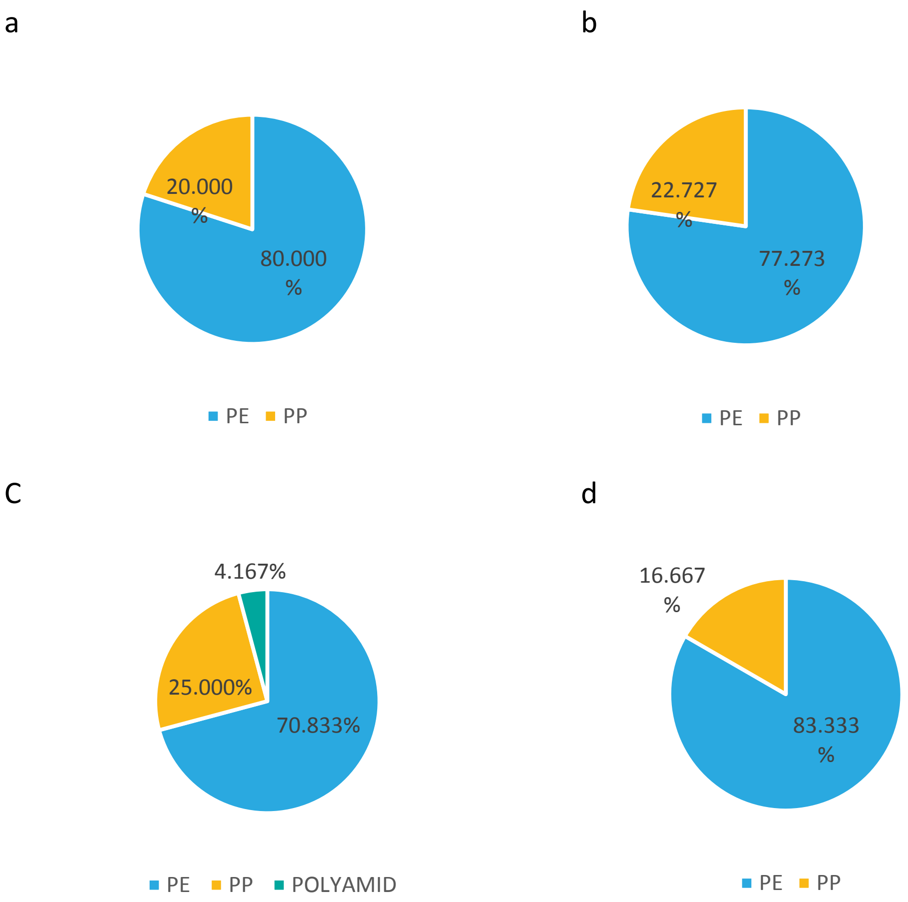
Figure 25: Chemical composition of small particles for each river collected with WFW surface net (a – Po; b – Danube; c – Rhine 2; d – Rhine 3)



WFW Suspension

Chemical analysis was performed on 22.8 % of all particles sampled by the WFW suspension net. Results of the chemical analysis of particles sampled by the WFW suspension net are very similar to the results of the chemical analysis of particles sampled with the WFW surface net. In all three rivers the most prevalent material is polyethylene (PE) and the second is polypropylene (PP). In the Rhine River polyamid was also found (Figure 26).

Figure 26: Chemical composition of small particles for each river collected with WFW suspension net (a – Po; b – Danube; c – Rhine 2; d – Rhine 3)



5.7 Likely Sources of the Litter

The analysis of likely sources of small litter in rivers was undertaken on 4197 small particles collected with the WFW nets (45% of all the small particles that were collected in total). In our analysis we attributed one quarter of small particles to industrial packaging, based on it's appearance ("thick" film). Urban sources likely represented 5% of small particles (including wastewater sources). For the majority of litter we were not able to indicate likely sources (66%) (Figure 27, Table 13).

Figure 27: Composition of Litter by Source (from analysis of small particles)

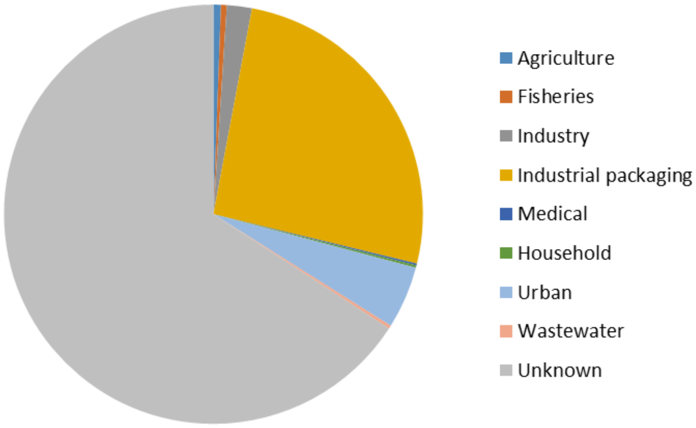


Table 13: Percentage of small particles coming from different likely sources for each river

% of small particles	Agriculture	Fisheries	Industry	Industrial packaging	Medical	Household	Urban	Wastewater	Unknown
DÅLALVEN									100
Po surface	8,2	8,2	8,7	32,8	1,1	2,2	5,5	2,7	30,6
Po suspension	0,7	0,7	0,5	50,0	0,0	0,2	14,5	0,5	32,8
Po overall	3,1	3,1	3,1	44,7	0,3	0,8	11,7	1,2	32,1
Danube surface	0,0	0,0	0,5	6,6	0,2	0,0	2,8	0,2	89,6
Danube suspension	0,3	0,0	0,0	19,4	0,0	0,1	0,8	0,0	79,3
Danube overall	0,2	0,0	0,1	15,6	0,1	0,1	1,4	0,1	82,4
Rhine 2 surface	0,0	0,0	9,1	60,6	0,3	0,0	16,5	0,3	13,1
Rhine 2 suspension	0,0	0,0	0,9	77,4	0,0	0,0	13,9	0,0	7,8
Rhine 2 overall	0,0	0,0	6,8	65,3	0,2	0,0	15,8	0,2	11,7
Rhine 3 surface	0,0	0,4	12,0	31,9	0,4	0,0	8,8	0,0	46,6
Rhine 3 susupension	0,0	0,0	2,5	50,0	0,0	0,0	10,0	0,0	37,5
Rhine 3 overall	0,0	0,3	10,7	34,4	0,3	0,0	8,9	0,0	45,4

The main likely litter sources in the sampled rivers are:

- Rhine River: industrial packaging and industry, urban areas, fisheries, household, medical waste, wastewater treatment, agriculture
- Dalålven River: unknown
- Po River: industrial packaging and industry, urban areas, household, agriculture, fisheries, household, medical waste, wastewater treatment
- Danube River: industrial packaging and industry, urban areas, household, agriculture, household, medical waste, wastewater treatment treatment

6.0 Interpretation of Analytical Results

6.1 Results from the analysis: amounts of microplastic litter found

Results of the analysis offer a view on microplastics (< 5 mm – >300 µm) in four European rivers. The first observation from these results is that all rivers are carriers of microplastics and for this reason also a source of microplastic in the seas and oceans. Among the selected rivers the most burdened river is the Po River, with an estimated prevalence of 6 million particles per km². The Po River is followed by the Danube and Rhine rivers, with an estimated prevalence of more than 3 million particles per km². In the Dalålven River, the sampling was done with the pump, and for this reason the results cannot be directly compared with the results of the other rivers. In the Dalålven River, 38 micro particles per m³ were found in three sampling days.

Among microplastic categories, the number of fragments is the largest (45 % of all founded particles). Fragments are the most prevalent particles in the Po and Rhine River, while in the Danube and Dalålven River, fibres are the largest group of particles. If foam particles, which in fact also represent the fragments, are added to the number of fragments this class is even more important totaling 59 % of all particles collected. Fragments and foam particles are, in the most cases, the result of fragmentation of larger plastic items (secondary source of origin). The results of the Dalålven River don't show any foam particles. The reason for such a result could be the method of sampling. When samples were collected with the submersed pump in the Dalålven, the light particles which usually float on the surface water could not go through the pump (like foam particles) and for this reason were not included into the analysis.

One interesting question is why in the Danube and Dalålven Rivers the most common particles are fibres and not fragments. Fibres have also been found in all samples. The number of fibres obtained across the rivers differs significantly with the Danube having by far the highest numbers (1086) followed by Po (530) and Rhine (51). Characterization of fibres is difficult due to their high aspect ratio although identifying them is less problematic (due to their length and often colour). Fibres are mainly derived from textiles either during industrial production/use or in domestic use. Fibres are most likely emitted through wastewater treatment and possibly also atmospheric deposition. Above the sampling site on the Danube, there are two wastewater treatment plants. The first is in Galati[17], between the sampling site and Siret River afflux, and the second is in the city Braila[18]. Our results of the Danube (large numbers of fibres) indicate the proximity of the outlet from the wastewater treatment plant near the sample collection location.

[17] http://discutii.mfinante.ro/static/10/Mfp/asistenta_preaderare/FM_Galati_apa/FM_Galati_apa.pdf

[18] http://prtr.ec.europa.eu/FacilityDetails.aspx?FacilityId=193154

However, synthetic fibres from synthetic clothing can also directly be released to the air and via atmospheric deposition enter the aquatic environment. Water treatment facilities, however, play a major role in their elimination before entering waterways. It is estimated that about 90% of the fibres is removed by WWTPs (Leslie et al., 2012)[19]. Nonetheless, this can be a relatively significant source as washing water efluents may contain several million fibres per laundry, etc…(A.D. Vethaak, press communication)[20]. Reports of plastic fibres found in sludges from water treatment plants can be found in the literature. The low population density in the Dalålven basin might mean that some households discharge their waste water after a very limited treatment into the river. Another possibility is that this result is an effect of the difference in sampling method. The absolute number of fibres is very low. So it is likely that the results obtained give an indication of the quality of water emissions treatment before entering the river, combined with a significant burden in wastewaters.

Pellets also show an interesting picture. By far the highest number was found in the Rhine (1st sampling) (584) followed by Po (297), Rhine 2nd sampling (107) and again only 9 in the Danube. The pellets classification includes larger pellets (>1 mm diameter) and small pellets (<1 mm diameter). The number of small pellets was very substantial. All types are perfectly round, so we believe they were manufactured as such and are not the result of fragmentation (i.e. a primary source of origin). Polyethylene (PE) microbeads are likely to derive from cosmetics or perhaps industrial mild abrasives. Polystyrene (PS) pellets on the other hand can be derived from PS raw materials after polymerization or for production of foamed PS (Expanded Polystyrene - EPS). Polystyrene beads are also used in ion-exchangers and in biochemistry as substrates. Based on all these potential sources pellets can be derived from population (cosmetics) or industry. In both cases where pellets were found in the highest numbers (Rhine and Po) it is likely that the result is a combination of both.

Between the 1st and 2nd samplings in the Rhine differences were measured in the number and mass of particles, but trends were similar. For both samplings, fragments were the most common category followed by pellets.

6.2 Results from the Analysis: Types of Plastics Found

Analysis of microplastics by material type was performed for 16 % of all particles, the Near-infrared spectroscopy and by the FTIR-ATR spectroscopy. From all the particles analyzed only a few particles among the fibres were found to be non-plastic (polysaccharides e.g. cellulose or protein). This confirms that the isolated particles were almost completely plastic. The analysis of plastic material of particles showed that the most common materials are plastic materials from the category of polyolefin

[19] Pilot study of the VU in cooperation with TU-Delft and Deltares

[20] STOWA, 2013, Microplastics in het zoetwatermilieu

(polyethylene - PE, polypropylene - PP and copolymer of PE and PP), with polyethylene being the most common.

This result could be expected. Polyethylene is the most commonly used plastic polymer in the world because it is strong, light, tough, resistant to acids, alkalis and other organic solvents and resistant to higher temperatures. It is an essential material for power transmission, food packaging, consumer goods, electronics, household goods, industrial storage, and transportation industries. The second reason for this result is the fact that polyethylene and polypropylene have very low densities and will thus float on water and be highly mobile. We believe that the combination of large quantities and the mobility due to floating leads to the observed situation. An exception to this situation is found in the class of foams, where expanded polystyrene (EPS) is the predominant type, followed by polyurethane (PU). All other materials are very seldom found and may be considered an exception.

Results of the analysis of small particles offer a view on litter composition, quantities and distribution in four different regions in Europe. From our results we can see that the TSG ML Master List that was prepared from different lists of marine litter items observed in all Europe is not really useful for riverine litter analysis. TSG ML set guidance and recommendations on lower sizes for beach and floating litter observations which were used for setting up the Master List. When analysing floating litter no items smaller than 2.5 cm should be recorded. TSG ML also recommends to record items larger than 2.5 cm on beaches. According to this, the Master List has been set where the majority of items is either bigger than 2.5 cm or smaller than 0.5 cm (for microplastics analysis). Items, collected in rivers are smaller than those collected in the marine environment (beaches), which were the basis for the TSG Master list. It is also therefore difficult to link the small riverine particles to sources because of their small size and unrecognizable characteristics without information on their chemical composition. As seen, only about 27% of all categories in the Master List were seen in all rivers across Europe.

All rivers showed plastic items to make up more than 91% of all items in a sample by number of particles, which is a very clear indication that plastic is a worse pollutant in the riverine environment than in the marine environment in relative terms. It might also be connected with the fact that other materials in rivers could be found on the bottom or on the river banks. This was not analysed within this project however.

6.3 Results from the Analysis: Possible Sources

What we have found from the analysis of items is that it was very difficult to assess the source of litter items from their appearance. This is especially the case for heavier (thicker walled) sheeting materials, which we attributed to “industrial packaging”, which were extremely common in the Danube River. Other literature on riverine litter mentions the industrial sector as main source of litter items in rivers and we could agree with those observations.

An interesting observation was also made on the difference between surface and suspension samples in respect of the number of different categories seen. The reason for this difference could lie in the shape, size, and material of items that are found in surface but not in suspension samples and vice versa. A plausible explanation would be the difference in the surface to volume ratio, keeping the "flatter" particles easier suspended in the watercolumn and the more buoyant compact particles at the surface.

Main suspected litter sources in the sampled rivers are:

- Rhine River: industrial packaging and industry, urban areas, fisheries, household, medical waste, wastewater treatment, agriculture
- Dalålven River: unknown
- Po River: industrial packaging and industry, urban areas, household, agriculture, fisheries, household, medical waste, wastewater treatment
- Danube River: industrial packaging and industry, urban areas, household, agriculture, household, medical waste, wastewater treatment treatment

The results gave the first perspective on regional differences and smiliarties in riverine litter composition. It appears that the main suspected litter sources for these four rivers are quite similar, even if for the Dalålven river suspected sources could not be determined. The results also showed that the plastic litter in different rivers has only minor differences in concentration and type. It is a step in the process of more fully identifying the litter cycle in the riverine and marine environments.

7.0 Discussion

7.1 Monitoring Methods

In this project, the focus was on floating and suspended small and microsized plastic litter. There is a lot of knowledge and literature about the flows and currents in the monitored rivers, as there is about the behaviour of solids in a river, but those solids are mostly sediment particles with an average density of 2 – 3 kg/dm^3. Litter consists for a large part of particles with a density that is in the same range as water, both a little bit lighter, and a little bit heavier. This means that the behaviour of litter in a turbulent flow is different from the behaviour of the normal river load of sediments.

There are a number of conditions that are relevant for the transport of plastic litter in riverine conditions:

- Characteristics of the litter items;
- Spatial characteristics of a river; and
- Temporal characteristics such as seasonal and tidal conditions.

7.2 Characteristics of the Litter Items

Litter consists of items of different materials, shapes, sizes, and natures (determined by production process or changes during their lifetime). Materials can be polymers or non-polymers (metal, wood, paper/carton, textiles, etc). The density, depending on the characteristics of the material, but also on processes such as ageing and fouling of the materials, determines whether the products can be buoyant or not.

But the nature of the particles is also a relevant factor. When the product is hollow or foamed and its volume consists of a certain amount of trapped air or when it is combined with another material that is heavy, buoyancy will be influenced and it will either sink to the bottom or rise to the surface.

Here shape plays a critical role too, determined by the surface to volume (S/V) ratio. A lighter than water product with a compact shape (like a plastic pellet) will rise to the surface very quickly, but when it is very flat (like a sheet of plastic) it will rise very slowly. The volume to surface ratio, combined with its buoyancy, determines the terminal velocity of the product in a viscous medium like water, either upwards or downwards. In calm water with no turbulence, all products with a positive buoyancy will be at the surface and with a negative buoyancy will be at the bottom, but in shallow, flowing rivers this is a rare condition.

Although not very well understood, size might also play a role in the positioning of particles in the water column. The S/V ratio of smaller particles is substantially larger than the S/V ratio of larger particles with the same shape. This might suggest that microplastics have a terminal velocity which is so low that they will be evenly suspended in the water column regardless of the turbulence, while the larger particles are much less subject to a higher difference in turbulence because of their higher terminal velocity.

7.3 Characteristics of the River

Relevant for sampling in a river is an understanding of the characteristics of the river and its basin. In particular, differences in water velocities in the cross section of the river and the resulting turbulence play a decisive role in the way solid items are transported and where they are vertically and horizontally located. Different sampling locations can thus lead to different outcomes and multiplying the occurrence of litter in sampled volumes to the discharge of the river can lead to significant methodological errors.

Rivers are turbid by nature, which means that very fine materials are suspended in the water as wash load, especially at higher discharge rates, when most of the litter is transported. Sampling should therefore ideally be done during a range of discharge conditions and the sampling equipment should be designed to sample in these kind of situations. The manta net, having openings of 300 µm, will be clogged very fast in these circumstances. During this project the WFW sampler was used with net openings of 3.2 mm. This larger mesh size was more suitable for rivers with a high organic content, since the net would clog less frequently.

Looking at the amounts and types of plastic litter found in this project in relation to the characteristics of the rivers is difficult, since there are many factors involved that differ between the rivers,. Some observations can be made.

1) The Po river showed the highest overall amounts of small litter items, because a floodwave passed the monitoring site during the monitoring period
2) The highest concentrations of plastic pellets were found in the river Rhine. This result could be explained by the fact that the river Rhine runs through highly industrialized areas. Furthermore, the location of sampling was very near a

harbour area, where virgin industrial pellets are trans-shipped between large oceanic vessels and inland boats for the further transportation to industrial areas further upstream.

3) Fragmented particles were most prevalent in the Po and Rhine River. Both these rivers are subjected to flooding and have extended floodplains. Large litter items could possibly be deposited on the river banks for extended periods of time and therefore fragment faster under the high irradiation and higher temperatures on land compared to the river conditions. During floods, these deposited and fragmented litter items would then flush further downstream.
4) In the Danube and Dalålven River, fibres are the largest group of particles. The Dalalven flows through a nature reserve, and although the fibres are the largest group, their numbers are small, and probably households are their main source. The tributary Siret of the Danube flows through an agricultural well developed area with several villages probably with a simple waste water treatment system.

The following estimated emissions from rivers are based on visual observations of the samples and flow pattern in a river at monitoring sites.

- The river basin of the Dalålven in Sweden consists of mainly woodland and agricultural fields and a few villages. The low population density and the absence of industries in that area explain the cleanliness of the river where visually no plastic litter is found.

- The river Po in Italy transports during a flood wave moderate amounts of plastic litter in comparison with the plastic litter transported by the Meuse River in The Netherlands. The concentration of plastic litter increases significantly as the floodplains start to be inundated during the rising limb of a hydrograph .

- The sampling just downstream of the confluence of the Siret River with the Danube River showed that a long distance is needed for the mixing of the high concentration of litter in the Siret with the water of the Danube. It seems that the plastic litter in the Siret has mainly domestic and agricultural sources.

- In the harbour of Rotterdam plastic litter accumulates in harbour basins depending on the wind direction. A change in the wind direction can cause transport of accumulated litter from a harbour basin to the main stream of the river Nieuwe Maas.

- A summary of these observations is that the monitoring of plastic litter in four European rivers has demonstrated that the concentration of plastic litter in a river varies strongly with time and in space; that is in two directions: in a cross section of a river and along the axis of a river. Therefore extensive monitoring is required of plastic litter in a river to assess the total contribution of rivers to the plastic litter in seas. Extrapolation of results from the field with the use of models, could provide further insights in the processes and the emissions of riverine litter to the marine environment.

7.4 Temporal Conditions

Seasonal and tidal conditions play a critical role in the transport of litter by the river. Precipitation in the entire watershed transports dispersed litter on land through different pathways to the main water channel, where it is transported to the sea. At the beginning of the wetter season the watershed gets cleaned and stored litter gets flushed away. This is a known phenomenon and is called “hysteresis.”

As noted, many different phenomena cause a variation in the presence of plastic litter. In the project we encountered several of them:

- A tributary may discharge a high concentration of plastic litter and the mixing of this litter may not be ‘complete’ until a considerable distance downstream of the confluence (e.g. the confluence of the Danube and Siret river).
- Local sources release plastic litter in a single location in a river (example: household waste transfer point in Rotterdam).
- The wind may force all floating litter to one riverbank. As the wind direction changes all accumulated litter might drift in a short period to another riverbank (example Po June 4th).
- In a harbour basin accumulated floated plastic litter is released when the wind direction changes (examples: Rhine Aug 7th and Sept 15th).
- The lateral mixing of the flow is small in an alluvial river in a delta and therefore also the lateral mixing of suspended plastic litter is small (Danube, june 11th). An alluvial river is a river that flows in its own sediment, its bed and banks are composed of sediment transported by the river.

7.5 Sampling Methods

One aspect that needs to be investigated further is that samplers might not catch all of the plastic litter in front of the opening of a sampler due to the hydrological effect of putting an obstruction with a certain resistance in the flow. From visual observations it is expected that the trap efficiency of the samplers could be less than 100 %.

This project was unique in the sense that multiple sampling methods were deployed, of which only the manta-trawl method has been used in other studies and from which results were reported in the scientific literature. The Waste Free Waters-sampler is still a prototype and was only tested in the Meuse in 2012 and later in 2013 in an assignment for the Dutch Water authorities (RWS).

The earlier projects with the manta net were mostly done at sea and seldom in riverine conditions. The known samplings in fresh waters were undertaken in the Great Lakes[21] , in Lake Geneva[22] and in one remote mountain lake in Mongolia[23]. Here too the

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[21] ERIKSEN, Marcus, et al. Microplastic pollution in the surface waters of the Laurentian Great Lakes

[22] FAURE, Florian, et al. Pollution due to plastics and microplastics in Lake Geneva and in the Mediterranean Sea

[23] FREE, Christopher M., et al. High-levels of microplastic pollution in a large, remote, mountain lake.

circumstances differ significantly from a flowing river and have more similarities with marine conditions.

The pump sampling technique was deployed as a last opportunity to sample in the Dalålven, where all other possibilities to deploy the manta or the WFW-sampler failed. The results from the Po, where both the manta-trawl method and the pump method could be compared show a reasonable coherence. But here validation of the method is necessary in order to use it in further research.

7.6 Sampling Duration

The difference between a net with a mesh of 0.3 mm or 3.2 mm determines that a manta net can be applied for a maximum of ca 30 minutes, while the WFW sampler can be applied for 2 - 3 hours. This results in sampled distances varying from 500 – 800 metres for the manta net to 10 – 15 kilometres for the WFW-sampler. This means that sparsely dispersed, bigger floating items are more easily caught in the WFW-sampler than in the manta-net. However, the downside of course is that the smaller microlitter items will not be collected with a larger mesh size.

7.7 A comparison of the Manta net and the WFW- samples

The type of items caught in the suspension net of the WFW sampler differs substantially from the type of items present on the surface, thereby providing a more complete picture of the plastics present in the water column. In the water column the representation of films and foils is more dominant than at the surface, especially in more turbulent conditions. The sampling project was mostly undertaken in the summer months, meaning that at conditions with higher discharges, the mixing of thin walled products (foils) in the water column will be more intense.

This segregation phenomenon is probably more dominant for larger items than for the micro sized items, meaning that there is a good reason to sample larger objects both in suspension as on the surface. There is a lot of knowledge about the transport behaviour of sediment, but the behaviour of plastics in different riverine conditions might show a different picture because of the difference in size, shape and density. Research here would be valuable.

7.8 Mesh Sizes

Sampling with a net with mesh sizes of tenths of millimetres results in a quantification of the presence of smaller (micro)plastics. Sampling with a net with mesh sizes of some millimetres results in a quantification of the bigger (macro)plastics. Microplastics dominate the “number” score while macroplastics dominate the “weight” score.

This suggests that for different purposes, different samplers should be applied. In the case that the research question is to determine the load of transported litter by a river to the sea in tonnes/year, samplers with a bigger mesh sizes are more appropriate. In case where the question is how many potentially harmful (micro)plastics are transported by rivers to the sea, samplers with smaller mesh sizes are more appropriate.

7.9 Sampling Position

During the project it became clear that sampling from a fixed location on a riverbank introduced a lot of practical difficulties and also methodological problems. For undertaking short-term samplings, as in this project, the availability of an accessible location limits the choice for the “ideal” spot. It requires co-ordination between the owner of the terrain and the authorities and users on the water. For longer lasting projects with more time to get all the permissions and co-operations, this could be a lesser problem, but for projects of a more unique, exploratory character, this is a real problem.

As for the methodological aspect, sampling from a fixed location has big disadvantages of which the impact of the wind direction is the most prominent. Sampling under exactly the same riverine conditions, but with a wind that changed from off-shore to on-shore, might give totally different results, probably more prominently for floating objects than for suspended objects. A solution might be to sample on two adjacent riverbanks at the same time.

Sampling for longer periods from one location (but preferrably on both sides) might also be an option when the intention is to determine seasonal trends in the presence of litter, but it is not applicable to determine the total load in the river. It is necessary then to assess the base load first and that is very difficult from the riverside.

In the case of sampling from a fixed location the discharge of the river determines the flow of water through the nets. At some instances during the project, almost no current was present, or the current was very low. This means that the hydrological behaviour of the water around the net could be different in each condition and consequently influence the trap efficiency of the nets. The experiences of sampling so far have mostly been with nets trawled behind or next to a boat, where there was a more or less constant flow of water through the net, which meant that the variations between the different samples were minimised.

Trawling nets with a bigger mesh by a boat also makes it possible to sample a larger surface or volume than by sampling from the riverbank, which increases the chance to catch the larger items that have such a high contribution to the weight aspect of the results.

In order to have statistically more significant results, mainly on weight, sampling the largest possible surfaces might be a necessity.

7.10 Relationship between River Emissions and the MSFD

It was observed that litter is present in all of the rivers sampled, indicating also that there is a contribution of these rivers to all of the Regional Seas within the EU. The overall estimates of the contribution of these rivers is quite substantial but should be interpreted with caution:

- Po river, feeding into the Mediterranean: estimated 6 million particles/ km^2 river surface
- Danube river, feeding into the Black Sea: estimated 3 million particles/km^2 river surface
- Rhine river, feeding into the North Sea: estimated 3 million particles/ km^2 river surface
- Dalalven: difficult to extrapolate for floating litterdue to different sampling technique, but comparable with the other methodologies for suspended litter

Several studies have been conducted on microplastics in marine waters in the EU, and microplastics have been reported for water surface of the Mediterranean, North Sea and Baltic (Collignon et al., 2012, Dubaish & Liebezeit, 2013 and Fries et al., 2013 respectively). For the Mediterranean, the highest abundances observed were around 0.36 particles/m^2, so 0.36 million particles per km^2. Comparison with the results in the North Sea is quite difficult, since these were expressed in particles/l. Here, 64-194 granular particles, 82-88 fibres and 30-41 black carbon particles were found per litre of seawater. For the Baltic, it is also difficult to compare because of the difference in sampling technique. For the Mediterranean, this comparison does show that the results observed from our study of the Po are comparable in order of magnitude with what is found in the marine environment.

Microplastics have also been studied in the Western Atlantic.[24] Here the distribution of microplastic items (up to 5 mm in size) were assessed per km^2. From this study, the highest category was 50.000 particles and higher per km^2 , which is an order of magnitude lower than results from our study for the freshwater environment. Another study, conducted in the North-Eastern Atlantic by Lusher et al., (2014) sampled the surface of marine waters through a pumping system as well, resulting in approximately 2315 potential plastic particles on a transect of 12,700 km.

Other studies in freshwater ecosystems, for example in the lakes in the United States of America, sampling with a Manta trawl resulted in an average abundance of approximately 43,000 microplastic particles/km^2 (Erikssen et al, 2014).

Our results from the four river systems agree well with observations from the marine environment and lakes, even if they are slightly higher. Results from our study are in the same order of magnitude for the Po and the Mediterranean. Compared with studies in the Western Atlantic, our results are an order of magnitude higher which can be expected due to the dilution and dispersion of plastic particles in the surface layer of the seas and oceans. In the freshwater environment, it seems that our results are an order of magnitude higher probably because the upper size limit included in our study is higher

[24] Distribution of microplastics (items km-2) in the surface waters of the western Atlantic, 1998-2008. Sea Education Center, Woods Hole, MA – (downloaded from www.onesharedocean.org

and also because of possible errors in the extrapolation of field results to estimated amounts discharged per km^2.

8.0 Conclusions and Recommendations

8.1 Monitoring

At the moment, there are no long-term monitoring programs on litter in freshwater systems in Europe. One of the main possible reasons for this is that litter is not included in the Water Framework Directive, and therefore there is no legal instrument to relate this monitoring too. Short-term projects are taking place in different EU countries, that are trying to make some first quantifications of the amounts and sources of plastic litter in rivers and are trying to establish good monitoring techniques as well as cause-effect relationships that can ultimately be used for monitoring.

Because of a lack of standardization, results are difficult to compare among the different studies. To come to a common European approach, monitoring and analytical methods should be further developed. For more reliable information longer term monitoring and analysis would be recommended to see if there are seasonal changes (related to possibly different uses) as well as to see how the variability in weather influences quantities of litter in rivers. In this project, the focus was on floating and suspended small and microsized plastic litter. Sediment and suspended matter are also matrices in which plastics can occur in the freshwater environment, and could potentially add to the amounts of litter transported to the marine environment.

8.1.1 Recommendations on Sampling Techniques

Sampling with a small mesh size restricts the available time for sampling due to the risk of clogging. The sample will represent the presence of the more densely and evenly dispersed small and micro particles. The dominant descriptor is the presence of (micro)particles in numbers per surface or volume unit.

Sampling with larger mesh sizes allows a much longer sampling time without the risk of clogging. The samplers can consequently sample larger surfaces or volumes, thus also catch the sparsely dispersed larger objects. The dominant descriptor then is the weight per surface or volume unit.

This means that for determining the riverine input of litter to the marine ecosystem in terms of tonnes/year, the WFW sampler, with its larger mesh size and possibility to measure suspended particles below the water surface, is more appropriate. For determining the potential harm of riverine input of microparticles in terms of numbers per year, the manta net is the best suited sampler.

What is apparent from this study is that, even though standardization of sampling techniques is required for comparison among different areas, this proves to be difficult in practice. Local conditions of sampling locations can differ to such an extent that some flexibility should be allowed to suit local needs. Therefore, even though concensus on the sampling technique is important, the first focus could rather be on consensus on the mesh sizes used as well as on the manner in which results are expressed.

8.1.2 Stationary Sampling

Stationary sampling from a fixed location can be applied for sampling microplastics. However it needs to be demonstrated that the concentrations in the whole river section (in transversal and vertical directions) are more or less the same.

Depending on the goals of the stationary sampling it can be recommended for macroplastics when it can be undertaken for longer sampling periods (for example during flood waves) and preferably at several locations on both adjacent banks at the same time.

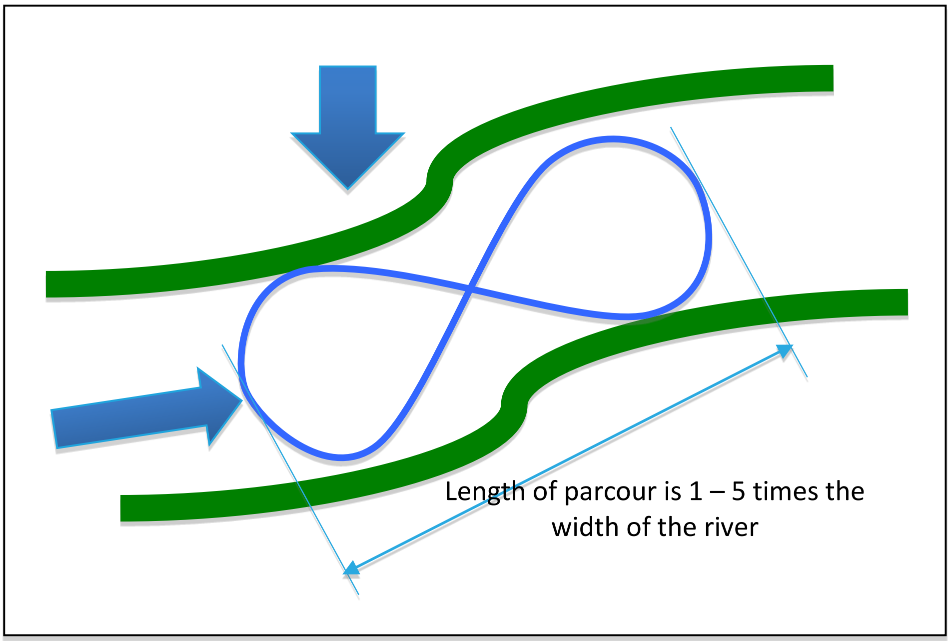
8.1.3 Trawling Method

The most preferred sampling method is the one that eliminates the influence of local variations in the river, either caused by turbulence and discharge variations or by meteorological phenomena or the impact of tributaries.

It could be done from a bridge, from which samplers are lowered in the water at regular intervals along the cross section. Although then the problems with the wind impact or tributaries are diminished, the relative low currents can still be a problem. Also bridges are rare at the last wide stretches of a river entering the sea.

A preferred option is to use a boat trawling equipped with standardised samplers and to sail a few times along a normalised 8-shaped parcours with a length of about 1km, to realize a sampling distance of about 5 to 10km depending on the rate of clogging of the nets (Figure 28).

Figure 28: Normalised parcours for sampling on river surface



The advantage of using a boat is mainly the flexibility to choose the best sampling location available without being dependent on authorities or facilities on land and to eliminate the bias caused by the wind and the changing current condition on both sides of the river. Also the constant sampling speed is an advantage, because of the more or less constant flow pattern around the sampler. This method can also be applied in sampling freshwater with hardly any current, like in lakes and basins. For determining the influence of possible emission points like cities, industries or waste water treatment plants it is possible to take samples upstream and downstream of these locations. From a boat it is also possible to take sediment samples or to monitor water temperature and salt intrusions.

The disadvantage of using/hiring a local boat is that it is rather expensive and that boats and trained personnel are not always available for longer sampling periods on the sampling location and that they may not be equipped with the necessary tools.

The monitoring in the Nieuwe Maas and the Nieuwe Waterweg near Rotterdam showed that safe monitoring in a boat encountering considerable wash from passing vessels, and thus requires a stable boat.

This leads to the conclusion that monitoring of plastic litter in these circumstances should be part of a general monitoring programme executed by monitoring vessels, suited to monitoring a series of different parameters, for example bed levels, salt intrusion and flow fields. This combination of efforts would also lead to further cost-effectiveness. All advantages and disadvantages are represented in the table that can be found at Annex A.5.0.

8.2 Analysis

In depth analysis of samples was performed as part of this project. All methods used and described in this report proved to be feasible for use. There is still a lack, however, of harmonization. Ideally, an interlaboratory study would take place and there would be a standardized method within the EU for analysing small plastic particles for each of the water compartments (surface waters, water column and sediments). Also, the manner in which the results are expressed, for example in amounts or weight per km^2 or m^3, should be standardized as much as possible. This makes comparison between different areas within the EU possible.

The selection of the method depends on the question that needs to be answered. For management purposes it is important to know quantities and types of plastic to enable identification of sources and prioritise management measures.

8.3 Amounts, Sizes and Types of litter

Results from this study are estimates based on limited data, also since one of the objectives of this study was to test sampling techniques. More research is necessary, not only on floating litter, but als on the water column and on sediments.

This study shows that there is plastic litter found in the EU rivers, even in those with a low population density. The results also showed that the plastic litter in different rivers only differ slightly in concentration and type, indicating that, at least at the locations close to the river mouth, there is not much difference between EU rivers, despite their specific differences in characteristics and possible sources.

8.4 Communication

Communication is critical when dealing with litter. On the one hand because of the need for co-operation with local parties, especially in the procurement of permits, and on the other hand because of the fact that the main focus for awareness raising has been on the marine environment, not on the freshwater environment, even though it seems that most of the sources are on land.

Within the project, cooperation was sought as much as possible with local organizations (see Annex A.6.0) mainly through our own networks and that of the Commission. This is therefore to a large extent an informal process. However, due to the complexity of the litter problem and the division of responsibilities over many different (governmental) bodies in European MSs, it is hard to determine key persons to involve and this process is time intesive. Awareness raising is to a large extent a political process, and should be promoted by the Commission, for example through the Regional Sea Conventions and international river basin authorities.

8.5 Management of Sources

The most effective environmental protection measures are those that prevent inputs of pollution from the source, however, this should be combined with cleaning up existing plastics to reduce the opporuntinities for macroplastics to fragment into microplastics. Since the main identified likely litter source in all sampled rivers is heavier (probably industrial) packaging it is recommended to take action in packaging practices by directly addressing packaging producers and users. Additional likely sources of packaging litter in rivers might be also bad practices in waste management, however, these were not specifically inventoried in the current study.

Similarly, urban areas are an important likely source in all sampled rivers, therefore waste management in urban areas and wastewater treatment practices should be investigated in order to identify actual causes of emissions of litter from urban areas.

In the Rhine and Po catchments further investigation should be done to identify industry, that could actually be emitting plastic to surface water.

Extensive public awareness raising is recommended to emphasise the importance of changing behaviour which contributes to the pollution of surface waters with litter.

Agriculture is also a likely important litter source identified mainly in the Po and Danube rivers. In these two catchments in depth analysis of litter pollution stemming from agriculture should be performed to identify problem areas.

In the Po and Rhine rivers fishing was identified as an important likely litter source. Awareness raising campaigns are recommended among fishermen in these two catchments.

8.6 MSFD and WFD

Plastic litter is included as part of the MSFD, but not of the WFD. Since the estimated contribution from rivers into the marine environment is considerable however, up to 6 million particles/km^2, some connection should be made between the marine, where the impact is most clearly visible, and freshwater systems, where the main sources are. Results from our study of the freshwater environment are an order of magnitude higher than the freshwater studies from literature and are also higher than the amounts/km^2 observed in the marine environment. More research is necessary to close this emission balance to estimate the relative contribution of rivers to the total marine pollution in the EU.

It is apparent that the inclusion of plastic litter in the WFD would be a complicated process, with a potential for lack of consensus from EU MSs due to the increased monitoring obligation. However, we have demonstrated that effective monitoring approaches exist and can be used in different EU rivers, depending on the questions that need to be answered. Estuaries are important areas to include in monitoring programs. The MSFD does require a program of measures to assess and possibly reduce plastic litter concentrations in the marine environment, which is difficult if the sources cannot be tackled.

Some further coordination on this topic is required between the MSFD and the WFD, or possibly with other suitable legal instruments for example the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH), especially because of the potential of high concentrations of chemicals to leach from plastics. Regional coordination of MSs with the RSCs and river basin authorities are important processes that can play a role in further awareness raising, coordination of monitoring and finally in decreasing the input of plastics into the aquatic environment.

APPENDICES

A.1.0 Detail of Sampling Methodology

Manta net method

In the project the manta net was used for microlitter sampling (see Figure A – 1). A Manta net is an improved design of the Neuston net. The used manta net is a modified manta net that is usually used for the sampling microlitter and plankton organisms on the sea surface. It doesn't have wings for floating and is shorter. It has styrodur floaters which help to keep it afloat and it has a 60 cm internal width and is 90 cm long. Its mesh size is 0.3 mm.

During sampling the spatial hydrological and meteorological conditions were recorded:

- actual discharge at sampling location,
- water velocity while sampling,
- duration of sampling,
- local prevailing wind direction, actual wind direction and wind strength,
- meteorological conditions (local temperature and rainfall),
- GPS location, date and time.

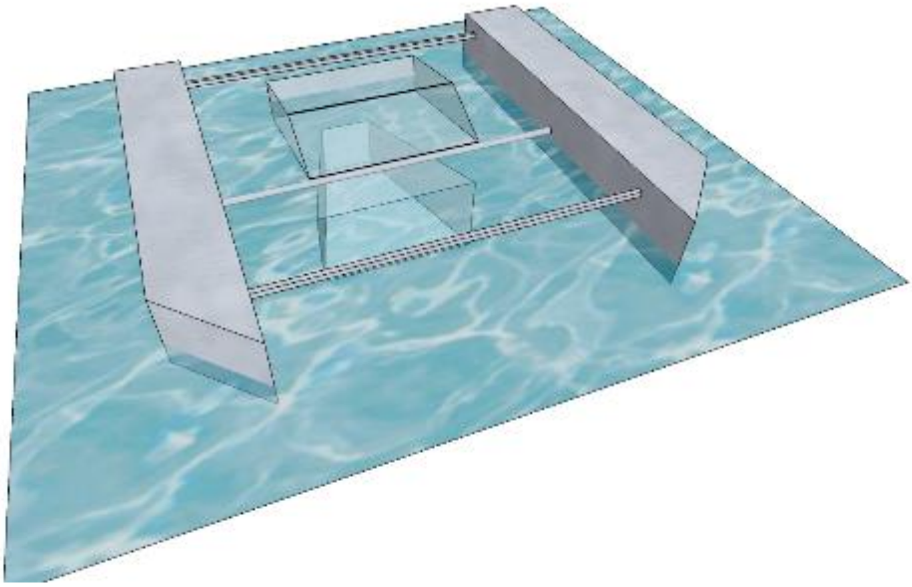
The manta net sampling procedure is described below:

1) Check condition of the manta net (ruptures, cracks, cleanness, clamps, etc.).
2) Check flow velocity.
3) Lower the net in the water, start timing. (During the sampling, monitoring of clogging the net and monitoring of approached large items were done.)
4) After sampling cycle, lift the manta net from the water. (The sampling time was maximum 30 minutes, depending of the amount of silt (turbidity) in the water, because of the risk of clogging of the net.)
5) Stop timing, collect flow velocity data.
6) Rinse the net from the outside with river water to put all the particles caught on the net into the cod end.
7) Manually pick larger items and rinse them inside the net, using a bottle filled with demineralized water, store them in a bucket with sample name (ID).
8) Rinse cod-end with demineralized water and flush the content in sample bottle. When quantities are too big, use a sieve with 0.3 mm mesh size to concentrate the caught material and flush the sieve with demineralized water.
9) Close, seal and label sample as prescribed and prepare for transport.
10) File metadata concerning a sample.

Waste Free Water sampler

The Waste Free Water sampler (WFW-sampler) consists of two floating bodies and in between two metal nets: a surface net and, below the waterline, a suspension net. Both nets have a width of 1 m and the suspension net has a height of 50 cm, creating a cross sectional area of 0.5 m^2. The leading edge of the surface net is 3 - 5 cm below the water surface. The suspension net collects samples at a depth of 20 to 70 cm below the water surface. However, in conditions with wind and ship waves these figures will change in a complex way. The trap efficiency of the sampler has not been determined yet, but it is believed it is close to 100 %.

Figure A - 1: Sketch of the WFW-sampler with surface and suspension net.



(Sketch prepared by the National Oceanic and Atmospheric Administration, Southwest Fisheries Center, https://swfsc.noaa.gov/)

Related to the water velocity, the surface net samples were expressed in items/m^2 and items /(m^3.s) and the suspension net samples were expressed in items/m^3 and items/(m^3.s). The mesh size of both nets is 3.2 mm, which means that large microplastics and macroplastic particles were caught.

The WFW-sampler sieve has a bigger mesh than the sieve of a manta net. Therefore it can be operated for a much longer time before clogging.

The sampling with the WFW sampler is described below:

1) Clean and attach surface net and suspension net to the floaters.
2) Record time sampling start (During the sampling, observation of clogging the net and approach of large items were done).
3) After the sampling period, remove both nets from sampler and record the end time.
4) Remove larger organic parts from the nets while assuring no litter particles are attached to these parts.
5) Empty the net by handling the content with tweezers.
6) Put the content in a larger container for drying.
7) Put dried content in the final sample box.
8) Close, seal and label sample as prescribed and prepare for transport.
9) File metadata concerning a sample.

Pump – manta net method

A new monitoring method was introduced in the Dalålven River out of necessity, because of the limitations that the banks of that river created for setting up the monitoring equipment. Especially no quay walls are present along its banks and the project did not obtain permission to sample at other potentially suitable monitoring locations. Therefore the project applied a so called 'pump - manta net method' with a manta net, a big 1000 litre liquid container and a pump with a hose. The manta net was placed above the container and acted as a sieve. With the pump in the water a sample of 5000 litres of river water was made

The characteristics of the used pump are described below:

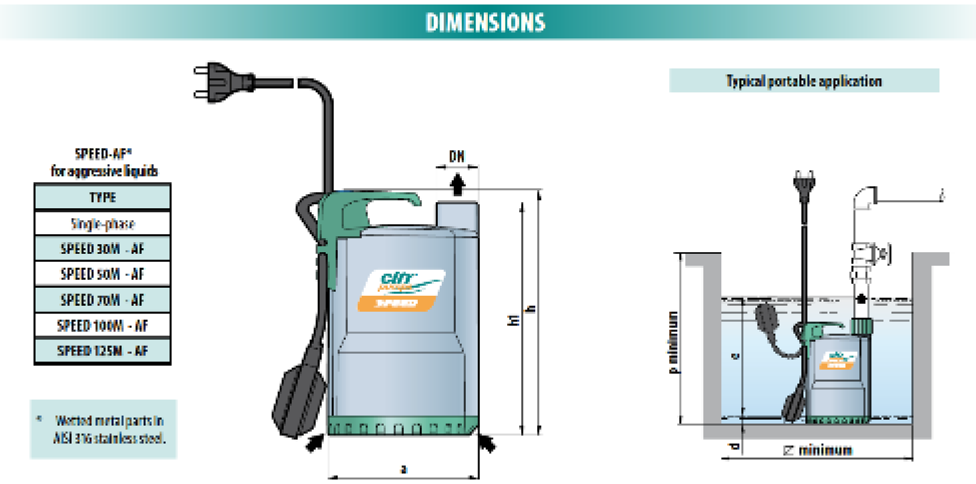
Type: City Pump Speed 70M

Dimension a (height): 152 mm

Maximum head: up to 10.5 m

Maximum flow rate: 260 l/min

Maximum particle size: 10 mm



The pump - manta net method is described below:

1) Fix the manta net above the 1000 litres container.
2) Close the emptying valve of the container.
3) Secure the water tube is secured inside the manta net.
4) Start the pump and record start time.
5) Fill the tank with 1000 litres river water.
6) Stop the pump.
7) Open the valve to empty the container.
8) Close the valve and repeat the filling/emptying of the container 5 times (5000 litres).
9) Rinse the manta net from the outside with river water to secure all the caught materials are flushed in the cod end.
10) Remove the cod end from the manta net and flush the content into a bottle using a spout-bottle with demineralized water.
11) Close, seal and label sample as prescribed and prepare for transport.
12) File metadata concerning a sample.

Due to the constraints from the project in terms of logistics, the monitoring techniques, like the Manta net and the WFW sampler had to be combined with more extensive materials such as a crane. This set-up makes the methodology applied suitable for long-term monitoring at one, single point in a river cross section. For an accurate assessment more points in a cross section need to be sampled to asses the transport of plastic litter in a river accurately. Therefore it is attractive to use a survey vessel for future monitoring of plastic litter in rivers. However, one has to realize that the forces on these nets are so extensive that the sampling cannot be done by hand and safety considerations put certain conditions to the size of a survey vessel which could be further optimized by the inclusion of plastic litter sampling in existing monitoring programs.

A.2.0 Sampling Conditions

Rhine River

Table A2.14: Sampling conditions, 2nd sampling, manta net (meta data) (discharge data was not available)

Date	Sampling day	Sample id	Start time	End time	Duration (s)	Current (m/s)	Distance (m)	Wind direction (°)	Sampled surface (m^2)
31 July 2014	1st	RH1T	11:00	11:20	1221	0.5	611	210	367
01 August 2014	2nd	RH2T	11:00	11:22	1303	0.5	652	210	391
02 August 2014	3rd	RH3T	11:00	11:20	1240	0.5	620	180	372
03 August 2014	4th	RH4T	12:00	12:20	1220	0.5	610	210	366
04 August 2014	5th	RH5T	12:00	12:23	1380	0.2	276	210	166
05 August 2014	6th	RH6T	13:00	13:28	1692	0.2	338	160	203
06 August 2014	7th	RH7T	15:00	15:21	1268	0.4	507	210	304
07 August 2014	8th	RH8T	16:00	16:21	1296	0.3	389	200	233

08 August 2014	9th	RH9T	17:30	17:47	1050	0.5	525	130	315

Table A2.15: Sampling conditions, 3rd sampling, manta net (meta data) (discharge data was not available)

Date	Sampling day	Sample id	Start time	End time	Duration (s)	Current (m/s)	Distance (m)	Wind direction (°)	Sampled surface (m^2)
10 September 2014	1st	RH10 T	08:30	08:52	1329	0,7	930,3	20	558
11 September 2014	2nd	RH11 T	09:10	09:39	1747	0,4	698,8	20	419
12 September 2014	3rd	RH12 T	10:34	10:59	1509	0,4	603,6	0	362
13 September 2014	4th	RH13 T	11:00	11:28	1700	0,4	680	25	408
14 September 2014	5th	RH14 T	12:00	12:22	1306	0,6	783,6	75	470
15 September 2014	6th	RH15 T	13:00	!3:21	1233	0,5	616,5	90	370
16 September 2014	7th	RH16 T	14:00	14:21	1284	0,6	770,4	90	462
17 September 2014	8th	RH17 T	14:00	14:22	1328	0,4	531,2	90	319
18 September 2014	9th	RH18 T	15:00	15:24	1439	0,7	1007, 3	90	604
19 September 2014	10th	RH19 T	16:00	16:23	1373	0,4	549,2	100	330

Table A2.16: Sampling conditions, 2nd sampling, WFW sampler (meta data) (discharge data was not available)

Date	Sampling day	Sample id	Start time	End time	Duration (s)	Current (m/s)	Distance (m)	Wind direction (°)	Sampled surface (m2)	Sampled volume (m3)
31 July 2014	1st	RH1A	13:10	15:30	8400	0,5	4200	210	4200	2100
01 August 2014	2nd		13:00	16:00	10800	0,3	3240	210	3240	1620
02 August 2014	3rd	RH3A	13:00	16:00	10800	0,4	4320	180	4320	2160
03 August 2014	4th	RH4A	14:00	17:00	10800	0,4	4320	320	4320	2160
04 August 2014	5th		14:00	16:35	9300	0,4	3720	270	3720	1860
05 August 2014	6th	RH6A	15:15	18:00	9900	0,3	2970	250	2970	1485
06 August 2014	7th	RH7A	16:15	18:45	9000	0,5	4500	210	4500	2250
07 August 2014	8th	RH8A	17:25	19:25	7200	0,6	4320	40	4320	2160
08 August 2014	9th	RH9A	18:20	20:20	7200	0,8	5760	130	5760	2880

Table A2.17: Sampling conditions, 3rd sampling, WFW sampler (meta data) (discharge data was not available)

Date	Sampling day	Sample id	Start time	End time	Duration (s)	Current (m/s)	Distance (m)	Wind direction (°)	Sampled surface (m2)	Sampled volume (m3)
10 Sept. 2014	1st	RH10A	09:50	12:20	9000	0,3	2700	45	2700	1350
11 Sept. 2014	2nd	RH11A	10:00	12:35	9300	0,3	2790	50	2790	1395
12 Sept. 2014	3rd	RH12A	11:30	14:00	9000	0,2	1800	45	1800	900
13 Sept. 2014	4th	RH13A	11:45	14:15	9000	0,2	1800	20	1800	900
14 Sept. 2014	5th	RH14A	12:40	15:10	9000	0,3	2700	75	2700	1350
15 Sept. 2014	6th	RH15A	13:40	16:10	9000	0,2	1800	90	1800	900
16 Sept. 2014	7th	RH16A	14:40	17:10	9000	0,6	5400	90	5400	2700
17 Sept. 2014	8th	RH17A	14:40	17:10	9000	0,7	6300	95	6300	3150
18 Sept. 2014	9th	RH18A	15:40	18:10	9000	0,6	5400	90	5400	2700
19 Sept. 2014	10th	RH19A	17:00	19:07	7620	0,5	3810	100	3810	1905

Dalålven River

Table A2.18: Sampling conditions, pump – manta net method (meta data)

Date	Sampling day	Sample id	Start time	Discharge (m^3/s)	Pump volume (m^3)	Pump surface (m^2)
02 May 2014	1st	DL1P1	11:00	575	5	50
02 May 2014	1st	DL1P2	14:30	575	5	50
04 May 2014	2nd	DL2P1	10:30	550	5	50
04 May 2014	2nd	DL2P2	15:00	550	5	50
05 May 2014	3rd	DL3P1	9:30	540	5	50
05 May 2014	3rd	DL3P2	15:30	540	5	50
06 May 2014	4th	DL4P1	9:00	650	5	50
06 May 2014	4th	DL4P2	15:45	650	5	50
07 May 2014	5th	DL5P1	10:00	500	5	50
07 May 2014	5th	DL5P2	15:00	500	5	50

Po River

Table A2.19: Sampling conditions, pump – manta net method (meta data)

Date	Sampling day	Sample id	Start time	Discharge (m^3/s)	Pump volume (m^3)	Pump surface (m^2)	Wind direction (°)
26 May 2014	1st	PO1P1	15:00	1918	5	50	90
26 May 2014	1st	PO1P2	17:00	1918	5	50	190
27 May 2014	2nd	PO2P	15:00	2046	5	50	190
28 May 2014	3rd	PO3P	16:00	1942	5	50	170
29 May 2014	4th	No sampling with pump – manta net method					
30 May 2014	5th	PO5P	14:58	1803	5	50	160
01 June 2014	No sampling with any method, bad weather						
02 June 2014	6th	PO6P	15:15	1495	5	50	120
03 June 2014	7th	PO7P	14:50	1420	5	50	140
04 June 2014	8th	PO8P	14:49	1360	5	50	145

Table A2.20: Sampling conditions, manta net method (meta data)

Date	Sampling day	Sample id	Start time	End time	Duration (s)	Current (m/s)	Distance (m)	Discharge (m^3/s)	Wind direction (°)	Sampled surface (m^2)
27 May 2014	2nd	PO2T	15:19	15:36	1077	0.82	883	2046	230	530
28 May 2014	3rd	PO3T	08:57	09:16	1195	0.84	1004	1942	300	602
29 May 2014	4th	PO4T	10:37	10:44	445	1.22	543	1843	250	326
30 May 2014	5th	PO5T	12:12	12:19	454	0.73	330	1803	225	198
01 June 2014	No sampling with any method, bad weather									
02 June 2014	6th	PO6T	12:07	12:18	657	0.78	511	1495	160	307
03 June 2014	7th	PO7T	12:17	12:29	737	0.76	560	1420	120	336
04 June 2014	8th	PO8T	10:05	10:22	1052	0.72	756	1360	80	454

Table A2.21: Sampling conditions, WFW sampler

Date	Sampling day	Sample id	Start time	End time	Duration (s)	Current (m/s)	Distance (m)	Discharge (m^3/s)	Wind	Sampled surface	Sampled volume
28 May 2014	3rd	PO3A	15:23	17:06	6218	0.81	5037	1942	170	5037	2518
30 May 2014	5th	PO5A	14:31	16:40	7260	0.77	5570	1803	160	5570	2785
02 June 2014	6th	PO6A	14:40	16:40	7200	0.78	5570	1495	120	5570	2785
03 June 2014	7th	PO7A	14:28	16:25	7020	0.76	5332	1420	140	5332	2666
04 June 2014	8th	PO8A	14:35	16:23	6480	0.72	4654	1360	145	4654	2327

Danube River

Table A2.22: Sampling conditions, manta net method (meta data)

Date	Sampling day	Sample id	Start time	End time	Duration (s)	Current (m/s)	Distance (m)	Sampled surface
04 July 2014	1st	DN1T	11:02	11:29	1654	0.41	686	412
05 July 2014	No sampling with any method							
06 July 2014								
07 July 2014	2nd	DN2T	12:21	12:43	1354	0.48	652	391
08 July 2014	3rd	DN3T	11:44	12:06	1320	0.35	458	275
09 July 2014	4th	DN4T	11:55	12:17	1317	0.42	547	328
10 July 2014	5th	DN5T	13:10	13:35	1348	0.38	518	311
11 July 2014	6th	DN6T	12:05	12:26	1275	0.44	560	336

Table A2.23: Sampling conditions, WFW sampler

Date	Sampling day	Sample id	Start time	End time	Duration (s)	Current (m/s)	Distance (m)	Sampled surface	Sampled volume
04 July 2014	1st	DN1A	15:15	17:05	6600	0.41	2736	2736	1368
05 July 2014	No sampling with any method								
06 July 2014									
07 July 2014	2nd	DN2A	15:48	18:14	8760	0.48	4220	4220	2110
08 July 2014	3rd	DN3A	14:09	16:10	7260	0.35	2521	2521	1260
09 July 2014	4th	DN4A	12:33	15:57	12240	0.42	5081	5081	2540
10 July 2014	5th	DN5A	13:48	17:10	12120	0.38	4662	4662	2331
11 July 2014	6th	DN6A	13:10	18:35	19500	0.44	8568	8568	4284

A.3.0 Detailed Presentation of Results

In this appendix information is presented on the daily changes of litter during the monitoring campaigns, first the microparticles and next the small particles.

A3.1 Microparticles

Figure A3.29: Number of items normalized per km² per each day per each river, collected with manta net

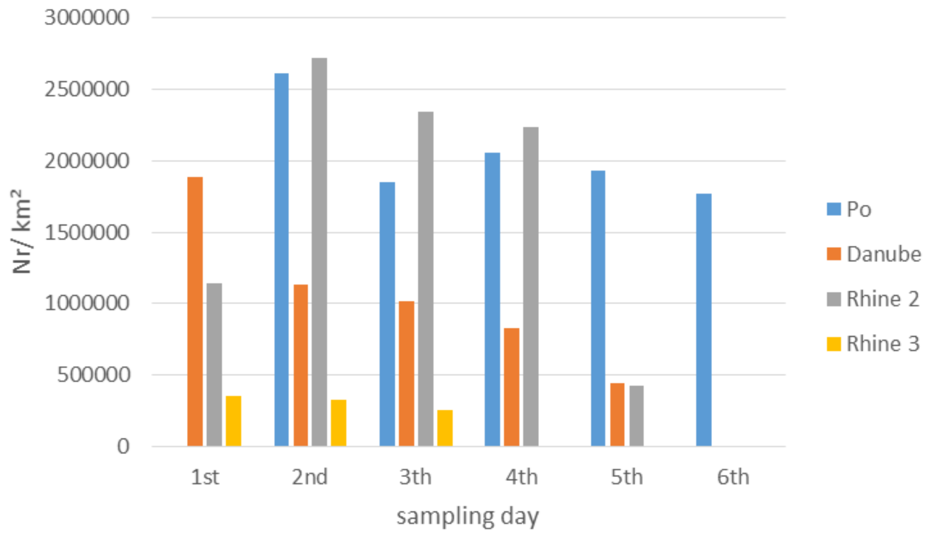


Figure A3.30: Mass (g) of items normalized per km² per each day per each river, collected with manta net

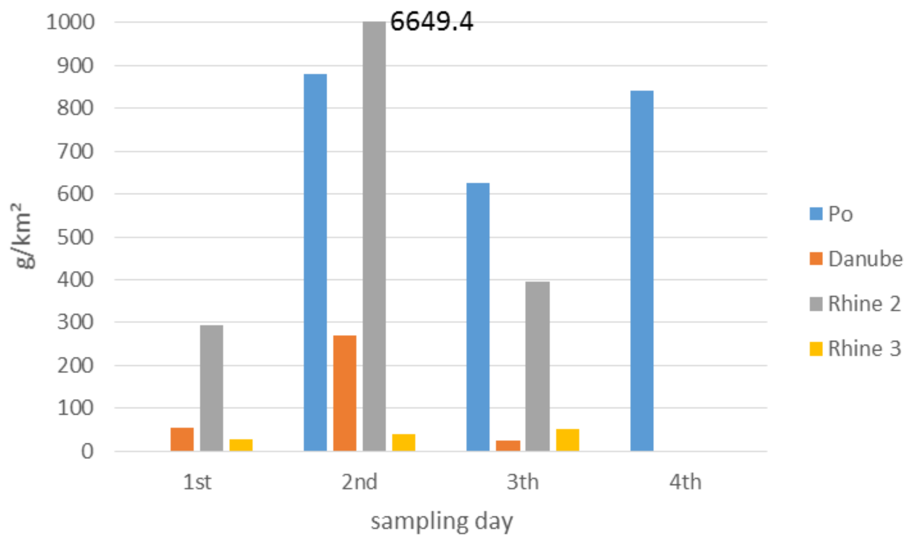


Figure A3.31: Number of items normalized per m³ per each day per each river, collected with pump-manta net method

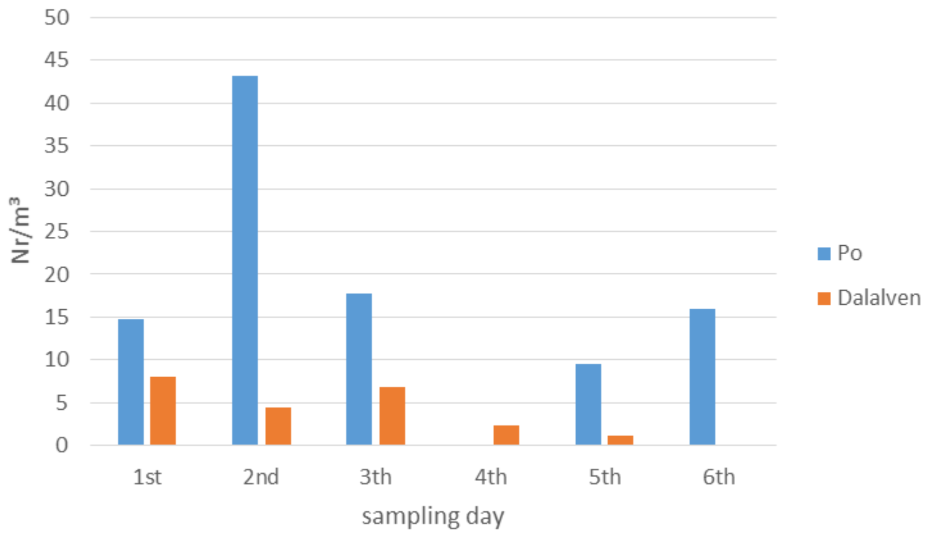
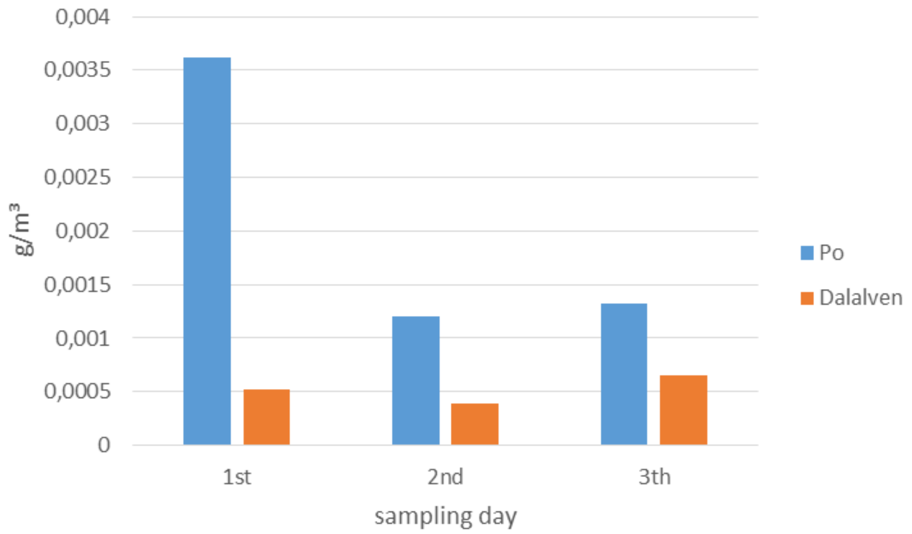


Figure A3.32: Mass (g) of items normalized per m^3 per each day per each river, collected with pump-manta net method



A3.2 Small particles

Figure A3.33: Number of small particles normalized per km^2 per each day per each river, collected with WFW surface net

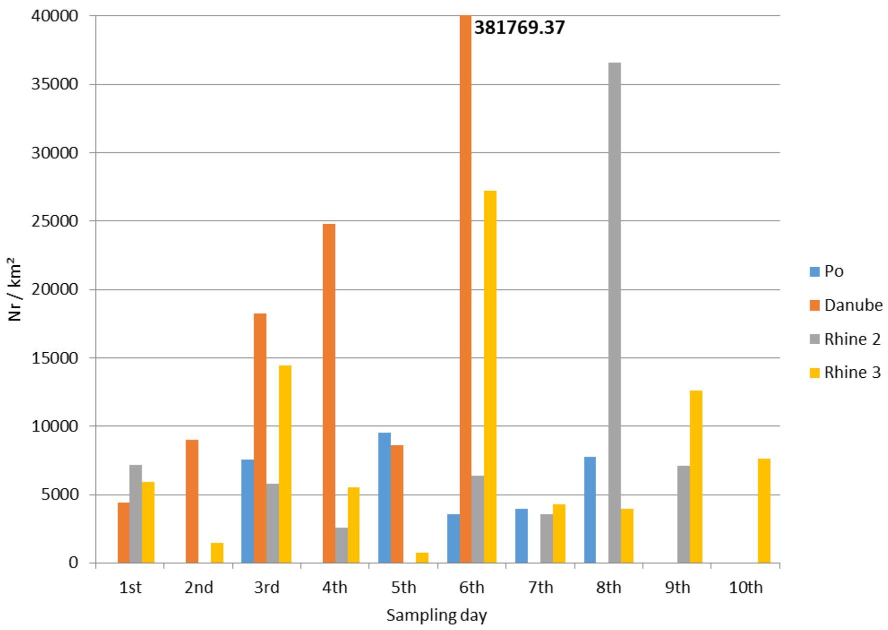


Figure A3.34: Mass (g) of small particles normalized per km² per each day per each river, collected with WFW surface net

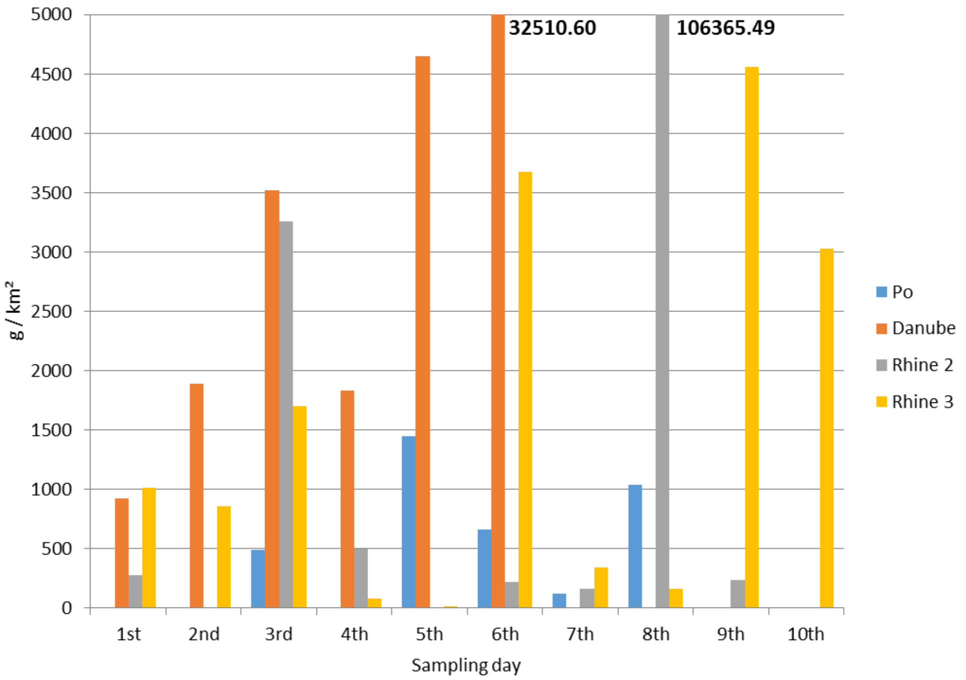


Figure A3.35: Number of small particles normalized per m³ per each day per each river, collected with WFW suspension net

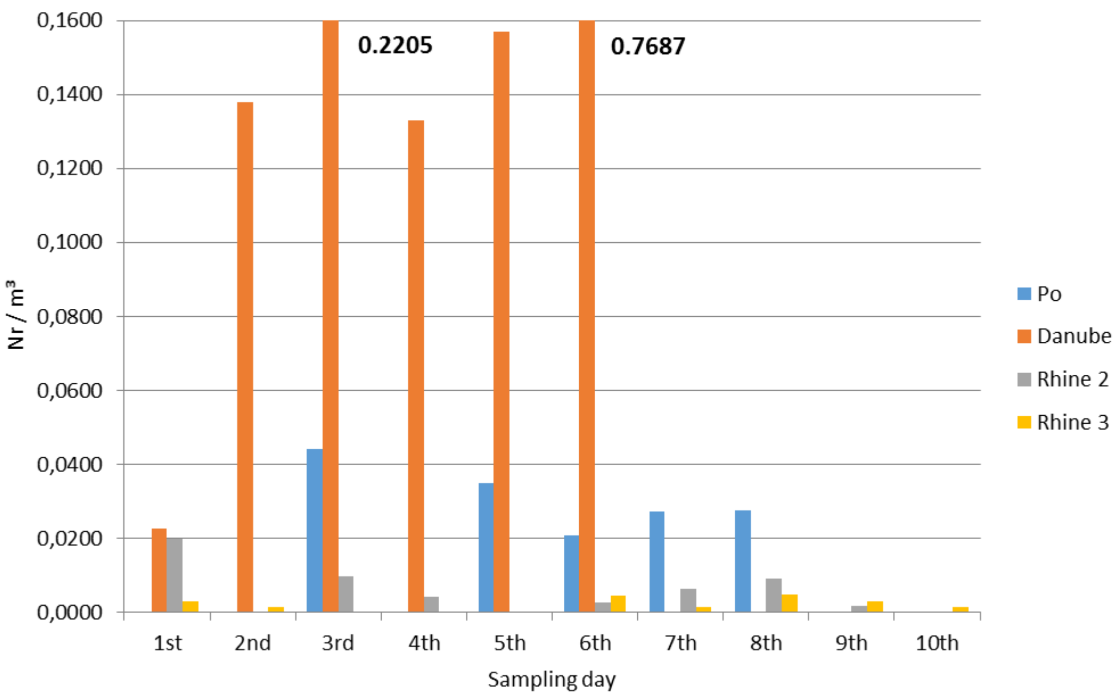
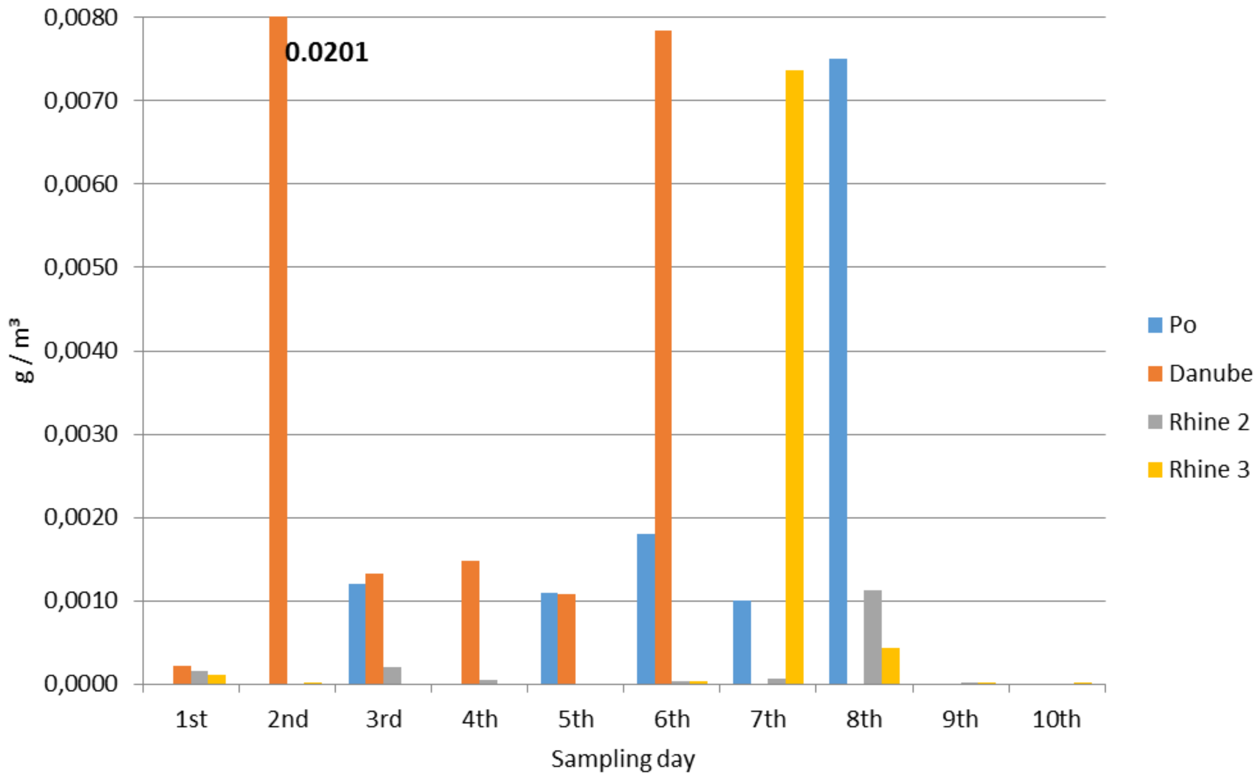


Figure A3.36: Mass (g) of small particles normalized per m^3 per each day per each river, collected with WFW suspension



A3.4 Detailed analysis of litter materials of small particles (meso-litter)

Table A3.24: Percentage of material composition for each river according to small particles number collected with surface and suspension net combined

Sample id	Material							
	Artificial Polymer materials	Rubber	Chemicals	Metal	Cloth/ textile	Glass/ ceramic	Processed/ worked wood	Paper/ cardboard
PO3A	95	1	3	1	0	0	0	0
PO5A	99	0	0	0	0	0	0	1
PO6A	97	1	0	0	1	0	0	1
PO7A	100	0	0	0	0	0	0	0
PO8A	98	0	0	1	1	0	0	0
DN1A	91	0	0	0	4.5	0	0	4.5

Sample id	Material							
	Artificial Polymer materials	Rubber	Chemicals	Metal	Cloth/ textile	Glass/ ceramic	Processed/ worked wood	Paper/ cardboard
DN2A	99	0	1	0	0	0	0	0
DN3A	88	0	11	0	0	0	0	1
DN4A	78	0.5	21	0	0.5	0	0	0
DN5A	91	0	7	0.5	0.5	0	0	1
DN6A	99.7	0	0.3	0	0	0	0	0
RH1A	97	0	0	0	0	0	0	3
RH3A	93	0	0	0	0	0	0	7
RH4A	85	0	0	0	0	0	0	15
RH6A	100	0	0	0	0	0	0	0
RH7A	100	0	0	0	0	0	0	0
RH8A	92	2	0	0.5	0	0.5	0	5
RH9A	96	0	0	0	2	0	2	0
RH10A	75	10	5	0	10	0	0	0
RH11A	83	0	0	0	0	0	0	17
RH12A	96	4	0	0	0	0	0	0
RH13A	100	0	0	0	0	0	0	0
RH14A	100	0	0	0	0	0	0	0
RH15A	89	0	2	0	2	0	2	5
RH16A	96	0	4	0	0	0	0	0
RH17A	100	0	0	0	0	0	0	0
RH18A	88	1	1	1	0	0	0	8
RH19A	94	0	0	0	3	0	0	3

Figure A3.37: Share (%) of categories in surface samples per each river, calculated from particles/km²

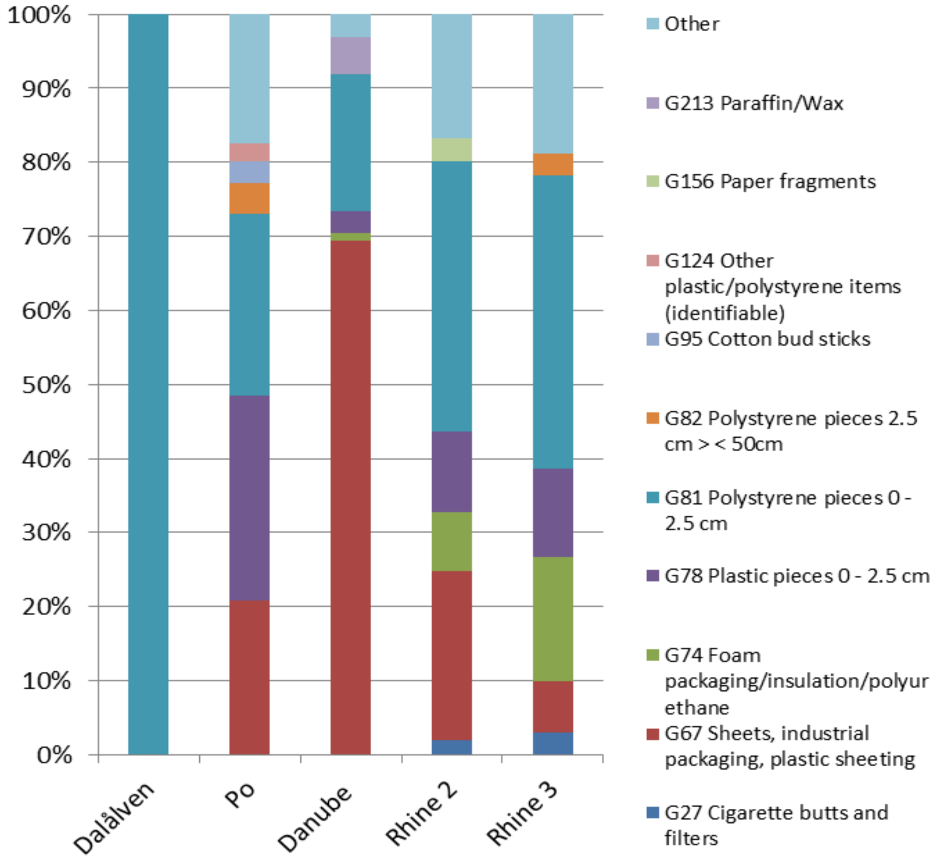


Figure A3.38: Share (%) of six most common categories in surface samples per each river, calculated from g/km²

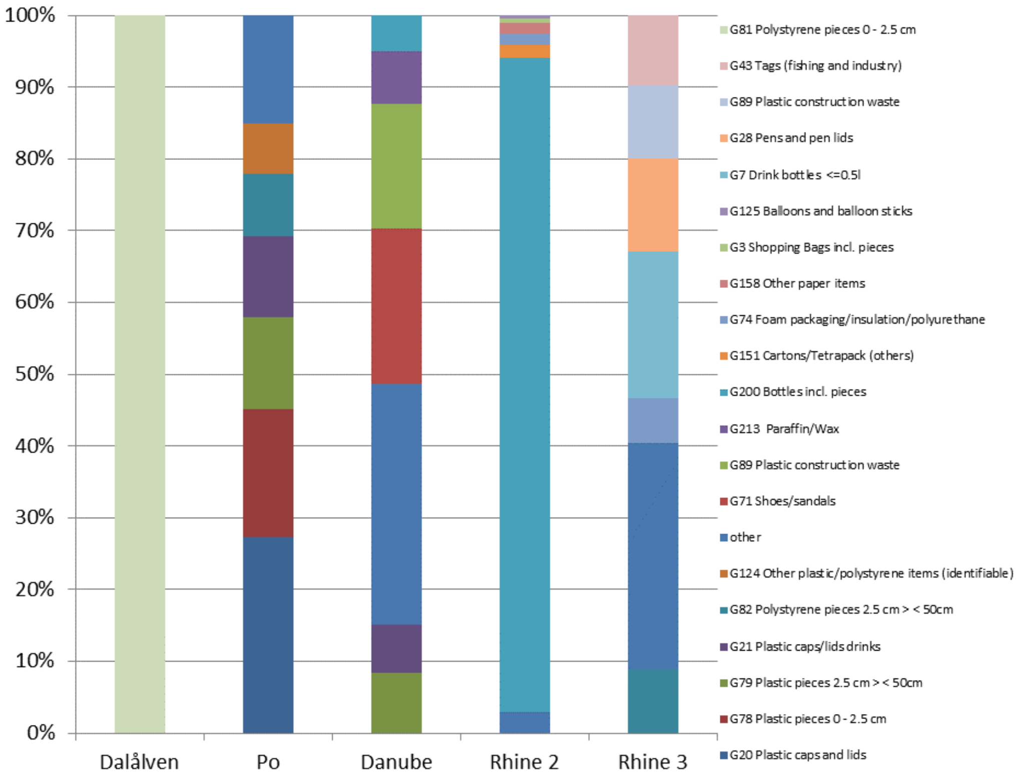


Figure A3.39: Share (%) of categories in suspension samples per each river, calculated from particles/m³

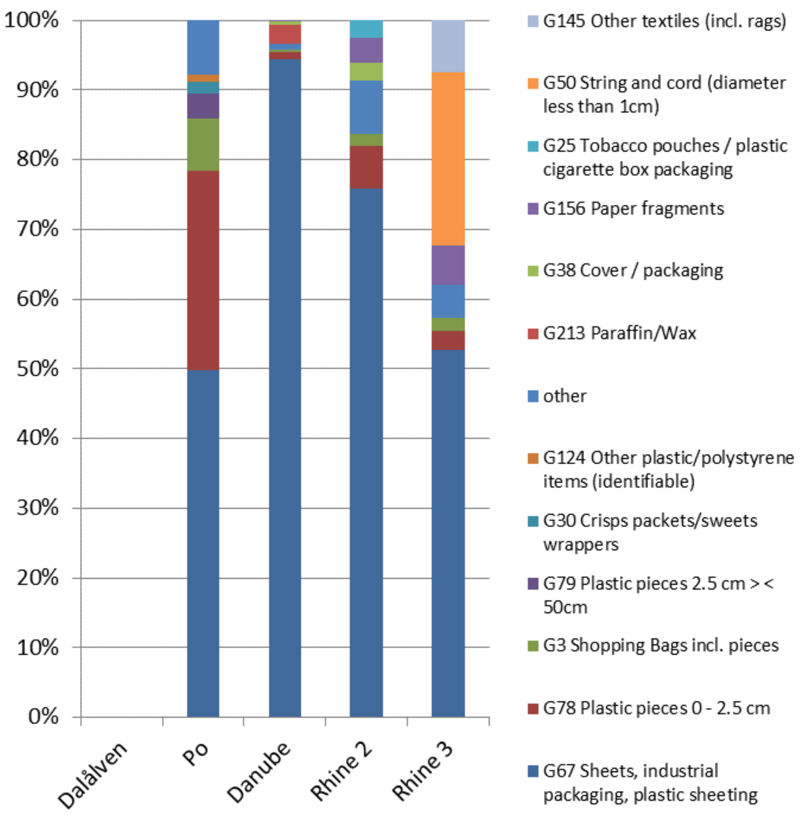
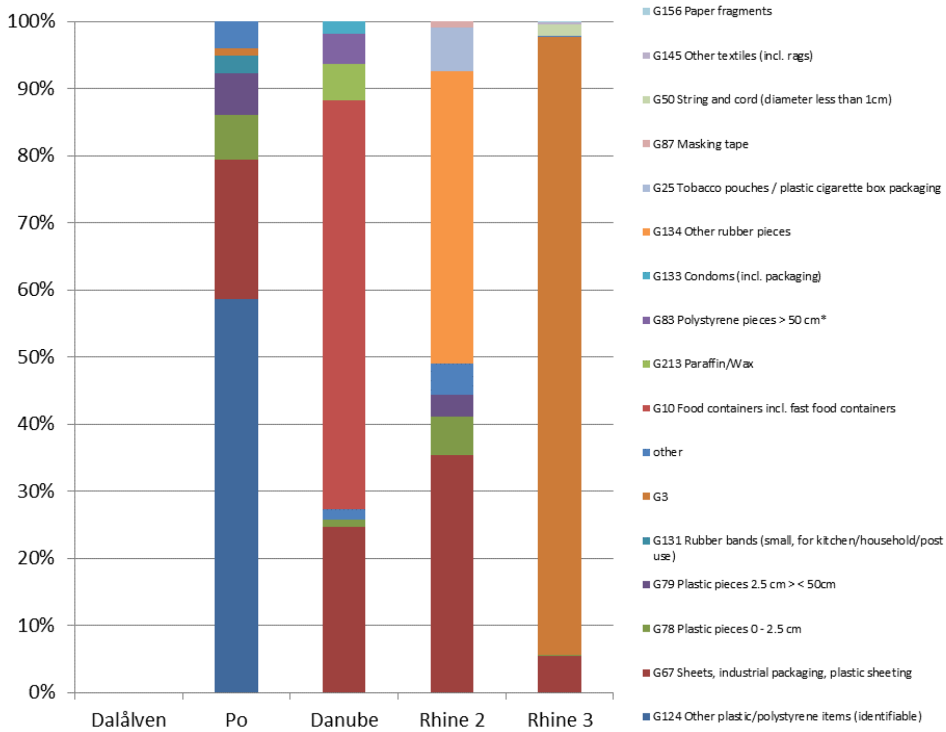


Figure A3.40: Share (%) of categories in suspension samples per each river, calculated from g/m³

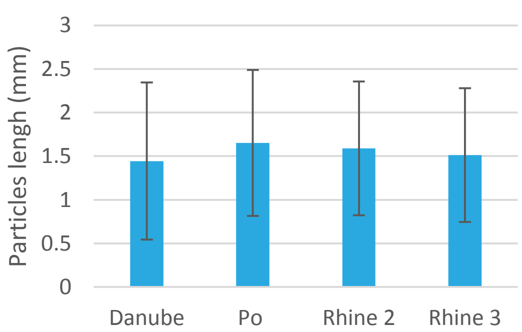


A3.5 The length of particles

A3.5.1 Microparticles

Figure A3.41: Comparison of length of particles of all categories together between Danube, Po and Rhine rivers, where sampling with manta net was done (a) and between Dalålven and Po, where sampling was done with the pump - manta net method (b).

A



b

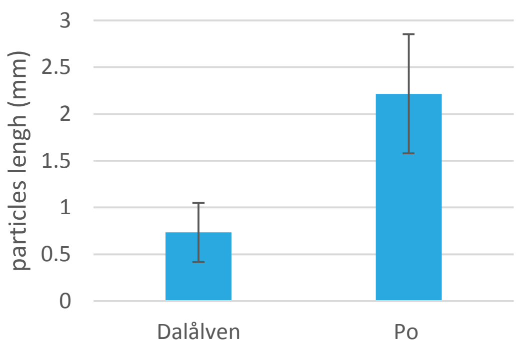


Table A3.25: Lengths of microplastic particles for each category separately.

Length (mm)	Danube – manta net			
	Fragments	**Pellets**	**Foams**	**Other**
Mean	1,35	1,05	2,35	1,01
Std Dev	1,21	0,69	0,97	0,73
Maximum	5,30	3,48	5,98	4,2
Minimum	0,08	0,37	0,31	0,17
Length (mm)	**Po – manta net**			
	Fragments	**Pellets**	**Foams**	**Other**
Mean	1,29	1,99	1,71	1,62
Std Dev	0,48	0,70	1,13	1,03
Maximum	5,14	5,7	5,3	4,33
Minimum	0,08	0,27	0,04	0,43
Lengh (mm)	**Rhine – manta net (2nd sampling)**			
	Fragments	**Pellets**	**Foams**	**Other**
Mean	1,05	1,75	1,81	1,75
Std Dev	0,50	0,34	0,97	1,25
Maximum	6,00	5,86	6,3	5,75
Minimum	0,07	0,31	0,04	0,54
Length (mm)	**Rhine – manta net (3rd sampling)**			
	Fragments	**Pellets**	**Foams**	**Other**
Mean	1,32	0,53	2,40	1,79
Std Dev	0,51	0,49	0,98	1,08
Maximum	4,09	3,50	3,88	3,98
Minimum	0,23	0,32	0,77	0,50

Length (mm)	Dalålven – pump – manta net method		
	Fragments	Pellets	Other
Mean	1,17	0,23	0,80
Std Dev	0,60	0,09	0,25
Maximum	3	0,69	1,95
Minimum	0,21	0,18	0,89

Length (mm)	Po – pump – manta net method			
	Fragments	Pellets	Foams	Other
Mean	2,16	1,56	1,98	3,16
Std Dev	0,49	0,62	0,54	0,9
Maximum	8,92	4,84	3,82	4,26
Minimum	0,64	0,89	1,02	2,12

A3.6 Small particles

Figure A3.42: The average length for all particles in each river.

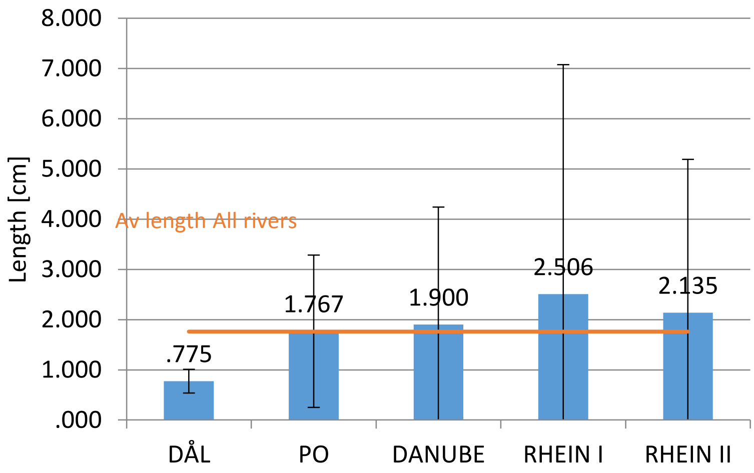


Figure A3.43: Comparison of average particle length for representation of an average particle length for each river in surface, suspension samples, on average for river and for all rivers combined (Dalålven River is not included).

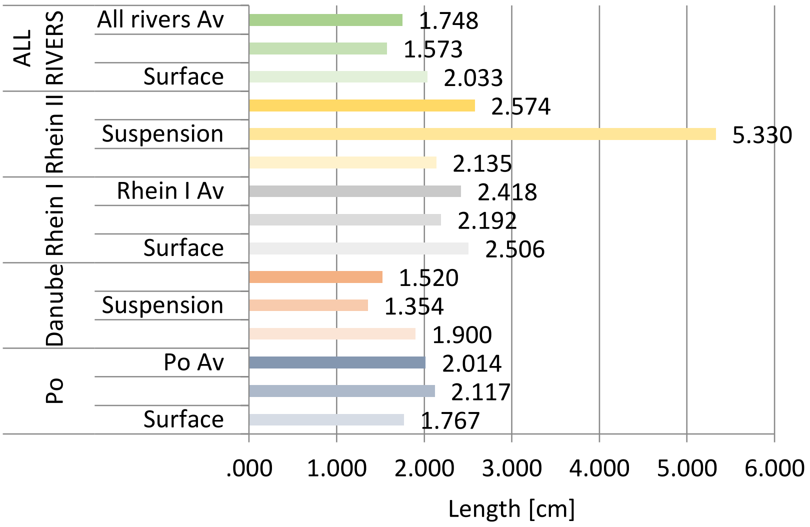
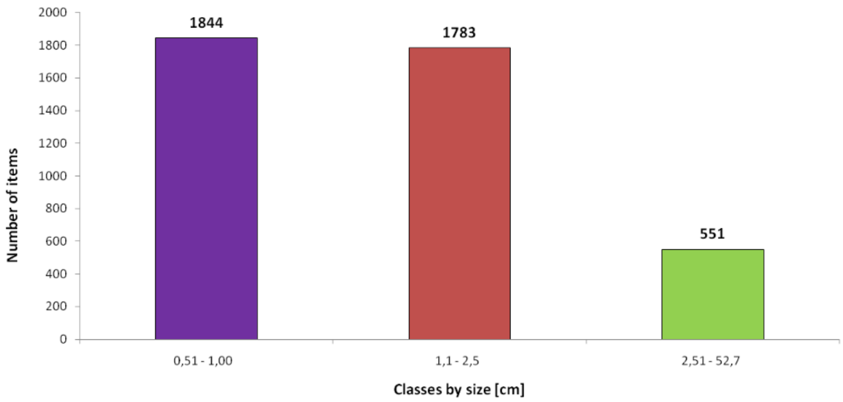


Figure A3.44: Size distribution in numbers of all particles collected according to three size classes

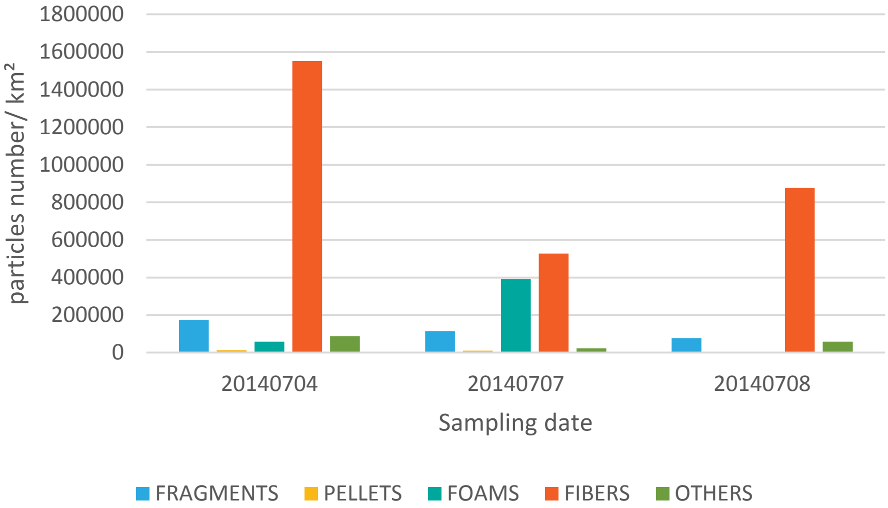


A3.7 Detailed analysis of microparticles (0.3 ≥ 5 mm)

A3.7.1 Particle number and mass per unit area for Danube, Po and Rhine River, sampling with the manta net

Figure A3.45: Number of plastic particles (a) and particles mass per km² (b) in Danube River for each sampling day and each category separately

a



b

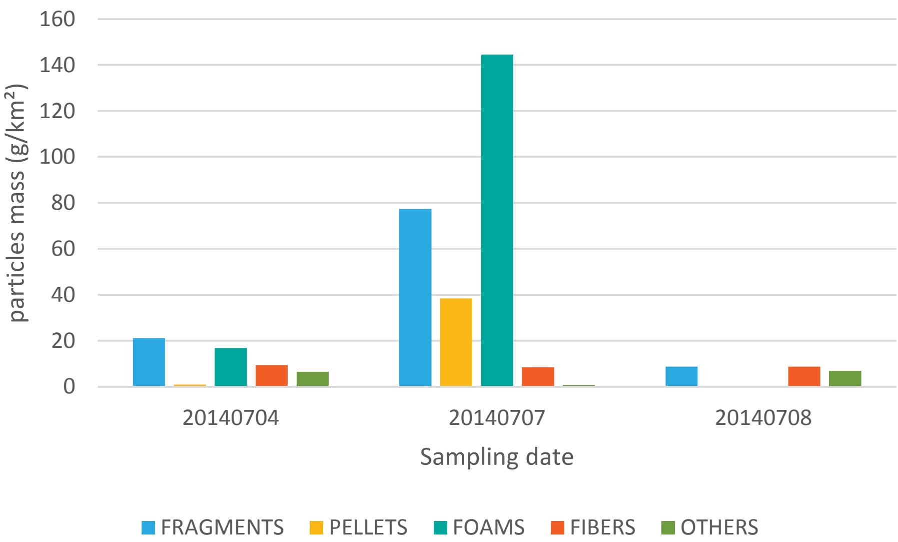
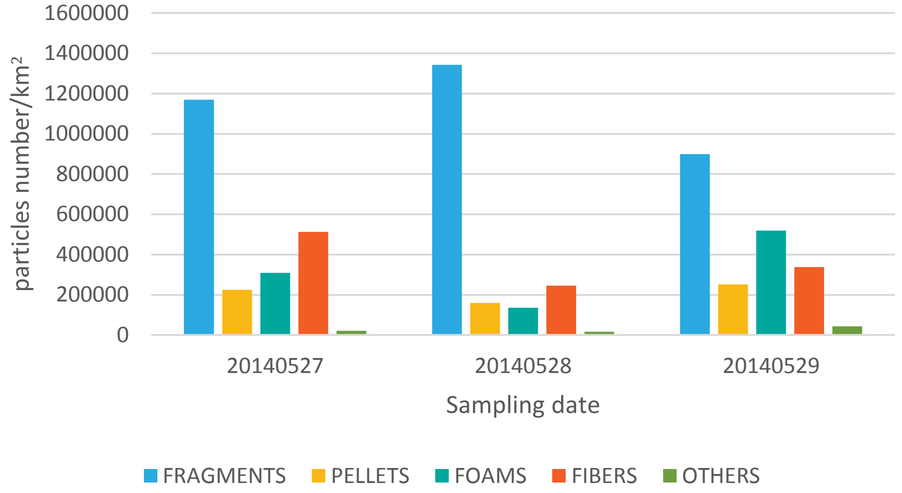


Figure A3.46: Number of plastic particles (a) and particles mass per km² (b) in Po River for each sampling day and each category separately

a



b

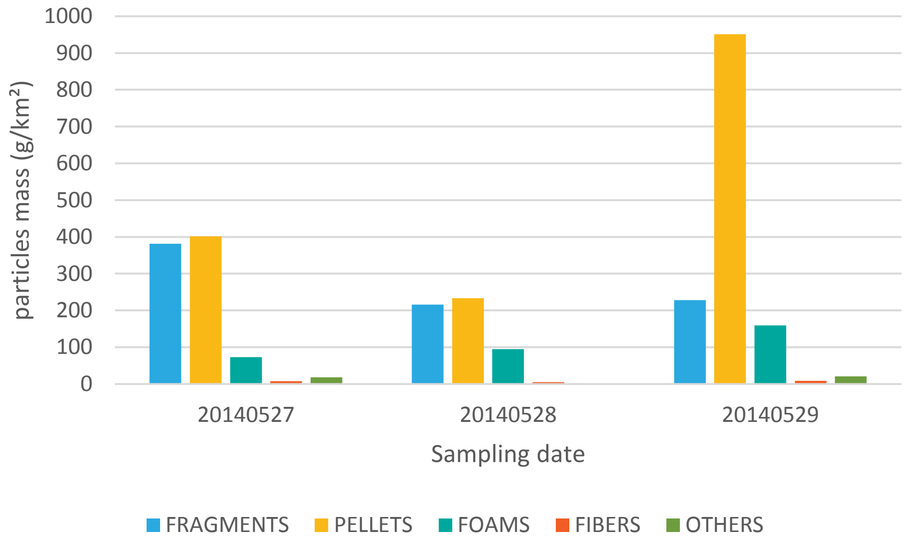
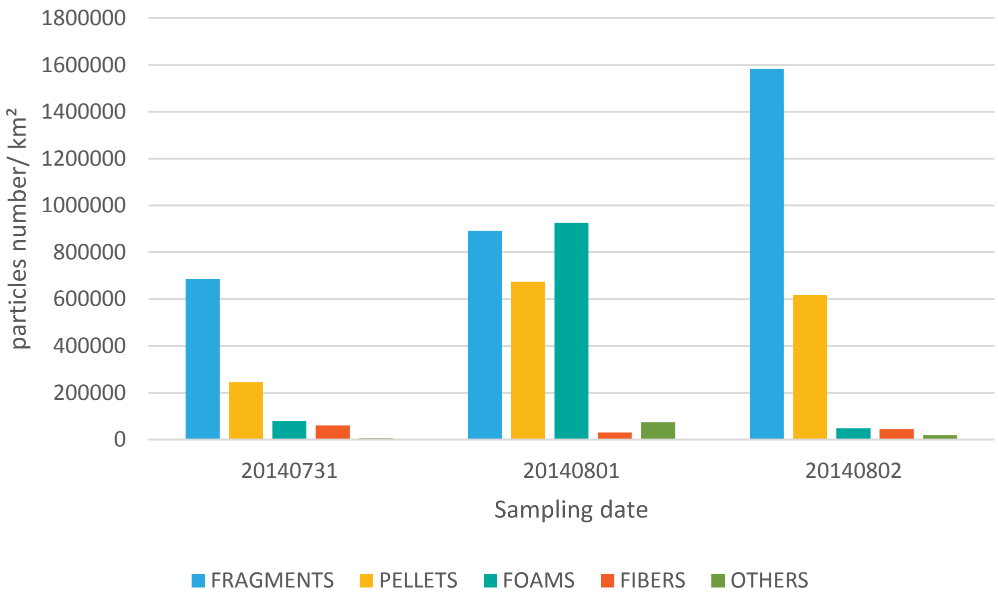
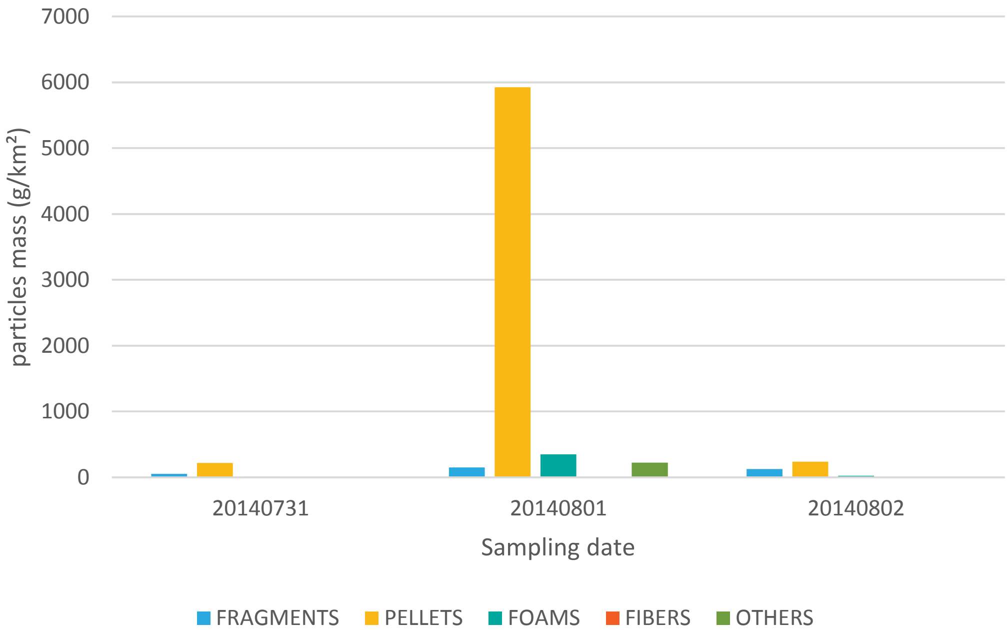


Figure A3.47: Number of plastic particles (a) and particles mass per km² (b) for the 1st sampling on the Rhine River (August 2014) for each sampling day and each category separately

a



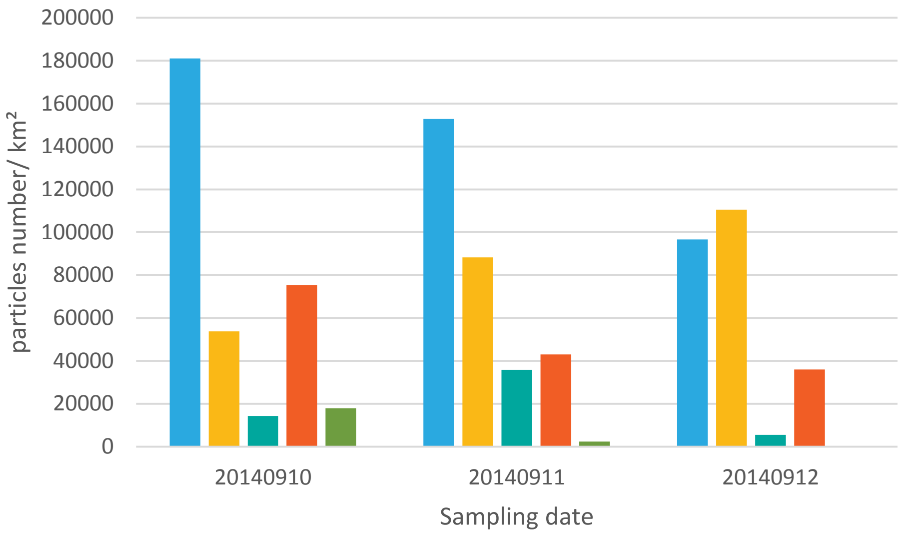
b



A3.7.2 Results of particles and mass for Rhine the second sampling and comparison with the first sampling

Figure A3.48: Number of plastic particles (a) and particles mass per km^2 (b) for the 2nd sampling on the Rhine River (September 2014) for each sampling day and each category separately

a



b

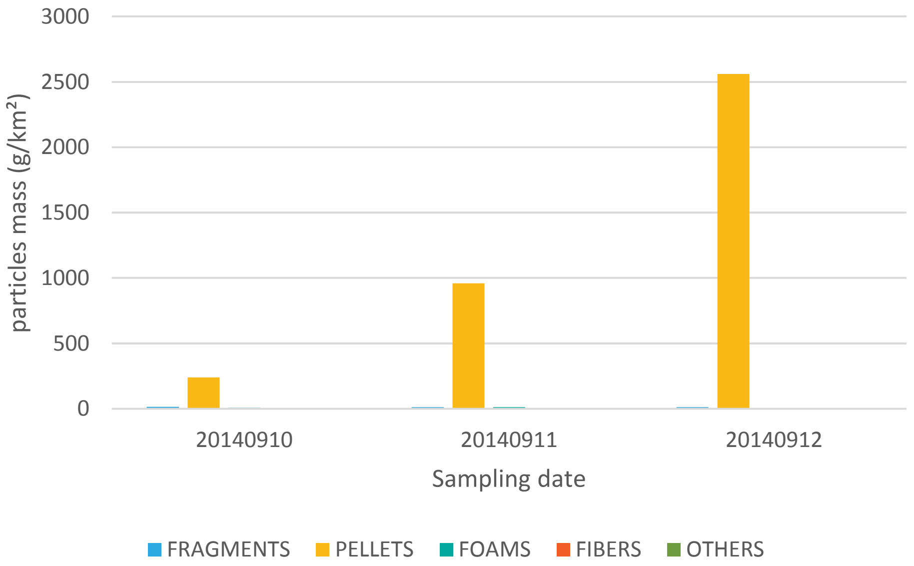
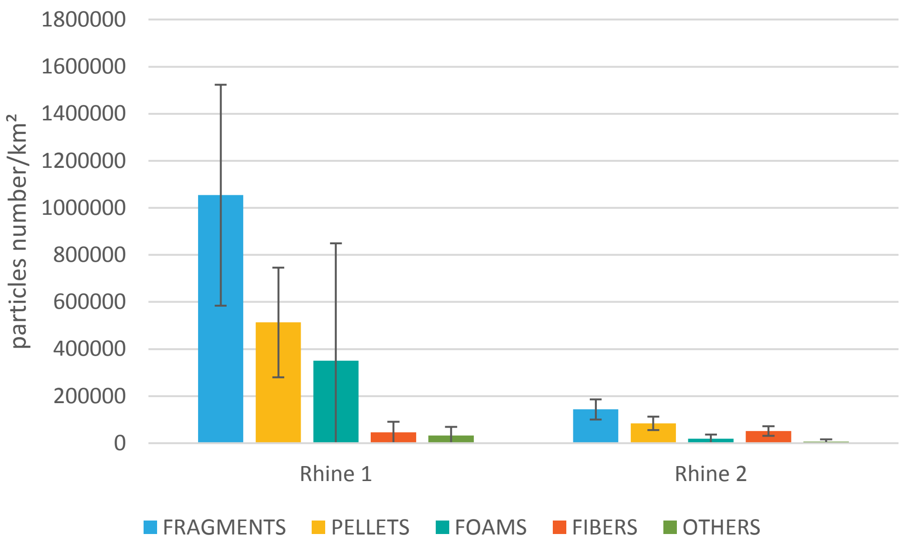
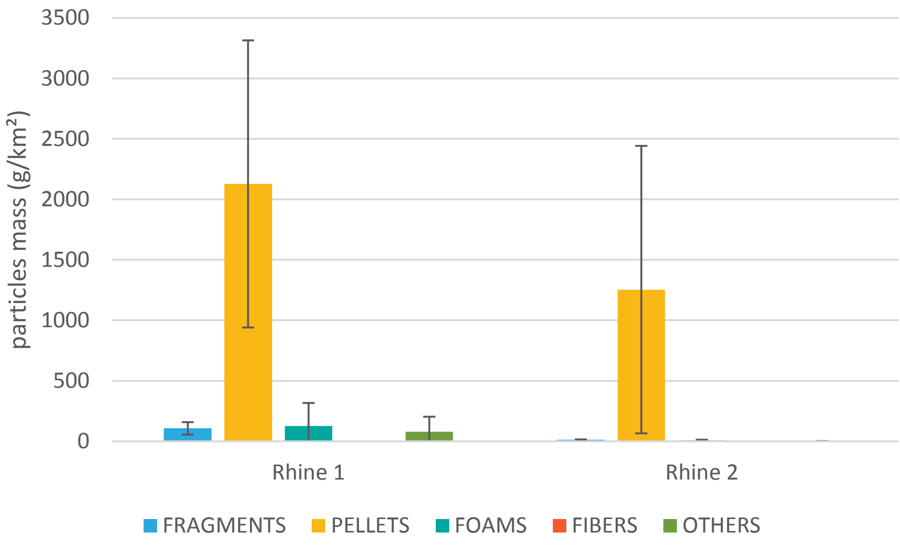


Figure A3.49: Comparison in particles number (a) and particles mass per km² (b) between 1st and 2nd sampling on the Rhine River, for each category separately

a



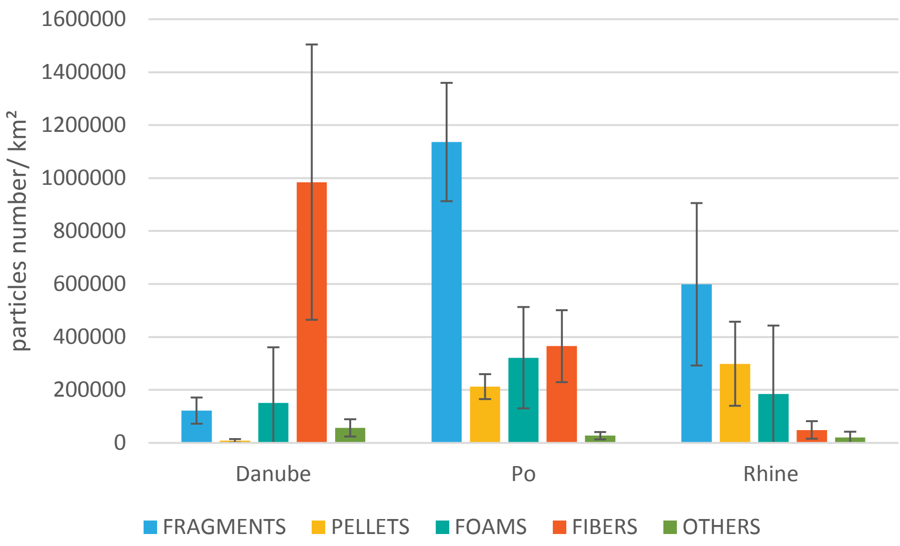
b



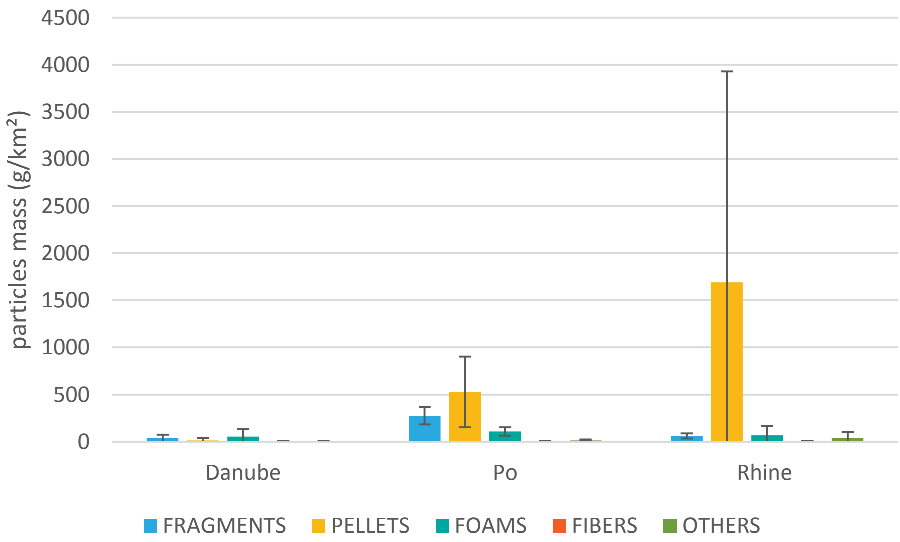
A3.7.3 Comparison between Danube, Po and Rhine in particle number and particle mass per unit area

Figure A3.50: Comparison of particles number (a) and mass (b) normalized per km² among Danube, Po and Rhine River.

a



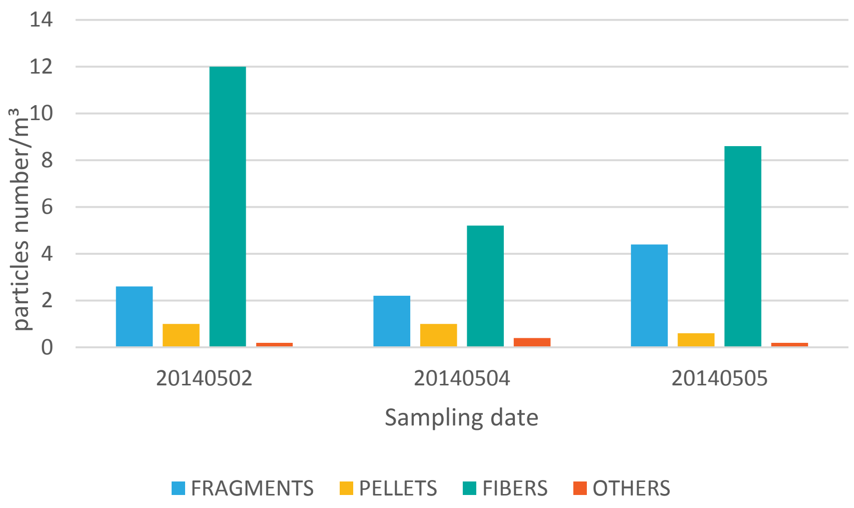
b



A3.7.4Results of particles and mass per unit volume for Dalålven and Po River, sampling with the pump

Figure A3.51: Number of plastic particles (a) and particles mass (b) per km² in Dalålven River, sampling with the pump, for each sampling day and each category separately

a



b

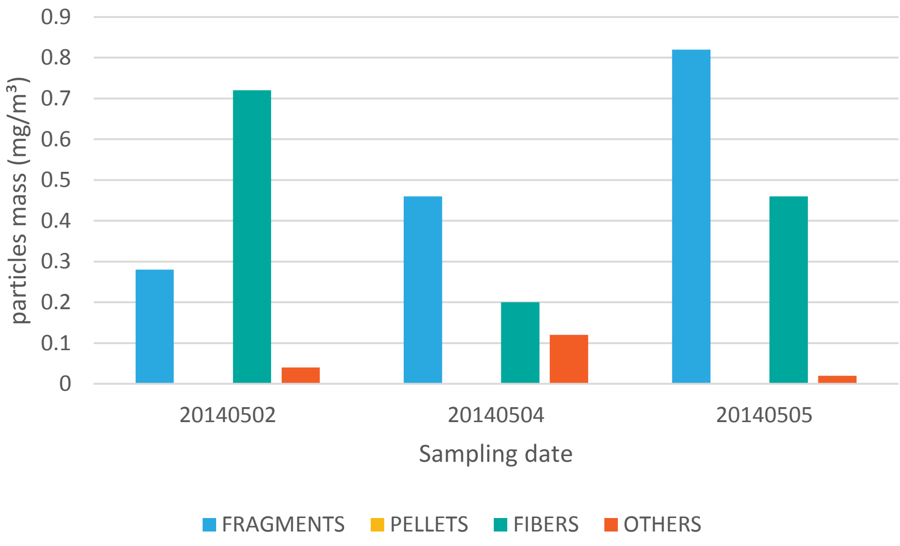
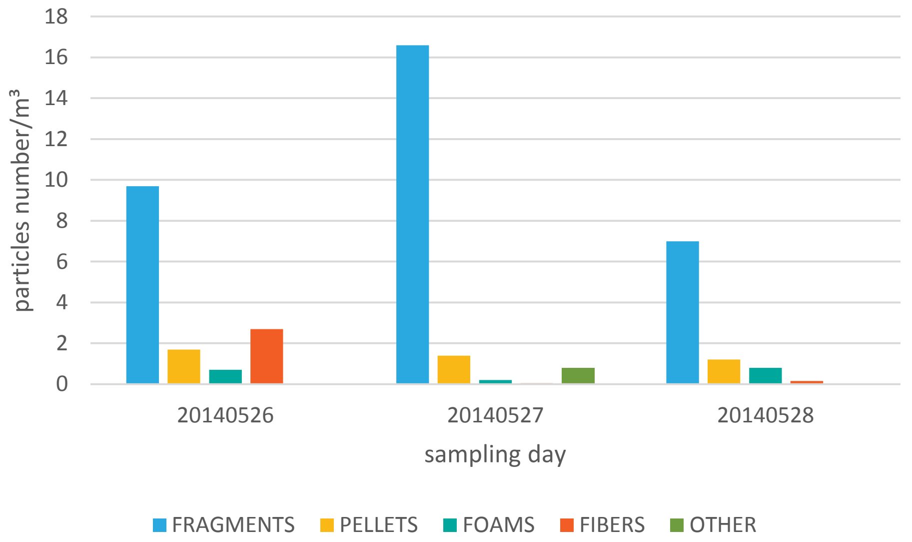
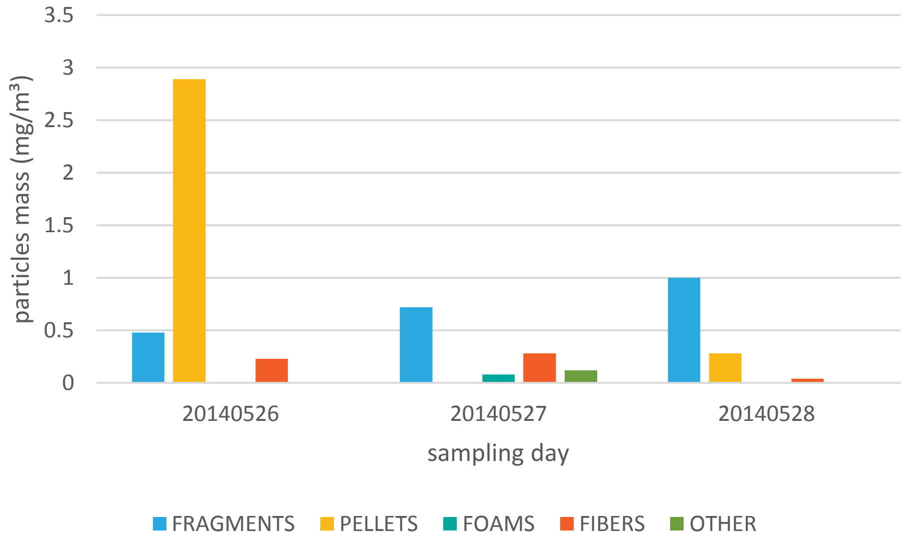


Figure A3.52: Number of plastic particles (a) and particles mass (b) per km² in Po River, sampling with the pump, for each sampling day and each category separately

a



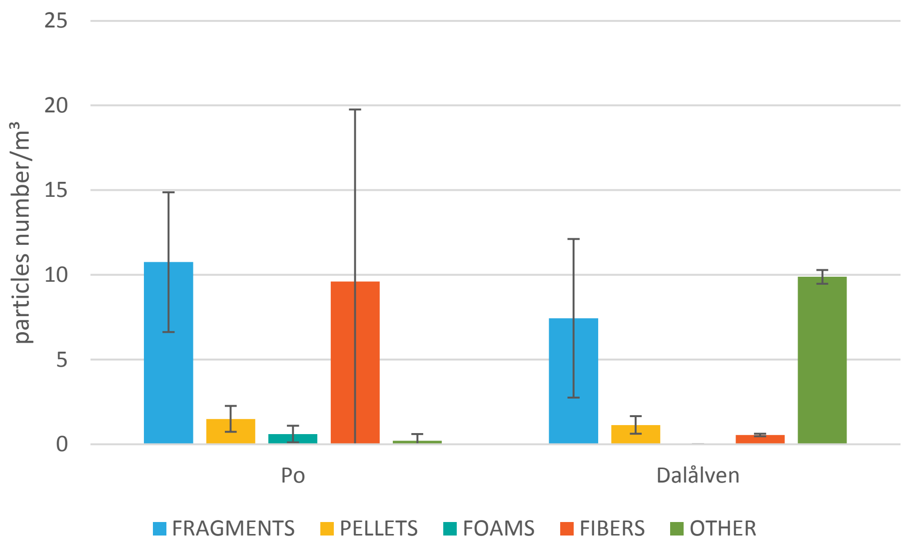
b



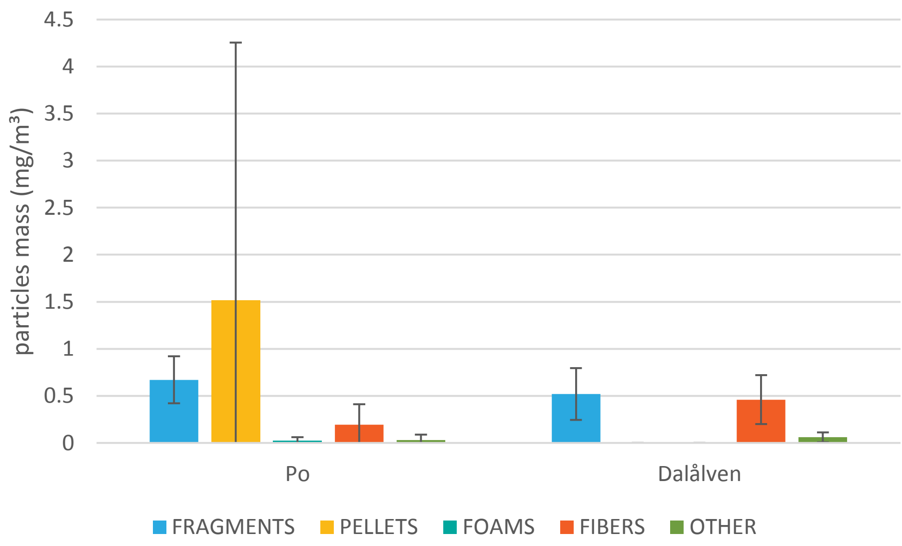
A3.7.6 Comparison between Dalålven and Po in particle number and particle mass per unit area

Figure A3.53: Comparison of particles number (a) and mass (b) normalized per m^3 among Dalåven and Po River

a



b



A3.8 Chemical Analysis of Microlitter

Figure A3.54: Chemical analysis of particles from Danube River, sampling with manta net method (a – fragments; b- pellets; c – foams; d – fibers) (ABS - Acrylonitrile butadiene styrene; PE – Polyethylene; PP – Polypropylene; iPP/EPR – Polypropylene/ethylene-propylene; PA – Polyamide; WOOL + PP = 3 : 2 – Wool + polypropylene mixture; PET – Polyethylene terephthalate; PS – Polystyrene)

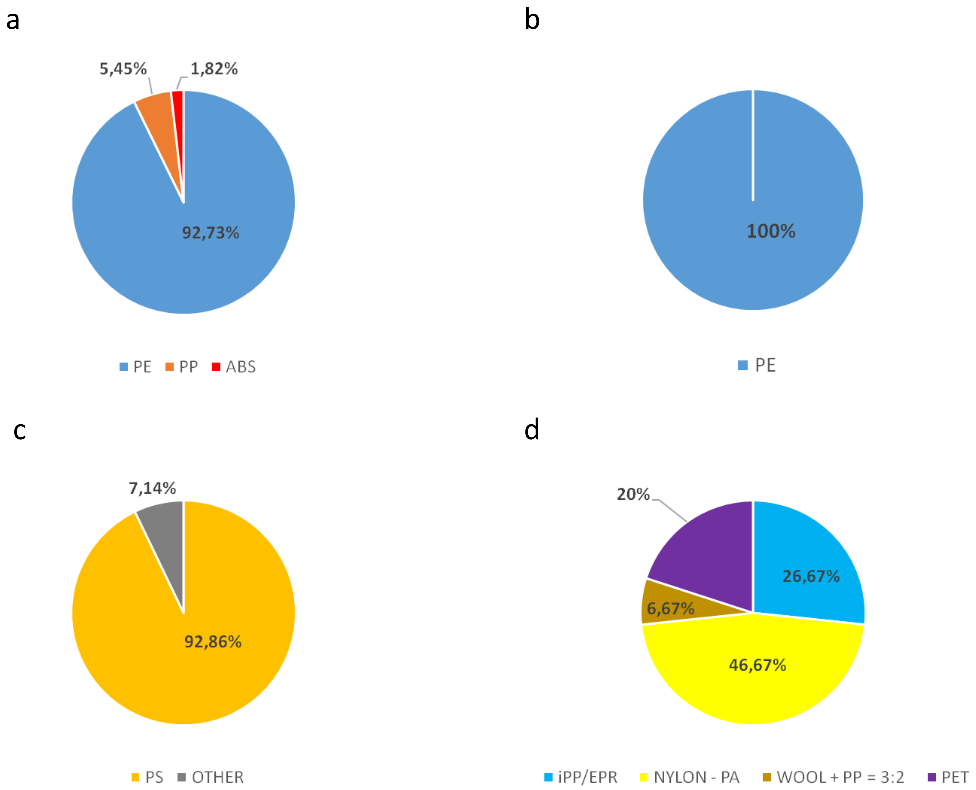


Figure A3.55: Chemical analysis of particles from Po River, sampling with manta net method (a – fragments; b- pellets; c – foams; d – fibers) (PE – Polyethylene; PP – Polypropylene; iPP/EPR – Polypropylene/ethylene-propylene; PA – Polyamide; HDPE – High density polyethilene; PO – Polyolefine; PVC – Polyvinyl chloride; WOOL + PP = 3 : 2 – Wool + polypropylene mixture; PET – Polyethylene terephthalate; PS – Polystyrene; PU – Polyurethane)

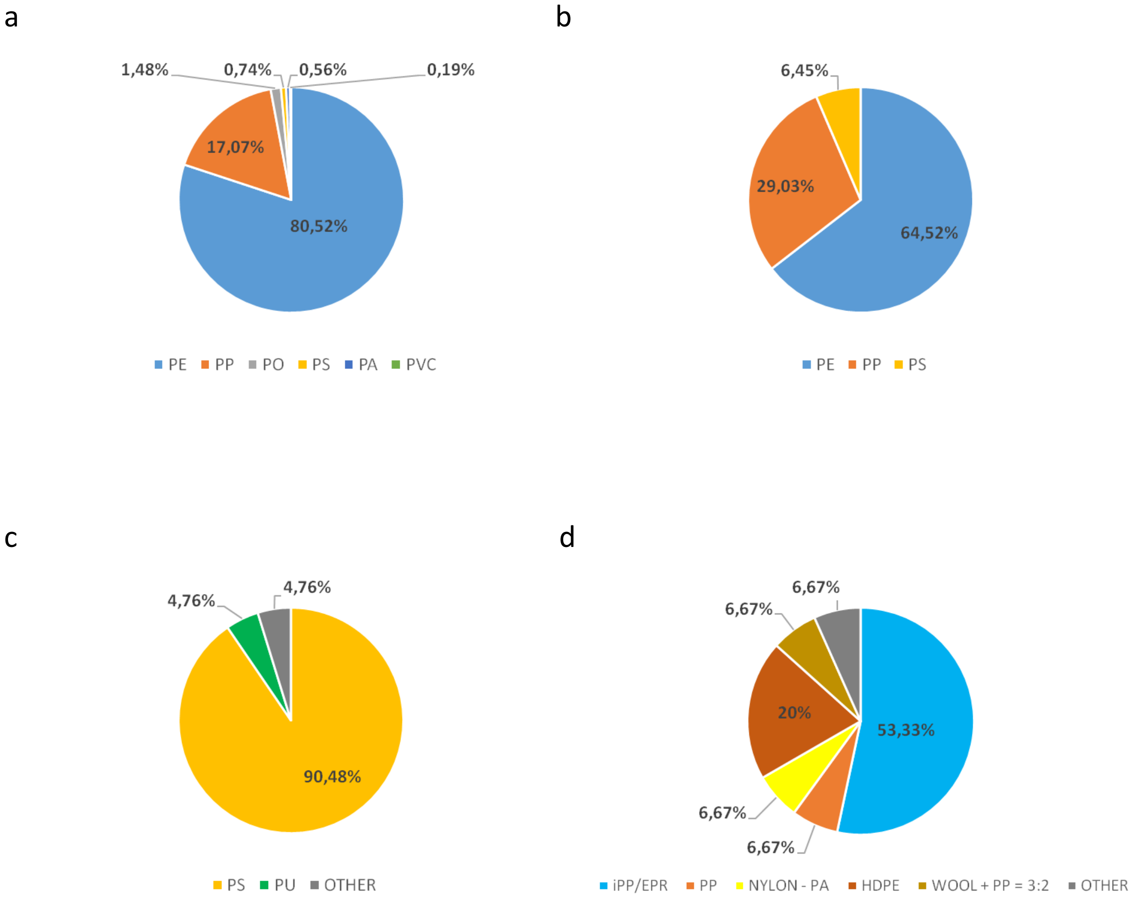


Figure A3.56: Chemical analysis of particles from Rhine River, the 2nd sampling with manta net method (a – fragments; b- pellets; c – foams; d – fibers) (PE – Polyethylene; PP – Polypropylene; iPP/EPR – Polypropylene/ethylene-propylene; PO – Polyolefine; WOOL + PP = 3 : 2 – Wool + polypropylene mixture; PS – Polystyrene; PVS – Polyvinyl stearate)

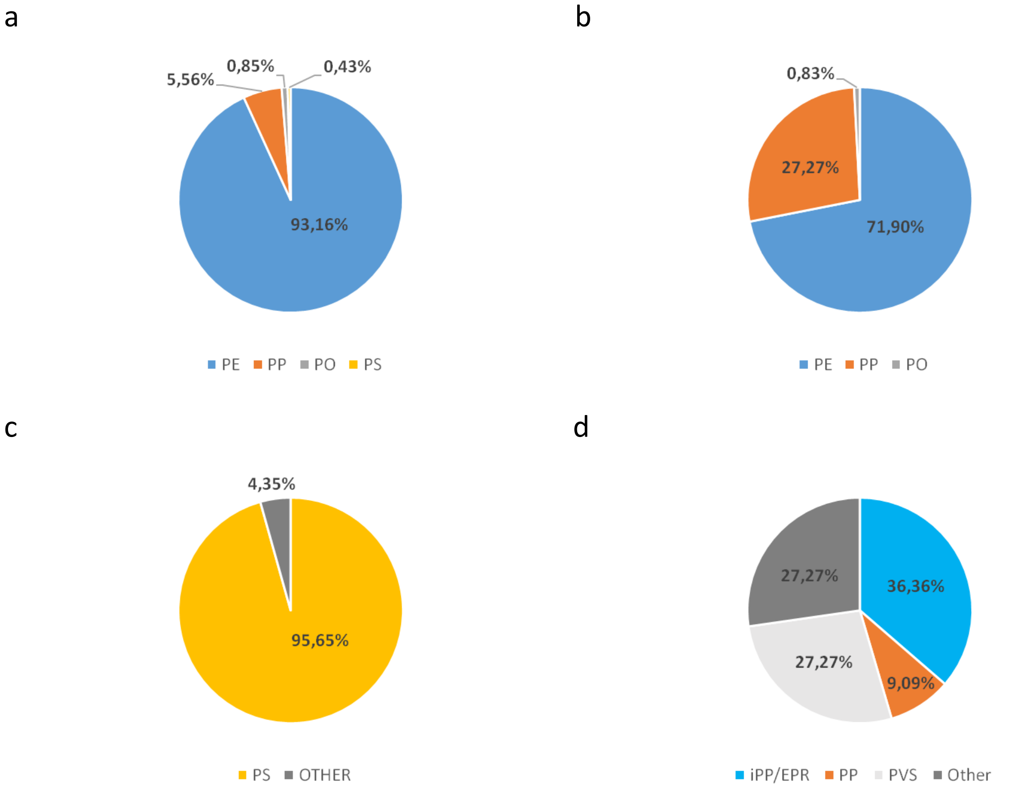


Figure A3.57: Chemical analysis of particles from Rhine River, the 3rd sampling with manta net method (a – fragments; b- pellets; c – foams; d – fibers) (PE – Polyethylene; PP – Polypropylene; PS – Polystyrene; PVC – Polyvinyl chloride; iPP/EPR – Polypropylene/ethylene-propylene; HDPE – High density polyethylene; WOOL + PP = 3 : 2 – Wool + polypropylene mixture; PET – Polyethylene terephthalate;)

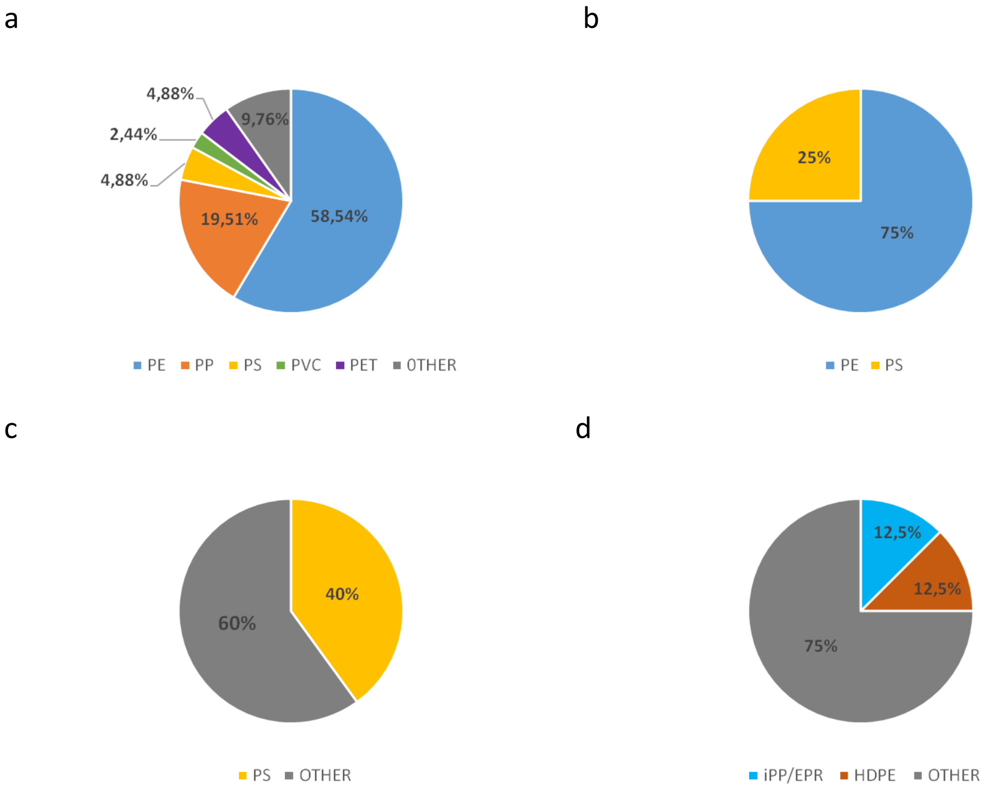
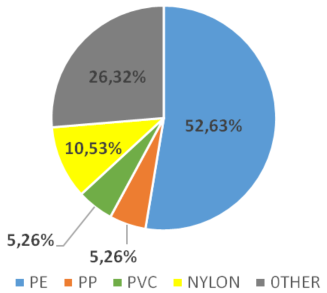
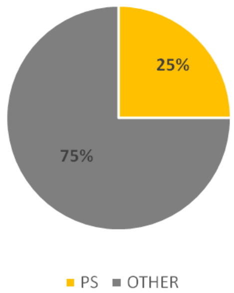


Figure A3.58: Chemical analysis of particles from Dalålven River, sampling with pump – manta net method (a – fragments; b- pellets; c – fibers) (PE – Polyethylene; PP – Polypropylene; PVC – Polyvinyl chloride; iPP/EPR – Polypropylene/ethylene-propylene; PA – Polyamide; WOOL + PP = 3 : 2 – Wool + polypropylene mixture; PS – Polystyrene; PU – Polyurethane; PVA – Polyvinyl acetate)

a



b



c

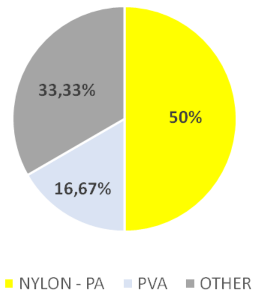


Figure A3.59: Chemical analysis of particles from Po River, sampling with the pump - manta net method (a – fragments; b- pellets) (PE – Polyethylene; PVC – Polyvinyl chloride; PA – Polyamide; PS – Polystyrene)

a b

A3.9 Data tables

Table A3.26: Average data for numbers and mass of particles for first 5 (numbers) or 3 (mass) sampling days, sampling with manta net method

Manta trawl	Number of particles		Weight of particles (g)		Nr / km^2		g / km^2	
	Average	STDEV	Average	STDEV	Average	STDEV	Average	STDEV
PO	818,4	417,3396	0,4145	0,0733	2043069,8	336637,4	782,1	138,23
DANUBE	381,6	245,70	0,0449	0,0529	1061126,2	530066,4	116,2	133,49
RHINE 2	648,8	400,21	0,9513	1,4278	1773392,8	957726	2445,5	3641,046
RHINE 3	142,3	54,20	0,0167	0,0017	311660,3	54269,11	39,2	11,90

Table A3.27: Average data for numbers and mass of particles for first 3 sampling days, sampling with pump - manta net method

Pump	Number of particles		Weight of particles (g)		Nr / m^3		mg / m^3	
	Average	STDEV	Average	STDEV	Average	STDEV	Average	STDEV
PO	101,4	65,85438	0,0102	0,0068	20,3	13,17088	0,0020	0,0014
DÅLALVEN	22,7	15,06	0,0026	0,0008	4,5	3,011164	0,0005	0,0002

Table A3.28: Average data for numbers and mass of particles for all sampling days, sampling with both WFW nets (surface and suspension)

WFW = surface+suspension	**Number of particles**		**Weight of particles**	
	Average	STDEV	Average	STDEV
DÅLALVEN	4		0,0076	
PO	114,2	33,21	10,15	7,38
DANUBE	1355	2555,98	68,86	120,34
RHINE 2	59,3	55,27	69,03	173,33
RHINE 3	29,2	22,68	7,55	8,92

Table A3.29: Average data for numbers and mass of particles for all sampling days, sampling with WFW surface net

WFW SURFACE	**Number of particles**		**Weight of particles (g)**		**Nr / km²**		**g / km²**	
	Average	STDEV	Average	STDEV	Average	STDEV	Average	STDEV
DÅLALVEN	4	0	0,0076					
PO	33,6	13,65	3,94	2,78	6464,8	2584,93	752,2	510,1
DANUBE	588,8	1314,55	54,82	109,79	74464,2	150731,7	7553,6	12299,43
RHINE 2	42,9	51,72	68,52	172,47	9874,5	11904,88	15859,2	39925,13
RHINE 3	25,2	20,33	5,40	7,59	8375,4	7938,63	1542,3	1648,67

Table A3.30: Average data for numbers and mass of particles for all sampling days, sampling with WFW suspension net

WFW SUSPENSION	Number of particles		Weight of particles (g)		Nr / m^3		g / m^3	
	Average	STDEV	Average	STDEV	Average	STDEV	Average	STDEV
DÅLALVEN								
PO	80,6	22,57	6,21	6,35	0,0309	0,0089	0,0025	0,0028
DANUBE	766,2	1243,62	14,04	18,81	0,2400	0,2668	0,0053	0,0077
RHINE 2	16,4	13,13	0,52	0,86	0,0077	0,0062	0,0002	0,0004
RHINE 3	4	4,59	2,15	6,24	0,0020	0,0018	0,0008	0,0023

Table A3.31: Raw data, number of particles and mass, and normalized data for each sampling day separately for all sampling methods used for each river (a – Po, b – Dalalven, c – Danube, d – Rhine 2nd sampling, e – Rhine 3rd sampling)

a

	WFW - SURFACE				WFW - SUSPENSION				MANTA NET				PUMP - MANTA			
SAMPLES ID	**Nr SUM**	**g SUM**	**Nr / km2**	**g / km2**	**Nr SUM**	**g SUM**	**Nr / m3**	**g / m3**	**Nr SUM**	**g SUM**	**Nr / km2**	**g / km2**	**Nr SUM**	**g SUM**	**Nr / m3**	**g / m3**
PO1													74	0,0181	14,8	0,00362
PO2									1385	0,467	2614194	881,13	216	0,006	43,2	0,0012
PO3	38	2,47	7544,17	491,3	111	2,91	0,044	0,0012	1113	0,3308	1847610	624,15	89	0,0066	17,8	0,00132
PO4									670	0,4457	2056476	840,94				
PO5	53	8,08	9515,26	1450,29	97	2,98	0,035	0,0011	382		1929293		48		9,6	
PO6	20	3,67	3590,66	658,42	58	4,92	0,021	0,0018	542		1767776		80		16	
PO7	21	0,66	3938,49	123,57	73	2,78	0,027	0,001								
PO8	36	4,83	7735,28	1037,54	64	17,45	0,028	0,0075								
Average	**33,6**	**3,94**	**6464,77**	**752,22**	**80,6**	**6,21**	**0,031**	**0,0025**	**818,4**	**0,4145**	**2043069,80**	**782,08**	**101,4**	**0,0102**	**20,2800**	**0,0020**
STDEV	**13,65**	**2,78**	**2584,93**	**510,10**	**22,57**	**6,35**	**0,009**	**0,00**	**417,34**	**0,07**	**336637,40**	**138,23**	**65,85**	**0,01**	**13,17**	**0,00**

b

	WFW - SURFACE				WFW - SUSPENSION				MANTA NET				PUMP - MANTA			
SAMPLES ID	**Nr SUM**	**g SUM**	**Nr / km2**	**g / km2**	**Nr SUM**	**g SUM**	**Nr / m3**	**g / m3**	**Nr SUM**	**g SUM**	**Nr / km2**	**g / km2**	**Nr SUM**	**g SUM**	**Nr / m3**	**g / m3**
DL1													51	0,0031	10,2	0,00062
DL1													29	0,0021	5,8	0,00042
DL2													22	0,0027	4,4	0,00054
DL2													22	0,0012	4,4	0,00024
DL3													41	0,0034	8,2	0,00068
DL3						ANY PARTICLE					NO SAMPLING		27	0,0031	5,4	0,00062
DL4													12		2,4	
DL4													12		2,4	
DL5													9		1,8	
DL5													2		0,4	
DL7	4	0,0076														
Average	**4**	**0,0076**											**22,7**	**0,0026**	**4,5400**	**0,0005**
STDEV													**15,06**	**0,00**	**3,01**	**0,00**

c

	WFW - SURFACE				WFW - SUSPENSION				MANTA NET				PUMP - MANTA			
SAMPLES ID	**Nr SUM**	**g SUM**	**Nr / km2**	**g / km2**	**Nr SUM**	**g SUM**	**Nr / m3**	**g / m3**	**Nr SUM**	**g SUM**	**Nr / km2**	**g / km2**	**Nr SUM**	**g SUM**	**Nr / m3**	**g / m3**
DN1	12	2,52	4385,96	922,40497	31	0,30	0,023	0,0002	776	0,0226	1885326	54,85				
DN2	38	7,98	9004,74	1890,4265	291	42,41	0,138	0,0201	443	0,1053	1132413	269,31				
DN3	46	8,87	18246,73	3517,5724	278	1,68	0,221	0,0013	279	0,0067	1015284	24,36	NO SAMPLING			
DN4	126	9,29	24798,27	1828,3606	338	3,75	0,133	0,0015	273		831810					
DN5	40	21,69	8580,01	4652,4882	366	2,51	0,157	0,0011	137		440798					
DN6	3271	278,55	381769,37	32510,598	3293	33,62	0,769	0,0078								
Average	**588,8**	**54,82**	**74464,18**	**7553,6417**	**766,2**	**14,04**	**0,240**	**0,0053**	**381,6**	**0,0449**	**1061126,20**	**116,18**				
STDEV	**1314,55**	**109,79**	**150731,69**	**12299,43**	**1243,62**	**18,81**	**0,267**	**0,0077**	**245,70**	**0,05**	**530066,42**	**133,49**				

d

	WFW - SURFACE				WFW - SUSPENSION				MANTA NET				PUMP - MANTA			
SAMPLES ID	**Nr SUM**	**g SUM**	**Nr / km2**	**g / km2**	**Nr SUM**	**g SUM**	**Nr / m3**	**g / m3**	**Nr SUM**	**g SUM**	**Nr / km2**	**g / km2**	**Nr SUM**	**g SUM**	**Nr / m3**	**g / m3**
RH1	30	1,15	7142,86	274,55	42	0,338	0,020	0,0002	418	0,107	1140207	292,643				
RH2									1066	2,600	2724949	6649,361				
RH3	25	14,09	5787,04	3261,16	21	0,446	0,010	0,0002	871	0,147	2341398	394,355				
RH4	11	2,14	2546,30	494,33	9	0,120	0,004	0,0001	819		2237705					
RH5									70		422705		NO SAMPLING			
RH6	19	0,66	6397,31	221,65	4	0,061	0,003	0,0000								
RH7	16	0,72	3555,56	159,78	14	0,162	0,006	0,0001								
RH8	158	459,50	36574,07	106365,49	20	2,446	0,009	0,0011								
RH9	41	1,37	7118,06	237,60	5	0,036	0,002	0,0000								
Average	**42,9**	**68,52**	**9874,45**	**15859,22**	**16,4**	**0,516**	**0,008**	**0,0002**	**648,8**	**0,951**	**1773392,80**	**2445,453**				
STDEV	**51,72**	**172,47**	**11904,88**	**39925,13**	**13,13**	**0,864**	**0,006**	**0,0004**	**400,21**	**1,428**	**957726,05**	**3641,046**				

e

	WFW - SURFACE				WFW - SUSPENSION				MANTA NET				PUMP - MANTA			
SAMPLES ID	**Nr SUM**	**g SUM**	**Nr / km2**	**g / km2**	**Nr SUM**	**g SUM**	**Nr / m3**	**g / m3**	**Nr SUM**	**g SUM**	**Nr / km2**	**g / km2**	**Nr SUM**	**g SUM**	**Nr / m3**	**g / m3**
RH10	16	2,74	5925,93	1015,56	4	0,142	0,0030	0,0001	199	0,0154	356630,82	27,60	NO SAMPLING			
RH11	4	2,39	1433,69	858,06	2	0,020	0,0014	0,0000	137	0,0162	326968,97	38,66				
RH12	26	3,06	14444,44	1699,89	0	0,000	0,0000	0,0000	91	0,0186	251381,22	51,38				
RH13	10	0,14	5555,56	78,06	0	0,000	0,0000	0,0000								
RH14	2	0,04	740,74	13,37	0	0,000	0,0000	0,0000								
RH15	49	6,62	27222,22	3675,83	4	0,026	0,0044	0,0000								
RH16	23	1,82	4259,26	337,56	4	19,876	0,0015	0,0074								
RH17	25	1,00	3968,25	159,21	15	1,373	0,0048	0,0004								
RH18	68	24,60	12592,59	4556,30	8	0,037	0,0030	0,0000								
RH19	29	11,54	7611,55	3029,00	3	0,038	0,0016	0,0000								
Average	**25,2**	**5,40**	**8375,42**	**1542,28**	**4,0**	**2,151**	**0,0020**	**0,0008**	**142,3333**	**0,0167**	**311660,34**	**39,21**				
STDEV	**20,33**	**7,59**	**7938,63**	**1648,67**	**4,59**	**6,242**	**0,0018**	**0,0023**	**54,20**	**0,00**	**54269,11**	**11,90**				

Table A3.32: Fragment microparticles analysis of number, mass and chemical composition of samples collected with manta net in the first three sampling days

River		Danube			Po			Rhine - 2nd sampling			Rhine - 3rd sampling		
	Sample id	DN1T	DN2T	DN3T	PO2T	PO3T	PO4T	RH1T	RH2T	RH3T	RH10T	RH11T	RH12T
Particles number	Number of pieces	72	45	21	620	808	293	252	349	589	101	64	35
	number/m²	0,175	0,115	0,076	1,170	1,342	0,899	0,687	0,893	1,583	0,181	0,153	0,097
	number/km²	174757,28	115089,51	76363,64	1170000,00	1342192,69	898773,01	686648,50	892583,12	1583333,33	181003,58	152744,63	96685,08
Particles mass	Mass all particles (g)	0,0087	0,0302	0,0024	0,202	0,13	0,0742	0,0184	0,0581	0,0455	0,0087	0,0054	0,0042
	Mass all particles (mg)	8,7	30,2	2,4	202	130	74,2	18,4	58,1	45,5	8,7	5,4	4,2
	mg/m²	0,021	0,077	0,009	0,381	0,216	0,228	0,050	0,149	0,122	0,016	0,013	0,012
	g/km²	21,12	77,24	8,73	381,13	215,95	227,61	50,14	148,59	122,31	15,59	12,89	11,60
Chemical analysis	N of pieces identified	23	23	8	241	164	134	92	47	95	20	11	10
	% of identified pieces	31,94%	51,11%	38,10%	38,87%	20,30%	45,73%	36,51%	13,47%	16,13%	19,80%	17,19%	28,57%
	PE	23	20	8	189	125	120	88	41	89	8	8	8
	PP	0	3	0	44	38	10	2	6	5	5	2	1
	PO	0	0	0	5	0	3	1	0	1	0	0	0
	PS	0	0	0	0	3	1	1	0	0	1	1	0
	PA	0	0	0	3	0	0	0	0	0	0	0	0
	PVC	0	0	0	0	0	1	0	0	0	1	0	0
	ABS	0	0	0	0	0	0	0	0	0	0	0	0
	PET	0	0	0	0	0	0	0	0	0	2	0	0
	NYLON	0	0	0	0	0	0	0	0	0	0	0	0
	0THER	0	0	0	0	0	0	0	0	0	3	0	1

Table A3.33: Fragment microparticles analysis of number, mass and chemical composition of samples collected with pump - manta net method in the first three sampling days

River		Dalalven						Po			
	Sample id	**DL1P1**	**DL1P2**	**DL2P1**	**DL2P2**	**DL3P1**	**DL3P2**	**PO1P1**	**PO1P2**	**PO2P**	**PO3P**
Particles number	**Number of pieces**	7	6	6	5	13	9	51	46	83	35
	number/m³	1,4	1,2	1,2	1	2,6	1,8	10,2	9,2	16,6	7
Particles mass	**Mass all particles (g)**	<0,0001	0,0014	0,0023	<0,0001	0,0016	0,0025	0,0022	0,0026	0,0036	0,005
	Mass all particles (mg)	0	1,4	2,3	0	1,6	2,5	2,2	2,6	3,6	5
	mg/m³	0	0,28	0,46	0	0,32	0,5	0,44	0,52	0,72	1
Chemical analysis	**N of pieces identified**	4	5	4	0	6	0	3	5	4	5
	% of identified pieces	57,14%	83,33%	66,67%	0,00%	46,15%	0,00%	5,88%	10,87%	4,82%	14,29%
	PE	2	1	3	0	4	0	2	1	3	4
	PP	0	0	0	0	1	0	0	0	0	0
	PO	0	0	0	0	0	0	0	0	0	0
	PS	0	0	0	0	0	0	0	0	0	0
	PA	0	0	0	0	0	0	0	0	0	0
	PVC	0	1	0	0	0	0	0	1	0	0
	ABS	0	0	0	0	0	0	0	0	0	0
	PET	0	0	0	0	0	0	0	0	0	0
	NYLON	1	0	0	0	1	0	0	0	0	0
	0THER	1	3	1	0	0	0	1	3	1	1

Table A3.34: Pellet microparticles analysis of number, mass and chemical composition of samples collected with manta net in the first three sampling days

River		Danube		Po			Rhine - 2nd sampling			Rhine - 3rd sampling		
	Sample id	DN1T	DN2T	PO2T	PO3T	PO4T	RH1T	RH2T	RH3T	RH10T	RH11T	RH12T
Particles number	Number of pieces	5	4	119	96	82	90	264	230	30	37	40
	number/m²	0,01	0,01	0,22	0,16	0,25	0,25	0,68	0,62	0,05	0,09	0,11
	number/km²	12135,92	10230,18	224528,3	159468,4	251533,7	245231,6	675191,8	618279,6	53763,44	88305,49	110497,2
Particles mass	Mass all particles (g)	0,0004	0,015	0,2128	0,1406	0,3101	0,0798	2,3178	0,0878	0,0012	0,0048	0,0128
	Mass all particles (mg)	0,4	15	212,8	140,6	310,1	79,8	2317,8	87,8	1,2	4,8	12,8
	mg/m²	0,001	0,038	0,402	0,234	0,951	0,217	5,928	0,236	0,240	0,960	2,560
	g/km²	0,97	38,36	401,51	233,55	951,23	217,44	5927,88	236,02	240,00	960,00	2560,00
Chemical analysis	N of pieces identified	0	3	14	4	13	6	110	5	2	1	1
	% of identified pieces	0,00%	75,00%	11,76%	4,17%	15,85%	6,67%	41,67%	2,17%	6,67%	2,70%	2,50%
	PE	0	3	8	3	9	5	78	4	1	1	1
	PP	0	0	4	1	4	1	31	1	0	0	0
	PO	0	0	0	0	0	0	1	0	0	0	0
	PS	0	0	2	0	0	0	0	0	1	0	0
	PA	0	0	0	0	0	0	0	0	0	0	0
	OTHER	0	0	0	0	0	0	0	0	0	0	0

Table A3.35: Pellet microparticles analysis of number, mass and chemical composition of samples collected with pump - manta net method in the first three sampling days

River		Dalalven			Po			
Particles number	Sample id	DL1P1	DL2P1	DL3P1	PO1P1	PO1P2	PO2P	PO3P
	Number of pieces	5	5	3	13	4	7	6
	number/m³	1	1	0,6	2,6	0,8	1,4	1,2
Particles mass	Mass all particles (g)	< 0,0001	< 0,0001	< 0,0001	0,0281	0,0008	< 0,0001	0,0014
	Mass all particles (mg)	<0,1	<0,1	<0,1	28,1	0,8	<0,1	1,4
	mg/m³	0	0	0	5,62	0,16	0	0,28
Chemical analysis	N of pieces identified	3	3	2	3	0	3	2
	% of identified pieces	60,00%	60,00%	66,67%	0	0	0	0
	PE	0	0	0	0	0	0	0
	PP	0	0	0	0	0	0	0
	PO	0	0	0	0	0	0	0
	PS	2	0	0	2	0	0	0
	PA	0	0	0	1	0	0	0
	OTHER	1	3	2	0	0	3	2

Table A3.36: Foam microparticles analysis of number, mass and chemical composition of samples collected with manta net in the first three sampling days

River		Danube			Po			Rhine - 2nd sampling			Rhine - 3rd sampling		
	Sample id	DN1T	DN2T	DN3T	PO2T	PO3T	PO4T	RH1T	RH2T	RH3T	RH10T	RH11T	RH12T
Particles number	Number of pieces	24	153	1	164	82	169	29	362	18	8	15	2
	number/m²	0,058	0,391	0,004	0,309	0,136	0,518	0,079	0,926	0,048	0,014	0,036	0,006
	number/km²	58252,43	391304,35	3636,36	309433,96	136212,62	518404,91	79019,07	925831,20	48387,10	14336,92	35799,52	5524,86
Particles mass	Mass all particles (g)	0,0069	0,0565	<0,0001	0,0386	0,0568	0,0518	0,0039	0,1353	0,0084	0,004	0,0051	0,0011
	Mass all particles (mg)	6,9	56,5	0	38,6	56,8	51,8	3,9	135,3	8,4	4	5,1	1,1
	mg/m²	0,017	0,145	0,000	0,073	0,094	0,159	0,011	0,346	0,023	0,007	0,012	0,003
	g/km²	16,748	144,501	0,000	72,830	94,352	158,896	10,627	346,036	22,581	7,168	12,172	3,039
Chemical analysis	N of pieces identified	5	8	1	8	5	8	3	18	2	3	5	2
	% of identified pieces	20,83%	5,23%	100,00%	4,88%	6,10%	4,73%	10,34%	4,97%	11,11%	37,50%	33,33%	100,00%
	PS	4	8	1	8	4	7	3	18	1	2	2	0
	PU	0	0	0	0	0	1	0	0	0	0	0	0
	OTHER	1	0	0	0	1	0	0	0	1	1	3	2

Table A3.37: Foam microparticles analysis of number, mass and chemical composition of samples collected with pump - manta net method in the first three sampling days

River		Po			
Particles number	Sample id	PO1P1	PO1P2	PO2P	PO3P
	Number of pieces	6	1	1	4
	number/m³	1,2	0,2	0,2	0,8
Particles mass	Mass all particles (g)	0,0001	< 0,0001	0,0004	< 0,0001
	Mass all particles (mg)	0,1	< 0,1	0,4	< 0,1
	mg/m³	0,02	0	0,08	0
Chemical analysis	N of pieces identified	0	0	0	0
	% of identified pieces	0	0	0	0
	PS	0	0	0	0
	PU	0	0	0	0
	OTHER	0	0	0	0

Table A3.38: Fibre microparticles analysis of number, mass and chemical composition of samples collected with manta net in the first three sampling days

River		Danube			Po			Rhine - 2nd sampling			Rhine - 3rd sampling		
	Sample id	DN1T	DN2T	DN3T	PO2T	PO3T	PO4T	RH1T	RH2T	RH3T	RH10T	RH11T	RH12T
Particles number	Number of pieces	639	206	241	272	148	110	22	12	17	42	18	13
	number/m²	1,55	0,53	0,88	0,51	0,25	0,34	0,06	0,03	0,05	0,08	0,04	0,04
	number/km²	1550971	526854,2	876363,6	513207,5	245847,2	337423,3	59945,5	30690,54	45698,92	75268,82	42959,43	35911,6
Particles mass	Mass all particles (g)	0,0039	0,0033	0,0024	0,0041	0,003	0,0028	0,0029	0,0016	0,0019	0,0007	0,0009	0,0005
	Mass all particles (mg)	3,9	3,3	2,4	4,1	3	2,8	2,9	1,6	1,9	0,7	0,9	0,5
	mg/m²	0,01	0,01	0,01	0,01	0,00	0,01	0,01	0,00	0,01	0,00	0,00	0,00
	g/km²	9,47	8,44	8,73	7,74	4,98	8,59	7,90	4,09	5,11	1,25	2,15	1,38
Chemical analysis	N of pieces identified	5	5	5	5	5	5	4	2	5	4	4	0
	% of identified pieces	0,78%	2,43%	2,07%	1,84%	3,38%	4,55%	18,18%	16,67%	29,41%	9,52%	22,22%	0,00%
	iPP/EPR	2	0	2	3	1	4	3	0	1	0	1	0
	PP	0	0	0	0	0	1	1	0	0	0	0	0
	NYLON - PA	3	2	2	1	0	0	0	0	0	0	0	0
	HDPE	0	0	0	1	2	0	0	0	0	0	1	0
	WOOL + PP = 3:2	0	1	0	0	1	0	0	0	0	0	0	0
	PET	0	2	1	0	0	0	0	0	0	0	0	0
	PVA	0	0	0	0	0	0	0	0	0	0	0	0
	PVS	0	0	0	0	0	0	0	0	3	0	0	0
	OTHER	0	0	0	0	1	0	0	2	1	4	2	0

Table A3.39: Fiber microparticles analysis of number, mass and chemical composition of samples collected with pump - manta net method in the first three

River		Dalalven						Po			
Particles number	Sample id	DL1P1	DL1P2	DL2P1	DL2P2	DL3P1	DL3P2	PO1P1	PO1P2	PO2P	PO3P
	Number of pieces	37	23	11	15	25	18	18	9	121	44
	number/m³	7,4	4,6	2,2	3	5	3,6	3,6	1,8	24,2	8,8
Particles mass	Mass all particles (g)	0,0029	0,0007	0,0004	0,0006	0,0017	0,0006	0,0023	< 0,0001	0,0014	0,0002
	Mass all particles (mg)	2,9	0,7	0,4	0,6	1,7	0,6	2,3	<0,1	1,4	0,2
	mg/m³	0,58	0,14	0,08	0,12	0,34	0,12	0,46	0	0,28	0,04
Chemical analysis	N of pieces identified	0	2	1	1	1	1	0	0	0	0
	% of identified pieces	0,00%	8,70%	9,09%	6,67%	4,00%	5,56%	0	0	0	0
	iPP/EPR	0	0	0	0	0	0	0	0	0	0
	PP	0	0	0	0	0	0	0	0	0	0
	NYLON - PA	0	2	0	0	1	0	0	0	0	0
	HDPE	0	0	0	0	0	0	0	0	0	0
	WOOL + PP = 3:2	0	0	0	0	0	0	0	0	0	0
	PET	0	0	0	0	0	0	0	0	0	0
	PVA	0	0	0	1	0	0	0	0	0	0
	PVS	0	0	0	0	0	0	0	0	0	0
	OTHER	0	0	1	0	0	1	0	0	0	0

Table A3.40: Other microparticles analysis of number, mass and chemical composition of samples collected with manta net in the first three sampling days

River		Danube			Po			Rhine - 2nd sampling			Rhine - 3rd sampling		
Particles number	Sample id	DN1T	DN2T	DN3T	PO2T	PO3T	PO4T	RH1T	RH2T	RH3T	RH10T	RH11T	RH12T
	Number of pieces	36	9	16	11	10	14	2	29	7	10	1	0
	number/m²	0,09	0,02	0,06	0,02	0,02	0,04	0,01	0,07	0,02	0,02	0,00	0,00
	number/km²	87378,64	23017,90	58181,82	20754,72	16611,30	42944,79	5449,59	74168,80	18817,20	17921,15	2386,63	0,00
Particles mass	Mass all particles (g)	0,0027	0,0003	0,0019	0,0095	0,0004	0,0068	0,0024	0,0871	0,0031	0,0008	<0,001	0
	Mass all particles (mg)	2,7	0,3	1,9	9,5	0,4	6,8	2,4	87,1	3,1	0,8	0	0
	mg/m²	0,007	0,001	0,007	0,018	0,001	0,021	0,007	0,223	0,008	0,001	0,000	0,000
	g/km²	6,553	0,767	6,909	17,925	0,664	20,859	6,540	222,762	8,333	1,434	0,000	0,000

Table A3.41: Other microparticles analysis of number, mass and chemical composition of samples collected with pump - manta net method in the first three sampling days

River		Dalalven			Po
Particles number	Sample id	DL1P1	DL2P2	DL3P1	PO2P
	Number of pieces	1	2	1	4
	number/m³	0,2	0,4	0,2	0,8
Particles mass	Mass all particles (g)	0,0002	0,0006	0,0001	0,0006
	Mass all particles (mg)	0,2	0,6	0,1	0,6
	mg/m³	0,04	0,12	0,02	0,12

A.4.0 Master List of categories of litter items[25]

Master List of Categories of Litter Items (DRAFT)									
TSG_ML General Code	OSPAR-Code	UNEP-Code	General Name	Level 1 - Materials	Beach	Seafloor	Floating	Biota	Micro
G1	1	PL05	4/6-pack yokes, six-pack rings	Artificial polymer materials	x				
G2		PL07	Bags	Artificial polymer materials		x	x		
G3	2	PL07	Shopping Bags incl. pieces	Artificial polymer materials	x				
G4	3	PL07	Small plastic bags, e.g. freezer bags incl. pieces	Artificial polymer materials	x				
G5	112		Plastic bag collective role; what remains from rip-off plastic bags	Artificial polymer materials	x				

[25] Galgani et al. 2013. Guidance on Monitoring of Marine Litter in European Seas. EUR 26113 EN – Joint Research Centre – Institute for Environment and Sustainability. 128 pp.

Master List of Categories of Litter Items (DRAFT)

TSG_ML General Code	OSPAR-Code	UNEP-Code	General Name	Level 1 - Materials	Beach	Seafloor	Floating	Biota	Micro
G6	4	PL02	Bottles	Artificial polymer materials		x	x		
G7	4	PL02	Drink bottles <=0.5l	Artificial polymer materials	x				
G8	4	PL02	Drink bottles >0.5l	Artificial polymer materials	x				
G9	5	PL02	Cleaner bottles & containers	Artificial polymer materials	x				
G10	6	PL06	Food containers incl. fast food containers	Artificial polymer materials	x	x			
G11	7	PL02	Beach use related cosmetic bottles and containers, eg. Sunblocks	Artificial polymer materials	x				
G12	7	PL02	Other cosmetics bottles & containers	Artificial polymer materials	x				
G13	12	PL02	Other bottles & containers (drums)	Artificial polymer materials	x				
G14	8		Engine oil bottles & containers <50 cm	Artificial polymer materials	x				

Master List of Categories of Litter Items (DRAFT)									
TSG_ML General Code	**OSPAR-Code**	**UNEP-Code**	**General Name**	**Level 1 - Materials**	**Beach**	**Seafloor**	**Floating**	**Biota**	**Micro**
G15	9	PL03	Engine oil bottles & containers >50 cm	Artificial polymer materials	x				
G16	10	PL03	Jerry cans (square plastic containers with handle)	Artificial polymer materials	x				
G17	11		Injection gun containers	Artificial polymer materials	x				
G18	13	PL13	Crates and containers / baskets	Artificial polymer materials	x	x	x		
G19	14		Car parts	Artificial polymer materials	x				
G20		PL01	Plastic caps and lids	Artificial polymer materials		x			
G21	15	PL01	Plastic caps/lids drinks	Artificial polymer materials	x				
G22	15	PL01	Plastic caps/lids chemicals, detergents (non-food)	Artificial polymer materials	x				
G23	15	PL01	Plastic caps/lids unidentified	Artificial polymer materials	x				

Master List of Categories of Litter Items (DRAFT)									
TSG_ML General Code	OSPAR-Code	UNEP-Code	General Name	Level 1 - Materials	Beach	Seafloor	Floating	Biota	Micro
G24	15	PL01	Plastic rings from bottle caps/lids	Artificial polymer materials	x				
G25			Tobacco pouches / plastic cigarette box packaging	Artificial polymer materials	x				
G26	16	PL10	Cigarette lighters	Artificial polymer materials	x				
G27	64	PL11	Cigarette butts and filters	Artificial polymer materials	x	x			
G28	17		Pens and pen lids	Artificial polymer materials	x				
G29	18		Combs/hair brushes/sunglasses	Artificial polymer materials	x				
G30	19		Crisps packets/sweets wrappers	Artificial polymer materials	x				
G31	19		Lolly sticks	Artificial polymer materials	x				
G32	20	PL08	Toys and party poppers	Artificial polymer materials	x				

Master List of Categories of Litter Items (DRAFT)										
TSG_ML General Code	**OSPAR-Code**	**UNEP-Code**	**General Name**	**Level 1 - Materials**	**Beach**	**Seafloor**	**Floating**	**Biota**	**Micro**
G33	21	PL06	Cups and cup lids	Artificial polymer materials	x				
G34	22	PL04	Cutlery and trays	Artificial polymer materials	x				
G35	22	PL04	Straws and stirrers	Artificial polymer materials	x				
G36	23		Fertiliser/animal feed bags	Artificial polymer materials	x				
G37	24	PL15	Mesh vegetable bags	Artificial polymer materials	x				
G38			Cover / packaging	Artificial polymer materials			x		
G39		PL09	Gloves	Artificial polymer materials		x	x		
G40	25	PL09	Gloves (washing up)	Artificial polymer materials	x				
G41	113	RB03	Gloves (industrial/professional rubber gloves)	Artificial polymer materials	x				

Master List of Categories of Litter Items (DRAFT)									
TSG_ML General Code	OSPAR-Code	UNEP-Code	General Name	Level 1 - Materials	Beach	Seafloor	Floating	Biota	Micro
G42	26	PL17	Crab/lobster pots and tops	Artificial polymer materials	x				
G43	114		Tags (fishing and industry)	Artificial polymer materials	x				
G44	27	PL17	Octopus pots	Artificial polymer materials	x				
G45	28	PL15	Mussels nets, Oyster nets	Artificial polymer materials	x				
G46	29		Oyster trays (round from oyster cultures)	Artificial polymer materials	x				
G47	30		Plastic sheeting from mussel culture (Tahitians)	Artificial polymer materials	x				
G48			Synthetic rope	Artificial polymer materials		x	x		
G49	31	PL19	Rope (diameter more than 1cm)	Artificial polymer materials	x				
G50	32	PL19	String and cord (diameter less than 1cm)	Artificial polymer materials	x				

Master List of Categories of Litter Items (DRAFT)									
TSG_ML General Code	OSPAR-Code	UNEP-Code	General Name	Level 1 - Materials	Beach	Seafloor	Floating	Biota	Micro
G51		PL20	Fishing net	Artificial polymer materials		x	x		
G52		PL20	Nets and pieces of net	Artificial polymer materials	x				
G53	115	PL20	Nets and pieces of net < 50 cm	Artificial polymer materials	x				
G54	116	PL20	Nets and pieces of net > 50 cm	Artificial polymer materials	x				
G55		PL18	Fishing line (entangled)	Artificial polymer materials		x			
G56	33	PL20	Tangled nets/cord	Artificial polymer materials	x				
G57	34	PL17	Fish boxes - plastic	Artificial polymer materials	x		x		
G58	34	PL17	Fish boxes - expanded polystyrene	Artificial polymer materials	x		x		
G59	35	PL18	Fishing line/monofilament (angling)	Artificial polymer materials	x	x			

Master List of Categories of Litter Items (DRAFT)									
TSG_ML General Code	OSPAR-Code	UNEP-Code	General Name	Level 1 - Materials	Beach	Seafloor	Floating	Biota	Micro
G60	36	PL17	Light sticks (tubes with fluid) incl. packaging	Artificial polymer materials	x				
G61			Other fishing related	Artificial polymer materials		x			
G62	37	PL14	Floats for fishing nets	Artificial polymer materials	x				
G63	37	PL14	Buoys	Artificial polymer materials	x		x		
G64			Fenders	Artificial polymer materials	x				
G65	38	PL03	Buckets	Artificial polymer materials	x				
G66	39	PL21	Strapping bands	Artificial polymer materials	x	x			
G67	40	PL16	Sheets, industrial packaging, plastic sheeting	Artificial polymer materials	x	x	x		
G68	41	PL22	Fibre glass/fragments	Artificial polymer materials	x				

Master List of Categories of Litter Items (DRAFT)									
TSG_ML General Code	OSPAR-Code	UNEP-Code	General Name	Level 1 - Materials	Beach	Seafloor	Floating	Biota	Micro
G69	42		Hard hats/Helmets	Artificial polymer materials	x				
G70	43		Shotgun cartridges	Artificial polymer materials	x				
G71	44	CL01	Shoes/sandals	Artificial polymer materials	x				
G72			Traffic cones	Artificial polymer materials	x				
G73	45	FP01	Foam sponge	Artificial polymer materials	x				
G74			Foam packaging/insulation/polyurethane	Artificial polymer materials			x		
G75	117		Plastic/polystyrene pieces 0 - 2.5 cm	Artificial polymer materials	x				
G76	46		Plastic/polystyrene pieces 2.5 cm > < 50cm	Artificial polymer materials	x				
G77	47		Plastic/polystyrene pieces > 50 cm	Artificial polymer materials	x				

Master List of Categories of Litter Items (DRAFT)									
TSG_ML General Code	OSPAR-Code	UNEP-Code	General Name	Level 1 - Materials	Beach	Seafloor	Floating	Biota	Micro
G78			Plastic pieces 0 - 2.5 cm	Artificial polymer materials	x				
G79			Plastic pieces 2.5 cm > < 50cm	Artificial polymer materials	x		x		
G80			Plastic pieces > 50 cm	Artificial polymer materials	x		x		
G81			Polystyrene pieces 0 - 2.5 cm	Artificial polymer materials	x				
G82			Polystyrene pieces 2.5 cm > < 50cm	Artificial polymer materials	x		x		
G83			Polystyrene pieces > 50 cm	Artificial polymer materials	x		x		
G84			CD, CD-box	Artificial polymer materials	x				
G85			Salt packaging	Artificial polymer materials	x				
G86			Fin trees (from fins for scubadiving)	Artificial polymer materials	x				

Master List of Categories of Litter Items (DRAFT)									
TSG_ML General Code	OSPAR-Code	UNEP-Code	General Name	Level 1 - Materials	Beach	Seafloor	Floating	Biota	Micro
G87			Masking tape	Artificial polymer materials	x				
G88			Telephone (incl. parts)	Artificial polymer materials	x				
G89			Plastic construction waste	Artificial polymer materials	x				
G90			Plastic flower pots	Artificial polymer materials	x				
G91			Biomass holder from sewage treatment plants	Artificial polymer materials	x				
G92			Bait containers/packaging	Artificial polymer materials	x				
G93			Cable ties	Artificial polymer materials	x	x			
G94			Table cloth	Artificial polymer materials			x		
G95	98	OT02	Cotton bud sticks	Artificial polymer materials	x	x			

Master List of Categories of Litter Items (DRAFT)									
TSG_ML General Code	OSPAR-Code	UNEP-Code	General Name	Level 1 - Materials	Beach	Seafloor	Floating	Biota	Micro
G96	99	OT02	Sanitary towels/panty liners/backing strips	Artificial polymer materials	x	x			
G97	101	OT02	Toilet fresheners	Artificial polymer materials	x				
G98		OT02	Diapers/nappies	Artificial polymer materials	x	x			
G99	104	PL12	Syringes/needles	Artificial polymer materials	x	x			
G100	103		Medical/Pharmaceuticals containers/tubes	Artificial polymer materials	x				
G101	121		Dog faeces bag	Artificial polymer materials	x				
G102		RB02	Flip-flops	Artificial polymer materials	x				
G103			Plastic fragments rounded <5mm	Artificial polymer materials					x
G104			Plastic fragments subrounded <5mm	Artificial polymer materials					x

Master List of Categories of Litter Items (DRAFT)									
TSG_ML General Code	OSPAR-Code	UNEP-Code	General Name	Level 1 - Materials	Beach	Seafloor	Floating	Biota	Micro
G105			Plastic fragments subangular <5mm	Artificial polymer materials					x
G106			Plastic fragments angular <5mm	Artificial polymer materials					x
G107			cylindrical pellets <5mm	Artificial polymer materials					x
G108			disks pellets <5mm	Artificial polymer materials					x
G109			flat pellets <5mm	Artificial polymer materials					x
G110			ovoid pellets <5mm	Artificial polymer materials					x
G111			spheruloids pellets <5mm	Artificial polymer materials					x
G112		PL23	Inudstiral pellets	Artificial polymer materials				x	
G113			Filament <5mm	Artificial polymer materials					x

Master List of Categories of Litter Items (DRAFT)									
TSG_ML General Code	**OSPAR-Code**	**UNEP-Code**	**General Name**	**Level 1 - Materials**	**Beach**	**Seafloor**	**Floating**	**Biota**	**Micro**
G114			Films <5mm	Artificial polymer materials					x
G115			Foamed plastic <5mm	Artificial polymer materials					x
G116			Granules <5mm	Artificial polymer materials					x
G117			Styrofoam <5mm	Artificial polymer materials					x
G118			Small industrial spheres (<5mm)	Artificial polymer materials				x	
G119			Sheet like user plastic (>1mm)	Artificial polymer materials				x	
G120			Threadlike user plastic (>1mm)	Artificial polymer materials				x	
G121			Foamed user plastic (>1mm)	Artificial polymer materials				x	
G122			Plastic fragments (>1mm)	Artificial polymer materials				x	

Master List of Categories of Litter Items (DRAFT)									
TSG_ML General Code	OSPAR-Code	UNEP-Code	General Name	Level 1 - Materials	Beach	Seafloor	Floating	Biota	Micro
G123			Polyurethane granules <5mm	Artificial polymer materials			x		
G124	48	PL24	Other plastic/polystyrene items (identifiable)	Artificial polymer materials	x	x	x		
G125	49	RB01	Balloons and balloon sticks	Rubber	x	x	x		
G126		RB01	Balls	Rubber	x		x		
G127	50		Rubber boots	Rubber	x	x	x		
G128	52	RB04	Tyres and belts	Rubber	x	x	x		
G129		RB05	Inner-tubes and rubber sheet	Rubber	x				
G130			Wheels	Rubber	x				
G131		RB06	Rubber bands (small, for kitchen/household/post use)	Rubber	x				
G132			Bobbins (fishing)	Rubber	x	x			
G133	97	RB07	Condoms (incl. packaging)	Rubber	x	x			
G134	53	RB08	Other rubber pieces	Rubber	x	x	x		

Master List of Categories of Litter Items (DRAFT)									
TSG_ML General Code	OSPAR-Code	UNEP-Code	General Name	Level 1 - Materials	Beach	Seafloor	Floating	Biota	Micro
G135		CL01	Clothing (clothes, shoes)	Cloth/textile			x		
G136		CL01	Shoes	Cloth/textile		x			
G137	54	CL01	Clothing / rags (clothing, hats, towels)	Cloth/textile	x	x			
G138	57	CL01	Shoes and sandals (e.g. Leather, cloth)	Cloth/textile	x				
G139		CL02	Backpacks & bags	Cloth/textile	x				
G140	56	CL03	Sacking (hessian)	Cloth/textile	x				
G141	55	CL05	Carpet & Furnishing	Cloth/textile	x	x	x		
G142		CL04	Rope, string and nets	Cloth/textile	x	x	x		
G143		CL03	Sails, canvas	Cloth/textile	x		x		
G144	100	OT02	Tampons and tampon applicators	Cloth/textile	x				
G145	59	CL06	Other textiles (incl. rags)	Cloth/textile	x	x	x		
G146			Paper/Cardboard	Paper/Cardboard		x			
G147	60		Paper bags	Paper/Cardboard	x				

Master List of Categories of Litter Items (DRAFT)									
TSG_ML General Code	**OSPAR-Code**	**UNEP-Code**	**General Name**	**Level 1 - Materials**	**Beach**	**Seafloor**	**Floating**	**Biota**	**Micro**
G148	61	PC02	Cardboard (boxes & fragments)	Paper/Cardboard	x	x	x		
G149		PC03	Paper packaging	Paper/Cardboard			x		
G150	118	PC03	Cartons/Tetrapack Milk	Paper/Cardboard	x				
G151	62	PC03	Cartons/Tetrapack (others)	Paper/Cardboard	x				
G152	63	PC03	Cigarette packets	Paper/Cardboard	x				
G153	65	PC03	Cups, food trays, food wrappers, drink containers	Paper/Cardboard	x				
G154	66	PC01	Newspapers & magazines	Paper/Cardboard	x		x		
G155		PC04	Tubes for fireworks	Paper/Cardboard	x				
G156			Paper fragments	Paper/Cardboard	x				
G157			Paper	Paper/Cardboard				x	
G158	67	PC05	Other paper items	Paper/Cardboard	x	x	x		
G159	68	WD01	Corks	Processed/worked wood	x				

Master List of Categories of Litter Items (DRAFT)									
TSG_ML General Code	OSPAR-Code	UNEP-Code	General Name	Level 1 - Materials	Beach	Seafloor	Floating	Biota	Micro
G160	69	WD04	Pallets	Processed/worked wood	x	x	x		
G161	69	WD04	Processed timber	Processed/worked wood	x				
G162	70	WD04	Crates	Processed/worked wood	x		x		
G163	71	WD02	Crab/lobster pots	Processed/worked wood	x				
G164	119		Fish boxes	Processed/worked wood	x				
G165	72	WD03	Ice-cream sticks, chip forks, chopsticks, toothpicks	Processed/worked wood	x				
G166	73		Paint brushes	Processed/worked wood	x				
G167		WD05	Matches & fireworks	Processed/worked wood	x				
G168			Wood boards	Processed/worked wood			x		

Master List of Categories of Litter Items (DRAFT)									
TSG_ML General Code	**OSPAR-Code**	**UNEP-Code**	**General Name**	**Level 1 - Materials**	**Beach**	**Seafloor**	**Floating**	**Biota**	**Micro**
G169			Beams / Dunnage	Processed/worked wood			x		
G170			Wood (processed)	Processed/worked wood		x			
G171	74	WD06	Other wood < 50 cm	Processed/worked wood	x				
G172	75	WD06	Other wood > 50 cm	Processed/worked wood	x				
G173		WD06	Other (specify)	Processed/worked wood		x	x		
G174	76		Aerosol/Spray cans industry	Metal	x				
G175	78	ME03	Cans (bevarage)	Metal	x	x	x		
G176	82	ME04	Cans (food)	Metal	x	x			
G177	81	ME06	Foil wrappers, aluminum foil	Metal	x				
G178	77	ME02	Bottle caps, lids & pull tabs	Metal	x				
G179	120		Disposable BBQ's	Metal	x				

Master List of Categories of Litter Items (DRAFT)									
TSG_ML General Code	OSPAR-Code	UNEP-Code	General Name	Level 1 - Materials	Beach	Seafloor	Floating	Biota	Micro
G180	79	ME10	Appliances (refrigerators, washers, etc.)	Metal	x	x			
G181		ME01	Tableware (plates, cups & cutlery)	Metal	x				
G182	80	ME07	Fishing related (weights, sinkers, lures, hooks)	Metal	x	x	x		
G183		ME07	Fish hook remains	Metal				x	
G184	87	ME07	Lobster/crab pots	Metal	x				
G185			Middle size containers	Metal		x			
G186	83	ME10	Industrial scrap	Metal	x				
G187	84	ME05	Drums, e.g. oil	Metal	x	x			
G188		ME04	Other cans (< 4 L)	Metal	x				
G189		ME05	Gas bottles, drums & buckets (> 4 L)	Metal	x				
G190	86	ME05	Paint tins	Metal	x				
G191	88	ME09	Wire, wire mesh, barbed wire	Metal	x		x		

Master List of Categories of Litter Items (DRAFT)									
TSG_ML General Code	**OSPAR-Code**	**UNEP-Code**	**General Name**	**Level 1 - Materials**	**Beach**	**Seafloor**	**Floating**	**Biota**	**Micro**
G192		ME05	Barrels	Metal			x		
G193			Car parts / batteries	Metal	x	x			
G194			Cables	Metal	x	x			
G195		OT04	Household Batteries	Metal	x				
G196			Large metallic objects	Metal		x			
G197			Other (metal)	Metal		x	x		
G198	89	ME10	Other metal pieces < 50 cm	Metal	x				
G199	90	ME10	Other metal pieces > 50 cm	Metal	x				
G200	91	GC02	Bottles incl. pieces	Glass/ceramics	x	x			
G201		GC02	Jars incl. pieces	Glass/ceramics	x	x			
G202	92	GC04	Light bulbs	Glass/ceramics	x				
G203		GC03	Tableware (plates & cups)	Glass/ceramics	x				
G204	94	GC01	Construction material (brick, cement, pipes)	Glass/ceramics	x				

Master List of Categories of Litter Items (DRAFT)									
TSG_ML General Code	OSPAR-Code	UNEP-Code	**General Name**	**Level 1 - Materials**	Beach	Seafloor	Floating	Biota	Micro
G205	92	GC05	Fluorescent light tubes	Glass/ceramics	x				
G206		GC06	Glass buoys	Glass/ceramics	x				
G207	95		Octopus pots	Glass/ceramics	x				
G208		GC07	Glass or ceramic fragments >2.5cm	Glass/ceramics	x	x			
G209			Large glass objects (specify)	Glass/ceramics		x			
G210	96	GC08	Other glass items	Glass/ceramics	x	x			
G211	105	OT05	Other medical items (swabs, bandaging, adhesive plaster etc.)	unidentified	x				
G212			Slak / Coal					x	
G213	181, 109, 110	OT01	Paraffin/Wax	Chemicals	x			x	
G214			Oil/Tar	Chemicals				x	
G215			Foodwaste (galley waste)	Food waste				x	
G216			various rubbish (worked wood, metal parts)	undefined				x	

Master List of Categories of Litter Items (DRAFT)									
TSG_ML General Code	**OSPAR-Code**	**UNEP-Code**	**General Name**	**Level 1 - Materials**	**Beach**	**Seafloor**	**Floating**	**Biota**	**Micro**
G217			Other (glass, metal, tar) <5mm	unidentified					x

A.5.0 Riverine Sampling Options

Riverine sampling options			micro			meso			macro		
			< 1 mm			1>5 mm			>5 mm		
vs3	date: 150209		floating	suspended	bedload	floating	suspended	bedload	floating	suspended	bedload
from vessel	flexible 300 micron net	sampling on surface	preferred, present standard method	but, bycatch from floating particles		preferred, present standard method	but, bycatch from floating particles		short sampling time	but, bycatch from floating particles	
		> 0.2 m below surface	but, bycatch from suspended particles	potentially suitable, testing needed		but, bycatch from suspended particles	potentially suitable, testing needed		but, bycatch from suspended particles	short sampling time	
		< 0.5 m above bottom		forces too high	forces too high		forces too high	forces too high		forces too high	forces too high
	rigid 3 mm net	sampling on surface				only > 3 mm	but, bycatch from floating particles		preferred, next to vessel	but, bycatch from floating particles	
		> 0.2 m below surface				but, bycatch from suspended particles	only > 3 mm		but, bycatch from suspended particles	preferred, next to vessel	
		< 0.5 m above bottom					forces too high	forces too high		forces too high	forces too high
stationary on both sides of river	pump	sampling on surface	potentially suitable, testing needed	but, bycatch from floating particles		potentially suitable, testing needed	but, bycatch from floating particles		selective sampling		
		> 0.2 m below surface	but, bycatch from suspended particles	potentially suitable, testing needed	but, bycatch from suspended particles	but, bycatch from suspended particles	potentially suitable, testing needed	but, bycatch from suspended particles		selective sampling	
		< 0.5 m above bottom		potentially suitable, testing needed	potentially suitable, testing needed		but, bycatch from heavy particles	potentially suitable, testing needed			selective sampling
	flexible 300 micron net	sampling on surface	preferred, needs sufficient current	but, bycatch from floating particles		preferred, needs sufficient current	but, bycatch from floating particles		short sampling time	but, bycatch from floating particles	
		> 0.2 m below surface	but, bycatch from suspended particles	preferred, needs sufficient current	but, bycatch from suspended particles	but, bycatch from suspended particles	preferred, needs sufficient current	but, bycatch from suspended particles	but, bycatch from suspended particles	short sampling time	but, bycatch from suspended particles
		< 0.5 m above bottom		but, bycatch from heavy particles	preferred, needs sufficient current		but, bycatch from heavy particles	preferred, needs sufficient current		but, bycatch from heavy particles	short sampling time
	rigid 3 mm net	sampling on surface				only > 3 mm	bycatch from floating particles		preferred, needs sufficient current	but, bycatch from floating particles	
		> 0.2 m below surface				but, bycatch from suspended particles	only > 3 mm	but, bycatch from suspended particles	but, bycatch from suspended particles	preferred, needs sufficient current	but, bycatch from suspended particles
		< 0.5 m above bottom					but, bycatch from heavy particles	only > 3 mm		but, bycatch from heavy particles	preferred, needs sufficient current

	= method not tested yet
	= suitable method
	= partially suitable method
	= unsuitable method

A.6.0 Authorities Contacted

Rhine (Rozenburg and Verkeerspost Stad in Rotterdam), The Netherlands:

Arie de Gelder RWS West Nederland Zuid, Rotterdam, The Netherlands.

He introduced us to his colleagues.

Silvana Ciarelli, RWS West Nederland Zuid, Rotterdam,.The Netherlands.

She is a colleague of A. de Gelder and within her tasks is also the transport of plastic litter in the Rhine estuary.

Simon Mostert, RWS West Nederland Zuid, Rotterdam, The Netherlands

He is a staff member management and maintenance, we contacted him for permission to use the Rijkswaterstaat station at Rozenburg, a town west of Rotterdam.

Peter Oskam, RWS West Nederland Zuid, manager of the Maeslantkering stormsurge barrier. Maassluis.

We contacted him for permission to use an alternative sampling location near the Maeslantkering.

Lex Oosterbaan, RWS, Contact at Ministery Infrastructure & Environment, The Hague.

He is a member of the Task Group Marine Litter and he is an advisor.

Jan Steentjes, Beheer Systemen & Vastgoed, employee BSV of the

Havenbedrijf Rotterdam N.V., Rotterdam, The Netherlands.

He gave permission to use the area of the Verkeerspost Stad, near the Lekhaven, as monitoring location.

Henk Groeneveld, Adviseur Havenmeester Beleid, Havenbedrijf Rotterdam N.V. World Port Center, Postbus 6622 3002 AP Rotterdam

Ben van de Wetering International Commission for the Protection of the Rhine (ICPR), Kaiserin-Augusta-Anlagen 15 D - 56068 Koblenz was informed about the project and expressed support to activities in the project; The Rhine Commission is well aware of the problem and already cooperates with the OSPAR secretariat to set up common management plan;

Dalålven River in Sweden:

Jens Fölster, Associate professor of the Swedish University of Agricultural Sciences, Dep. of Aquatic Sciences and Assessment, Uppsala.

Georg Hanke introduced us to him and he suggested to sample plastic litter in the Dalålven River. Jens referred us to Tommy Rosendahl

Tommy Rosendahl, Site Manager Research Facilities, SLU – Fiskeriförsöksstationen, Brobacken, 814 94, Älvkarleby, Sweden. Tommy referred us to the Fishing Organisation

Olof Olsson, President of the Fishing Organisation

Älvkarleby Sportfiske, Fiskekontoret, Forskarstigen 14B, 814 94 Älvkarleby, Sweden. Manager of the river with respect to all aspects of fish life in the river. He referred us to Stephan and Kamilah

Stephan and Kamilah [surname not known]

Owners of finally selected sampling location

Långsandsvägen 33 Älvkarleby, Sweden, local riparian habitants with a more or less suitable location for monitoring activities.

For a permission to sample plastic litter from the river we did not contact a formal river authority. It means also that we did not found in Sweden an organisation interested in the riverine input of plastic litter to the marine environment.

Po River near Ferrara in Italy

Dr Georg Hanke

TSG ML lead, appointed us to Dr Roberto Crosti in search for location for sampling. Mr Crosti suggested contacting Legambiente (League for the Environment) .

Dr Roberto Crosti (PhD Environmental Science)

Italian Ministry of the Environment Land and Sea, General Direction for Environment Protection, "Marine and Coastal Protection Unit"

Stefania Di Vito and Giorgio Zampetti

Legambiente Onlus, Roma

They work in the scientific office of Legambiente ONLUS and they are involved in ongoing studies about marine and beach litter. They provided us with information about possible sampling location, and they also contacted owners of possible sampling sites locations.

Georg Sobbe

Secretary of sport boating club Canottieri Ferrara, Via Ricostruzione, 121 - 44123 Pontelagoscuro (FE)

After doing an extensive search of possible sampling location with a great help from Legambiente Roma and Legambiente Ferrara, Società Canottieri Ferrara A.S.D. was suggested as a great location contact for sampling. Contact person was secretary Mr Georg Sobbe. The collaboration was very satisfactory, we were asked to present findings of our research to the club for their local newspaper.

Silvano Pecora

Servizio Idro-Meteo-Clima (Area Idrologia) di Parma

He works for ARPA Emilia-Romagna and he sent us hydrological data for the Po River.

Danube River, Romania

Peter de Kiewit

Product Manager of Damen Shipyard and contactperson for Romanian operations, Damen Shipyards., The Netherlands. Peter has tried to introduce us to his local contacts useful to our project but due to the holiday period in the summer it did not work out in time.

Otilia Mihail

Ministry of Environment and Climate Changes, Romania Ministry of Environment and Water Management, Bucharest Romania was informed about the project and expressed support to activities in the project, but the official way to support the project in practice was not possible in the project time frame;

Dr. Mary-Jeanne Adler

Scientific Director of the National Institute of Hydrology and Water Management, Senior adviser Ministry of Environment and Climate Change-Department for Waters, Forests and Fisheries

Petruta Moisi

President Ecological Consulting Center Galati, Romania.

Petruta was a big help to obtain permission from the municipality for sampling in the Danube. She introduce dus to Silviu Bacalum. She is probably interested in the findings of our project.

Silviu Bacalum

Director General Public Service Municipality Galati, Primãria Municipiului Galati, Directia Generalã Servicii Publice, Galati, România.

Silviu arranged permission to stay on and to sample from his marina.

Oder River, Poland

Tamara Zalewska

Institute of Meteorology and Water Management, National Research Institute, Maritime Branch, Gdynia, Poland

She was on holydays during our planned sampling period. She is potentially interested in our report.

Kazimierz Rabski

Chairman of the Society for The Coast (EUCC-Poland), Szczecin, Poland.

He referred us to Piotr Domaradzki.

Piotr Domaradzki

Chief Inspector, of Inspectorate of Seashore Protection, Maritime Office in Szczecin.

He is head of the local harbour authority that grants permission to sample from the harbour pier. He referred us to the Ministry of Infrastructure and Development for permission to sample in the river itself.

Jacek Giejlo

Ministry of Infrastructure and Development, Department for Maritime Transport and Shipping Safety, Warsaw, Poland.

He granted us permission to sample in the mouth of the Oder River.

A.7.0 Stakeholder Comments & Responses

Comments from stakeholders on the draft final report, the way in which the project team has revised the report in response, are shown in Table 42. All responses received are noted below and have been used to inform revisions to the final report.

Table 42: Stakeholder Comments & Project Team Responses

Stakeholder	Comment	Report amended as a result of comment	Detail
Surfrider Foundation Europe	Sampling on more spots on the catchment would be welcomed to get more representative idea of the litter pollution at this scale.	No	The comment is very useful. We will consider it for the next work. In this project the duration of the project, financial constraints and complicated methodology of sampling did not allow such kind of sampling.
Surfrider Foundation Europe	We are mainly concerned about the feasibility of the methodology of sampling proposed in the report. Indeed, the methodology of sampling is really clear but requires a lot of materials such as cranes to be implemented and duplicated. From a scientific point of view, the protocol is forthright but it might be not easy to setup for small	No	We agree with this comment. We will think about other methods that could be useful also for the Universities and NGOs.

	structures such as Universities or NGOs, as it requires large investment and logistics capacities.		
Surfrider Foundation Europe	More explanation could be welcomed on the standard deviation indicated on page 32.	Yes	Further detail added to enhance explanation (new chapter 5.2.7)
Surfrider Foundation Europe	The description of the drying method in order to weigh the litter collected would also need more explanations.	Yes	Further detail added to enhance explanation.
Surfrider Foundation Europe	A major part of samplings were also completed during summer. We can very easily understand why, but we have to be aware that the protocol would gain accuracy if samplings were to be undertaken all year long. In this regard, it would be in particular interesting to extend the study during several years to improve representativeness and reinforce statistical analysis. We really appreciated that the study permitted to point out the sewage connection problems of houses.	No	We agree with this comment and recommendation.
Richard Cronin and	The comments relate to the methodology of sampling, chapter E.2.1 “Was the full channel depth sampled?”	No	This was not the subject of the project. In the proposal of the project just sampling on the surface water was proposed.

Thomas Maes	“only first meters, what about denser items on the bottom flow?”		
Richard Cronin	This comment discounts the values contained in the report. I would like to understand - a discussion from the researchers – about how much of an impact this had on the quality of the data produced in the report and whether a solution to the problem could be found in order to improve the quality of the data.	No	There is an plausible explanation why litter quantities fluctuate during a year. The limitations in the scope of the project make it impossible to produce reliable data on the total load transported to the seas, but mere produce an indication.
Thomas Maes	The comment relates to the recommendation in the summary: “Litter amounts are constantly varying across the river width, how will a boat take this non homogenous condition into account as it cant cover the whole river at once? Would booms suspended between bridges not be a cheaper and more robust method as demonstrated in the Seine (Fr)?”	No	The more explained answer is given here:A boom floating on the surface only catches very buoyant and compact particles with a low surface to volume ratio, like bottles and EPS foam. The water flowing under the boom will take the thinner and smaller products like pellets, films and bags past the barrier. Collecting the products that are collected on front of the boom will result in further loss of products. There is also great doubt about the sampling efficiency for smaller products, surely in case of incoming and outgoing tides. Also the determination of the waterspeed during sampling along the total width of the boom will be a problem. Besides that, a boom across the whole river-width is only applicable in case there is no shipping traffic or where a bridge is present. Using a vessel, sailing a figure 8 shaped parcours, covers the whole river width while the temporal and spatial variation

			of litter during the 2 - 3 hours that the sampling takes place is expected to be of minor influence.
Thomas Maes	The comments relates to the monitoring recommendation, “monitoring of plastic litter in these circumstances should be part of a general monitoring programme executed by large monitoring vessels, suited to monitoring a series of different parameters, for example bed levels, salt intrusion and flow fields.” Chapter E.2.1.“Large monitoring vessels seem rather unhandy in rivers?”	Yes	The description was changed.
Richard Cronin	Can the figures for upstream catchment area (km2) and population be included? This sets some relevant context on the numbers.	Yes	Further detail added to enhance explanation.
Thomas Maes	The comment relates to the sentence from the summary that describe where is the reason for big litter number in Danube river. »Why? Evidence? References?«	Yes	Further detail added to enhance explanation.
Richard Cronin	The comment relates to the description of results of microparticles.Is this per km2 of the overall upstream catchment?	Yes	Further detail added to enhance explanation.

	Or some other unit of measurement?		
Thomas Maes	The comment relates to the results of microplastic particles, caught by manta net. (from the summary) “The first sentence of this page said: The highest number of plastic litter particles, 2E+12 (2,000,000,000,000) are transported by the River Danube to the Black Sea > or are these not microparticles?”	Yes	Further detail added to enhance explanation. The more explained answer is given here: In the calculation of riverine input of plastic litter to the sea, the average discharge is included. The results normalized per km2 show that Po is the most polluted river with microparticles, but when we calculate the riverine input of microplastic to the sea, the Danube transfer more microplastic than Po, because Danube has for 4.4x higher average discharge.
Thomas Maes	The comment relates to the results of microplastic of 2nd and 3rd sampling (from the summary). “Rhine numbers indicated high variability!”	No	We agree with this observation.
Richard Cronin	The comment is from the summary. “Can the use of commas and full stops be consistent? 300,000 or 300.000.”	Yes	We check for all nonconsistence with commas.
Thomas Maes	How derived? Weight of catch or number of MPs multiplied with average MP weight?	No	This is described in the chapter 5.2, Analysis of manta net and pump method samples.

Thomas Maes	The comment relates to the summary results of meso-litter. “Which method here?”	Yes	Further detail added to enhance explanation.
Thomas Maes	The comment relates to the types of litter. “How is this a category? Which chemical? PAH, PCB, DDT, ...?”	Yes	Further detail added to enhance explanation.
Thomas Maes	The comment relates to the daily variation of results in summary. “3rd day? 3rd sample in one day? Confusing”	Yes	Further detail added to enhance explanation.
Thomas Maes	The comment relates to the description of results of daily variation of quantity of meso-litter (from the summary) “Is this relevant or does it indicates the high variability between days?”	Yes	We would like to represent the variability between sampling days, but maybe this is not realy important for the summary. These sentences were deleted.
Thomas Maes	The comment relates to the results of chemical analysis from the summary. “Methodology? By FTIR or Raman?”	Yes	Further detail added to enhance explanation.
Thomas Maes	The comment relates to the sentence: “Based on our analysis we could conclude that one quarter of small	Yes	Further detail added to enhance explanation. The more explained answer is given here:

	particles most resembles packaging materials used in the industrial sector." From the chapter E.3.3 "How was this so accurately determined?" "How was this determined and what made packaging industrial or public?"		It is very hard to determine the original use from a sampled fragment. Most of the fragments could not be related to a certain first use. The rest are catagorised on the basis of highest probability.
Thomas Maes	The comment relates to the sentence from the summary: "A combination of the applied two methods is insufficient for reliable estimates of plastic litter in river." "So methods not recommendable."	Yes	Further detail added to enhance explanation.
Richard Cronin	When should monitoring be carried out for the most representative samples of riverine inputs to the marine environment? The project appears to have carried out the sampling during early-late summer 2014 which is not the ideal time (hydrologically). In Ireland (and much of the OSPAR region) the predominant population settlement pattern is within the intertidal zone (c. 65% of Irish population	Yes/No	Further detail added to enhance explanation. The more explained answer is given here: - Monitoring should ideally be carried out at regular intervals during the whole year and/or during the rising limb of the hydrograph, but the time and financial constraints of the project did not allow to sample longer periods. During the sampling although we did experience, both in the Po and the Danube, the effects of heavy rainfall, causing a significant increase of the number of caught particles.

	–and a higher proportion of the urban population- reside within 10km of the coast). The methodology in this report does not address this issue. This may mean that adopting this methodology is not relevant for OSPAR contracting parties. Some of the conclusions and recommendations appear to be project specific and would not be relevant in a national monitoring programme (i.e. access and site selection and the consequential sampling methodology).		- Only OSPAR countries have high tidal differnces. Other regional seas have very low tides, so there we could sample on any time a day. In the Rhine we sampled only during the outgoing tide. Exploratory sampling activities in OSPAR rivers could be performed to assess the total transported load during the high-low tide cycles in order to find some sort of average. - In all rivers except the Rhine we could sample downstream major urbanized area's and upstream the delta, but the Rhine delta starts already at the German Dutch border, so we had to sample in the tidal zone in order to take into account the emissions from the Dutch part of the watershed. Extra research should be done to develop a methodology that takes into account the effects of the tides and how measurements at outgoing and incoming tides can be combined. - The project specific aspects are correctly addressed, but by visiting multiple locations, a lot of experience has been gained to bring the discussion and development of a generic european methodology to a higher level.
Thomas Maes	The comment relates to the sentence from the chapter E.4.0: "In particular, monitoring at the time of the rising limb of a hydrograph, when the flood plains become inundated, is recommended, because during that period high concentrations of plastic	Yes	Further detail added to enhance explanation

	litter in rivers might be expected."Monitoring at peaks, during floods?? How is this representative for normal conditions, will it not only create a biased vision?"		
Thomas Maes	The comment relates to the recommended sampling method in the summary. "Trawling up river, how do you calculate exact volumes going through?"	No	The answer is described in the chapter 9.
Thomas Maes	The comment relates to the sentence: »Similarly urban areas are also an important source in all sampled rivers, therefore waste management in urban areas and wastewater treatment practices should be investigated in order to identify actual causes for emissions of litter from urban areas.« »How determined? Do we need monitoring to know this?«	No	Yes, we think that we need monitoring to know this. The monitoring on the outlets from the wastewater treatment plants would be very useful. In a watershed there are a great number of large cities and wastewater treatment plants, so for this project, we choose to sample only in the river mouth.
Thomas Maes	The comment relates to the sentence: »Extensive public awareness raising is recommended to emphasise the importance of changing behaviour which	Yes	Further detail added to enhance explanation.

	currently contributes to litter entering rivers.« “Waste water overflows?”		
DECLG – Richard Cronin	Are the data about the major sources of marine litter of OSPAR region availabile?	Yes	The reference of OSPAR were added.
DECLG – Richard Cronin and Thomas Maes	The comments relates to the description of Honolulu Strategy: “Where does this sit in the context and hierarchy of Government commitments? This strategy is a framework and does not supplant the work of member states and the areas under their control.” “Agree, not the most relevant here”	Yes/No	This paragraph was kept in the report, just small part of one sentence, that is not important for understanding, was deleted.
Thomas Maes	The comment relates to the chapter 2.3.1 - A river system, where A Conceptual Model of Riverine Litter Emission, Transport and Storage is described: “Missing part on hydrodynamics in river, laminar and turbulent flows?”	Yes	Information on riverine state with regard to flow is added.
John Mouat	The comment relates to the statements that Reversal of the flow direction and	Yes	Further detail added to enhance explanation

	periods with flow below a minimum velocity occur often in a tidal estuary. “How were these taken into consideration?”		
Thomas Maes	The comment relates to the description of methodology from the summary and from the chapter 4.1 - Applied of monitoring methods: “How to compare different monitoring methods?” “What does this mean in volume?” “How to compare cubic metres with square metres above? Are methods even comparable?” “But totally different method (manta vs pump) so how can this be compared?”	Yes	Further detail added to enhance explanation
Thomas Maes	The comment relates to the statement that in conditions with wind and ship-induced waves the depth of collected water can change in a complex way . “How to monitor taking into account this variability?”	Yes	The sentence was deleted because it made the reader confused.
Thomas Maes	The comment relates to the chapter 5.1, Analysis of WFW Surface and WFW	Yes	Further detail added to enhance explanation.

	Suspension samples (small particles 5-25 mm). “VISUAL, NO FTIR > Link to Source unreliable!”		
Thomas Maes	The comment relates to the chemical analysis methodology for microplastic. “On all microplastics or a subset?”	Yes	The text was a little bit changed, further detail added to enhance explanation.
Thomas Maes	The comment relates to the method of microplastic categorisation, chapter 5.2.6. “New? Harmonisation?”	No	From our experiences we conclude that the categorisation of pellets and fragments according to their shapes is very hard, time consuming, subjective and without added value.For this reason we changed the microplastic categories. The samples are stored in our laboratory and all the particles are also photographed with microscope camera, so the categorisation according the categories from Guidance on Monitoring of Marine Litter in European Seas is possible.
Thomas Maes	The comment relates to the big SD number calculated for the weight of particles from Rhine 2. “Is this number correct?”	Yes	We have added a new explanation below the table as to why this SD number is so high.
Thomas Maes	The comment relates to the figure 13. “No significant difference except for Rhine 3?	No	We agree with this observation.

Thomas Maes	The comment relates to the sentence from the Chapter 6.1.1.1 Comparison between Manta-Trawl Method and Pump Method: “This means that the assumption that the manta net, taking samples to a depth of 10 cm, can be compared to the pump method, where 5000 litter is equivalent with 500 m2 sampled surface.” “speculative!”	Yes	This sentence was deleted.
Thomas Maes	The comment relates to the sentence in chapter 6.5, “The averaged data was multiplied by the average river discharge.” “Average * average = error?”	No	The first »average« relates to the average of the sampling period, the second »average« relates to the average yearly river discharge.
Thomas Maes	The comment relates to the sentence from the chapter 7, Conclusions: “The results of the Dalålven River don’t show any foam particles. The reason for such a result could be the method of sampling. When samples were collected with the submersible pump in the Dalålven, the foam particles could not go through the pump, because they float on the surface of the river.”	Yes	Further detail added to enhance explanation.

	"Bias"		
Thomas Maes	The comment relates to the sentence from the chapter 7, Conclusions: "Fibres are most likely emitted through wastewater treatment so we believe that results of the Danube (large numbers of fibres) indicate the proximity of the outlet from the wastewater treatment plant near the sample collection location." "Bias"	Yes	Further detail added to enhance explanation.
Thomas Maes	The comment relates to the sentence that polyethylene (PE) pellets are likely to derive from cosmetics or perhaps industrial mild abrasives. "Preproduction pellets in cosmetics?? Or do they mean microbeads?"	Yes	The word pellet was exchange with the word microbeads.
Thomas Maes	The comment relates to the sentence from the chapter 7, Conclusions: "Analysis of microplastics by material type was performed for 16 % of all particles, by stereomicroscope." "Microscope for material typing?? > FTIR"	Yes	The sentence was corrected.

Thomas Maes	The comment relates to the sentence from the chapter 8.1: “There is a lot of knowledge and literature about the flows and currents in a river, as there is about the behaviour of solids in the river, but those solids are mostly sediment particles with an average specific weight of 2 – 3 kg/dm3.” “The units for specific weight are N/m3”	Yes	The word specific weight was changed with the word density.
Richard Cronin	System output dependence on the current inputs and the history of past inputs. For litter I assume as opposed to for rainfall events.	No	That is correct, litter deposited during periods with low discharge (e.g. during summer), will be flushed at the first heavy rainfall events, leaving the watershed cleaned when the next rainfall event occurs. Meaning that the same amounts of precipitation can lead to differences in riverine load of pollution during the whole year cycle.«
Thomas Maes	The comment relates to the sentence that samplers might not catch all of the plastic litter in front of the opening of a sampler, from the chapter 8.5. “Bow waves?”	Yes	Further detail added to enhance explanation
Richard Cronin and Thomas Maes	The comments relate to the fact that most of samples were sampled in the summer month. (chapter 8.7) “Low volumes”	No	Nothing was changed, because the chapter was finished with the sentence: »Research here would be valuable.«

	“Changing during the year?” “So this wouldn’t be the time when full channel flow would be taking place.”		
Thomas Maes	The comment relates to the sampling method, why sampling should be done from the fixed location on a riverbank and “Why not from bridges?”	No	Just the explanation on the comments is below: “Staying on a bridge with all the equipment should obstruct the traffic too much and there are not many bridges in the river mouth, so it is not a serious possibility.”
Richard Cronin	The comment relates to the recommendation on a trawling method, chapter 9.3. “Any specific minimum or maximum duration?”	yes	Further detail added to enhance explanation
Richard Cronin	The comment relates to the sentence from the chapter 9.3 Trawling method: “The advantage of using a boat is mainly the flexibility to choose the best sampling location available without being dependent on authorities or facilities on land and to eliminate the bias caused by the wind and the changing current condition on both sides of the river. ”Is this a project specific observation?	No	Yes, in case of arranging longer term sampling activities, the cooperation between different authorities, both on land as on the river could be a less big problem, as it would be easier to prepare a sampling site to the requirements of the sampling activities.

Comments from Marta Ruiz, HELCOM Project Co-ordinator, commenting as an independent expert, are included below.

1: What do you think of the overall quality of the report? it is a very interesting project report, which shows the operational difficulties of conducting litter monitoring in European rivers. It contains detailed analysis of the obtained data. The report illustrated with graphical material increasing visibility of the conclusions.

2: Do you find the results interesting / new / surprising? the results shown in the project report contribute to increase the knowledge on land based sources of marine litter. In view of the results shown it seems that there is a need of a more comprehensive sampling of the rivers under study to be in the position to estimate their transport of plastic litter.

3: What is your opinion about the different aspects of the report:

3.1: choice of rivers? it may also be interesting to consider similar characteristics of the catchment area when selecting the river to monitor in order to enable subsequent comparison of the data obtained (highly urbanised and industrialized catchment area in the Rhine *versus* nature reserve in the case of the Dalålven might be difficult to compare).

3.2: choice of locations? the reasoning behind the selection of location is well supported. It seems to have been quite a complicated process to be allowed to conduct the sampling.

3.3: sampling from a stationary location? the use of the specially designed crane seems to have been a limiting factor when selecting the sampling site. Is it possible that this may have had a consequence on the sampling data obtained?

3.4: sampling methods: microplastics with mantanet, macroplastics with WFW-sampler, could another method be applied? it would have been beneficial for the outcome of the project that all three sampling methods applied would have been applied in all the sampling sites, for further comparison of the methodologies.

3.5: methods of categorization: size/material/color/source (usefulness of the Masterlist), could other methods be applied)? the effort conducted by the TG on ML regarding the development of such a categorization is worth considering, plus it provides a harmonized procedure to be applied. However, there might be a need for adapting it to river monitoring.

3.6: Are the results presented in a way that helps you to make decisions? Yes. The obtained data were carefully analyzed, classified and visualized in the form of tables and graphs. The conclusions are transparent and well prepared for decision making.

4: Is there a need for a follow-up and what do you think the next step would be? bearing in mind the process stated in the project report there may be a need for further cooperation between different levels of administrations to enable a regular monitoring of litter in rivers. It may be also of interest to consider sampling of litter in sediments, especially microlitter, since it may be re-suspended to the water column and be finally transferred to the sea.

5: Who should take the initiative for a follow up? litter is a global issue, which affects a wide spectra of stake holders, from competent authorities to researchers and the general public. All of them, in my opinion, are to be involved in the initiative that may rise to follow up this project.

6: Do you have recommendations, other issues to address? regarding the project report as such, it may be of interest to include monitoring of litter in sediments and in biota in the section dedicated to monitoring methods of litter in seas an rivers. A chapter dedicated to bibliographic references for further consultation could be useful. In order to increase confidence of the conclusions, longer periods of observations are needed. The observation periods should cover different seasons with the different discharge of the rivers.

A.8.0 Background Information

A.8.1 Existing Information on Policies and Classification

A.8.1.1 Overview of Policies

Marine litter is generally recognised as a threat to the marine environment, causing environmental and socio-economic damage on a global scale. It is understood and commonly suggested that a large proportion of marine litter items originate from land-based sources, but the contribution to sea-based sources differs from region to region.

In the NE Atlantic, maritime activities and coastal recreation and tourism activities are found to be the predominant source of marine litter (ARCADIS 2013 , UNEP 2009).[26,27] Five major sources of marine litter in the OSPAR region were identified in a pilot project (OSPAR 2007)[28]. These are fishing (including aquaculture), galley waste (non-operational waste from shipping, fisheries and offshore activities), sanitary waste/sewage-related waste, shipping (including offshore activities operational waste) and tourism and recreational activities. Black Sea sources are not so clearly defined. Local surveys and studies (UNEP 2009, Topcu et al. 2012) cite municipal waste/sewage and badly managed landfills as the most important source of marine litter.[29] By contrast, ARCADIS (2013) concluded from the items found at beaches near Constanta that recreational and tourism activities (both land- and sea-based) represent the most important source. The items found indicate consumer sources as the most important source of marine litter in the Baltic Sea; the literature identifies a high share of household-related waste (and waste generated by recreational/tourism activities) (ARCADIS 2013, UNEP 2009). In the Mediterranean Sea items found indicate a predominance of land-based litter, stemming mostly from recreational/tourism activities (ARCADIS 2013). All regions seem to have a lack of data with regard to evaluating riverine inputs, as suggested by the Issue Paper to the “International Conference on Prevention and Management of Marine Litter in European Seas” .[30]

Rivers are one of the vectors that bring land-based litter into the marine environment. Although much of the literature addresses land-based sources of what eventually becomes marine litter, there appears to be relatively little published literature describing

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[26] ARCADIS (2013). Final report. Pilot project 4 seas: Case studies on the plastic cycle and its loopholes in the four European Regional seas areas. European Commission project.

[27] UNEP, 2009. Marine Litter: A Global Challenge. Nairobi: UNEP. 232 pp.

[28] OSPAR Commission (2007). OSPAR Pilot Project on Monitoring Marine Beach Litter. Monitoring of marine litter in the OSPAR region. OSPAR Commission. Assessment and Monitoring Series.

[29] Topçu, E. N., Tonay, A. M., Dede, A., Öztürk, A. A., & Öztürk, B. (2013). Origin and abundance of marine litter along sandy beaches of the Turkish Western Black Sea Coast. Marine environmental research, 85, 21-28.

[30] Available at: http://www.marine-litter-conference-berlin.info/userfiles/file/Issue%20Paper_Final%20Version.pdf

riverine input of plastics to the marine environment. Nevertheless, the literature recognizes the importance of rivers as a major input of litter into the marine environment.

Many countries and international organizations have been tackling the marine litter issue for decades. The Honolulu Strategy, adopted at the fifth International Marine Debris Conference in Honolulu, Hawaii, specifies three overarching goals focused on reducing threats of marine litter. The first goal mentioned is dedicated to reducing the amount and impact of land-based litter and solid waste introduced into the marine environment. Strategy A5 (Improve the regulatory framework regarding stormwater, sewage systems, and debris in tributary waterways dedicated to this goal) includes activities to develop Total Maximum Daily Load (TMDL) levels for trash in rivers and other water systems.

We did not want to repeat the descriptions of all international policies adopted to tackle environment issues, including marine litter, so we will just name them here, and pinpoint the ones that tackle riverine litter as well.

- United Nations Convention on the Law of the Sea (UNCLOS)
- UN General Assembly Resolution A/RES/60/30 – Oceans and the Law of the Sea (2005)
- International Convention for the Prevention of Marine Pollution from Ships, modified by Protocol of 1978 (MARPOL 73/78)
- London Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter (1972)
- Protocol to the London Convention (1996; commonly referred to as the "London Protocol")
- Basel Convention on the Transboundary Movements of Hazardous Wastes and their Disposal (1994)
- Global Program of Action for the Protection of the Marine Environment from Land-Based Activities (1995)
- UNEP Global Initiative on Marine Litter (2006)
- "The future we want", Rio+20 conference document

A broad range of EU policies and legislation are related directly or indirectly to marine litter. The European Commission in its Commission Staff Working Document SWD (2012) 36515 published an overview of EU policies, legislation and initiatives related to marine litter.[31]

Van Acoleyen et al. (2014) assessed which of these instruments are most relevant. Marine Strategy Framework Directive (2008/56/EC) came in only as seventh, while Packaging and Packaging Waste Directive (94/62/EC) was the most highly scored in terms of relevance, feasibility and priority.

[31] SWD(2012)365 final of 31/10/2012, available at: http://ec.europa.eu/environment/marine/pdf/SWD_2012_365.pdf

Other Directives related to waste and of relevance to marine litter are:

- Directive 2008/98/EC repealing Directive 2006/12/EC, Waste Framework Directive;
- Directive 2000/ 59/EC on port reception facilities for ship-generated waste and cargo residues, which focuses on ship operations in Community ports and addresses in detail the responsibilities of the different operators involved in delivery of waste and residues in ports;
- Directive 1999/31/EC on the landfill of waste to prevent negative effects on the environment from the landfilling of waste, including the pollution of surface water.

In freshwater environments the Water Framework Directive (2006/60/EC) (WFD) acts as a policy instrument to achieve or maintain good chemical and ecological status. Litter is expected to be added as one of the additional pressures to be considered in management of land based pollution sources but is currently not part of the WFD.

On the 27th of June 2014 the OSPAR Commission adopted on the Regional Action Plan (RAP) for Prevention and Management of Marine Litter in the North-East Atlantic (OSPAR Agreement 2014-1) was adopted. OSPAR RAP mentions the importance of cross-sectorial co-operation, and that the RAP should be implemented in close collaboration with River Basin Commissions. It also outlines actions to combat land-based sources.

In December 2013, the Contracting Parties of the Barcelona Convention adopted the Regional Plan on Marine Litter Management in the Mediterranean. One of the main objectives of the plan is to prevent marine litter pollution in the Mediterranean. The Contracting Parties shall by the year 2020 take necessary measures to establish as appropriate adequate urban sewer, wastewater treatment plants, and waste management systems to prevent run-off and riverine inputs of litter. In addition the Contracting Parties shall take enforcement measures to combat dumping in accordance with national and regional legislation including littering on the beach, illegal sewage disposal in the sea, the coastal zone and rivers in the area of the application of the Regional Plan.

In HELCOM countries a Regional Action Plan on Marine Litter is under development and should be approved by 2015 aiming at significantly reducing marine litter pollution by 2025. Cross-sectoral cooperation with River Basin Commissions is mentioned in this document as well. By mid-2015 common indicators and associated targets related to quantities, composition, sources and pathway of marine litter, including riverine inputs, will be developed in order to gain information on long-term trends.

Within the Black Sea Convention there are no legal instruments dedicated specifically to the management of marine litter. The Strategic Action Plan for the Environmental Protection and Rehabilitation of the Black Sea (the BS SAP 2009) seems to be the most appropriate framework for addressing marine litter issues of regional significance.

A.8.1.2 Marine Strategy Framework Directive

The only directive dedicated specifically to the issue of marine environmental strategy and state, including marine litter, is the Marine Strategy Framework Directive (2008/56/EC) (MSFD). The MSFD establishes a framework within which Member States shall take the necessary measures to achieve or maintain good environmental status (GES) in the marine environment by the year 2020. One of the eleven qualitative descriptors for determining GES under the MSFD is: “Properties and quantities of marine litter do not cause harm to the coastal and marine environment” (known as ‘Descriptor 10’). The MSFD requires the European Commission to establish criteria and methodological standards to enable a consistent evaluation of the extent to which GES is being achieved in the marine environment of the EU. Commission Decision on criteria and methodological standards (2010/477/EU) proposed 56 criteria for the achievement of GES, including trends in the amount of litter:

- washed ashore and/or deposited on coastlines (Indicator 10.1.1);
- litter in water column and deposited on seafloor (Indicator 10.1.2); and
- amount of micro-particles (in particular microplastics) (Indicator 10.1.3).

To aid in technical aspects of the implementation of the MSFD, Technical Subgroups (TSGs) have been established consisting of a group of experts. Recently, the TSG for Marine Litter has developed Monitoring Guidance providing guidelines for the monitoring and analysis of marine litter.[32] The group offered in its document a list of marine litter (Master List) which was used also in our work for identification of collected litter items. The Master List is a comprehensive list of 217 items of litter, relating to five different compartments (beach, floating, seabed, microplastics, biota). The Master List was developed based on the categories of items used in a series of other programmes (OSPAR, UNEP, HELCOM, NOAA, ECOOCEAN, CEFAS, HELMEPA, IBTS, ICC and others). The list was developed with an associated aim to identify major sources of marine litter.

TSG ML pointed out the importance of rivers which are believed to be the biggest contributor to marine litter, by introducing land-based litter into marine environment. The TSG (now TG) started preparing the report on riverine litter. It was recognized by the group members that the development of harmonized monitoring methodologies and their implementation across Europe is needed in order to target measures and identify priority areas for riverine litter.

In the MSFD reporting in 2012 on initial assessment, indicators and targets, Member States reported on marine litter. Despite the lack of data on marine litter quantities and sources, a small number of Member States indicated complementary targets to reduce marine litter through pathways (e.g. riverine input). France stated their ambition to “reduce the amount of waste transported by rivers”. Germany, Danmark and Spain were

[32] Technical Subgroup on Marine Litter has recently been promoted to Technical Group on Marine Litter, TSG ML is used in this document as it was the title at the start of the project.

the only Member States beside France that proposed a reduction of litter from land-based sources as their target (Van Acoleyen, 2014).

A.8.1.3 Objectives for Management

Since rivers are thought to contribute substantially to marine litter, it is paramount from a management point of view that information on types and sources of litter in rivers are recognized and quantified where possible. Through this knowledge additional measures to reduce not only litter in rivers but also in the marine environment can best be implemented.

In response to the agreement at the Rio+20 summit to achieve, by 2025, “significant reductions in marine debris to prevent harm to the coastal and marine environment”, as well as the call in the 7th Environment Action Programme (7th EAP) for an EU-wide “quantitative reduction headline target” for marine litter, the European Commission is in the process of developing such a reduction target.

The new policy initiative "Towards a circular economy: A zero waste programme for Europe" includes proposals for revising the waste legislation and for an aspirational target for reducing marine litter by 30% by 2020.[33] A study analysing options for marine litter reduction was recently finalised (Van Acoleyen, 2014).[34] The study was one of many studies relating to marine litter recently undertaken for the European Commission. The main scope of the study was to support the development of an EU headline marine litter reduction target that can be used for benchmarking progress towards good environmental status for marine litter. The proposed headline reduction target for marine litter is:

“A 30% reduction of the number of items of the top ten litter categories found as coast litter in each regional sea, by 2020, compared with 2015, applying the screening method from the technical guidance documents on monitoring of marine litter and excluding fragmented or undefinable litter items with guidance document codes G75, G76, G134, G145, G158, G210.”

Authors of the final report concluded that if the target is to be met, not only general waste management actions, but also specific measures targeting individual litter types will be needed. Awareness raising campaigns, economic incentives (Deposit-Refund

[33] Available at: http://ec.europa.eu/environment/circular-economy/

[34] Final report of the study titled Marine Litter study to support the establishment of an initial quantitative headline reduction target - SFRA0025, Project Number BE0113.000668, available at: http://ec.europa.eu/environment/marine/good-environmental-status/descriptor-10/pdf/final_report.pdf

scheme) and dedicated infrastructure seem to be the most effective measures to reduce marine litter pollution (Van Acoleyen, 2014).[35]

The most efficient option for decreasing the amount of litter in the marine environment is to prevent emissions at the source. The priority sources of marine litter and the most relevant loopholes in the flow of plastic packaging are defined by three recent marine litter pilot projects for the European Commission:[36]

- Study of the largest loopholes within the flow of packaging material;
- Feasibility Study of introducing instruments to prevent littering; and
- Case studies on the plastic cycle and its loopholes in the four European regional seas areas.

The common conclusion of these three studies on marine litter is that plastic is the dominant fraction in the marine environment and that plastic packaging waste (PPW) in marine litter comes primarily from land based activities, including riverine input. Sanitary waste (coming through sewage outflow) is recognized as of special importance in the Mediterranean region and in the Baltic region by these reports (ARCADIS 2013).

Due to the material's longevity and widely distributed use, plastics generally make up a large proportion of marine litter, posing an additional chemical risk. Small plastic particles and microplastics are a major concern, since they are easily ingested by organisms throughout the food chain and can end up in species used for human consumption.

Reliable quantitative data on all litter categories (micro-, meso- and macrolitter) in rivers is lacking, both at an EU and Member State level. Potential sources and their relative contribution to riverine litter should be identified and a co-ordinated approach to monitoring of riverine litter needs to be developed. The current project will aggregate current knowledge on riverine litter and propose an effective approach to monitoring and identification of land based litter sources. Furthermore, this project provides an opportunity to test TSG marine litter guidelines in the field in cooperation with local partner organisations.

The three studies identified individual behaviour and people's attitudes and perceptions as a major influential factor with respect to littering. Other important factors include context (e.g. cleanliness of the area, administrative capacity and competences, etc.) and available waste infrastructure (e.g. sewerage systems) and facilities (e.g. port reception facilities, suitable receptacles). Due to the important impact that individual behaviour has on marine litter, increased knowledge of the behaviour of individuals and

[35] Final report of the study titled Marine Litter study to support the establishment of an initial quantitative headline reduction target - SFRA0025, Project Number BE0113.000668, available at: http://ec.europa.eu/environment/marine/good-environmental-status/descriptor-10/pdf/final_report.pdf

[36] All three studies, along with a "common chapter" are available at: http://ec.europa.eu/environment/marine/good-environmental-status/descriptor-10/index_en.htm

organisations responsible for litter can assist with the formulation of effective policy measures to address the problem of marine litter.

A.8.1.4 Classification

Marine litter is defined to include any anthropogenic, manufactured, or processed solid material (regardless of size) discarded, disposed of, or abandoned in the environment, including all materials discarded into the sea, on the shore, or brought indirectly to the sea by rivers, sewage, stormwater, waves, or winds (Honolulu Strategy, 2011).

Often used terms macro- and meso- litter do not have officially accepted definitions. It is broadly accepted that macro-litter comprises litter of a size greater than 25mm which is the lower limit of beach litter assessment used by most of the researches, including TSG ML Guidance document.

Micro-litter is a term, based on the definition of microplastics, accepted at the International Research Workshop on the occurrence, effects, and fate of microplastic marine debris in 2008, University of Washington Tacoma, WA, USA. The Workshop participants defined microplastics as plastic particles smaller than 5mm.

The size range between 5 and 25 mm is regarded as »meso-litter«, which is rarely covered in marine litter monitoring protocols, but is included in this study as ‘small’ litter.

Plastics, such as polyethylene and polystyrene, are synthetic molecules that are formed by joining monomers at high temperature and pressure or by creating a free radical monomer which produces a long chain polymer.

A.8.2 Transportation of Litter in Rivers

A river is a complex system in the way it transports solid inert particles with a specific mass or density comparable to the density of water. The transport of plastic litter in rivers occurs through different transport modes:

- a fraction floats on the water surface;
- a fraction is transported in suspension in the water column; and
- a fraction is transported as part of the bed load near the bottom of a river.

These fractions can be stored temporarily in floodplain vegetation, the banks, near hydraulic structures (like barriers) and at the river bottom with ripples and other bed forms.

A.8.2.1 A River System

A river consists of a water body that has a width in the order of meters to hundreds of meters and a depth to a maximum of around 100 meters. Within this confined space strong gradients are present with regard to flow velocities. Also the impact of obstacles like barriers, dams and protruding obstacles creates complex flow patterns. This might result in a variable concentration of plastic litter particles, both in a transverse, in a longitudinal and in a vertical direction.

The most visible fraction is a coarse fraction (≥ 25 mm) of floating plastic litter during floods.

The transport of plastic litter often with a foil like shape is the so-called suspended load, which stays in the water column for extensive periods of time because the downward forces – as part of the natural turbulent fluctuations in flowing water – are in excess of the buoyancy force from the particle.

A part of the plastic litter - those items with a higher density than water - sinks to the river bed, eventually becomes part of the bed load transport process and can be stored temporarily in the ripples, local scour holes and river dunes. The propagating velocity of the bed load is much smaller than the velocity of the flow (van der Wal et al, 2013)[37].

The transport process of plastic litter in rivers shows some analogies with the transport of other items: transport of vegetation and transport of sediment. Literature concerning the transport of seeds might give some indications on the behaviour of plastics in the riverine environment, but seeds tend to change during their stay in the water and are not as inert as most of the litter items (Gurnell, 2007).[38] On the other hand, plastics also pollute or get covered with a biofilm, leading to a change in their density, however, the rate at which this occurs is much slower than for organic materials.

The varying river discharge originating from snowmelt and precipitation in the wider catchment results in varying concentrations of plastic litter transported in rivers. These variations depend also on the controlled flow by locks, dams and weirs.

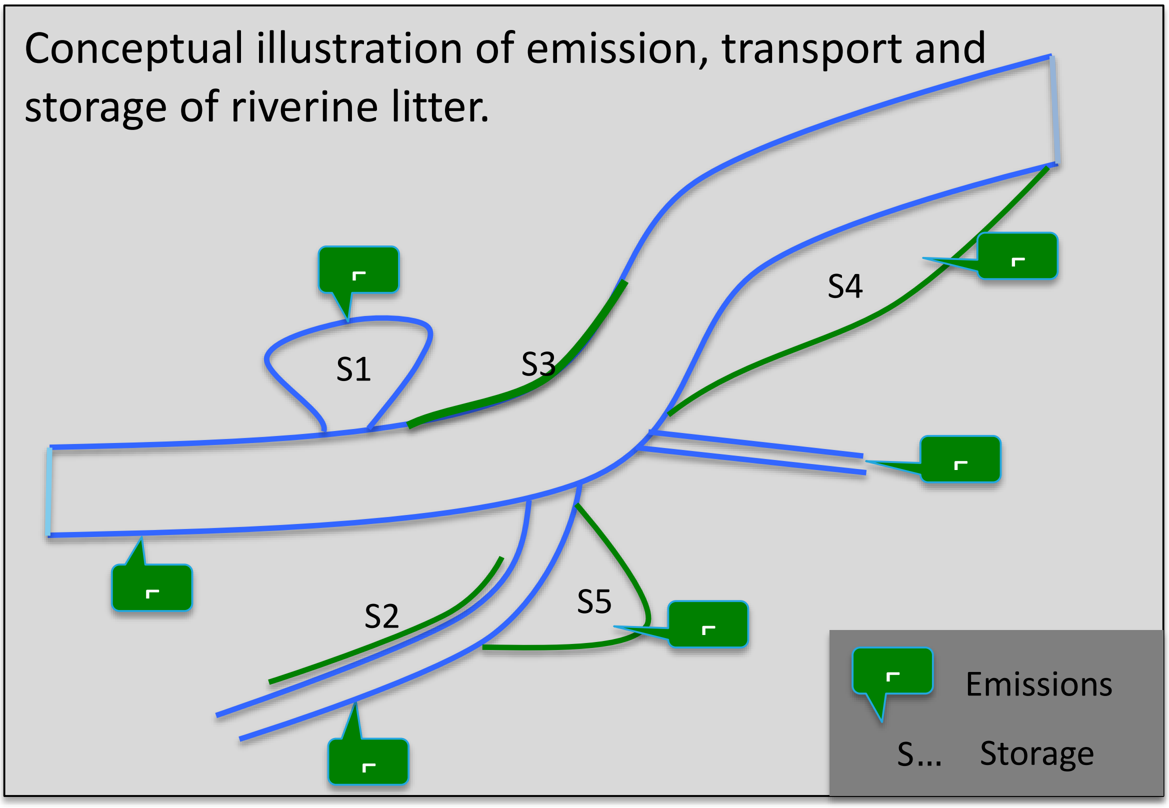
Plastic litter can be stored in a watershed, mainly in floodplains, for shorter or longer periods. Very localalised processes (like a change in wind direction) can release these stocked items to be transported just a bit further, see Tweehuysen, 2012.[39]

[37] Wal, M. van der, M.D. van der Meulen, E.W.M. Roex, Y. Wolthuis, G. Tweehuysen en A.D. Vethaak, (2013) Summary report plastic litter in Rhine, Meuse and Scheldt, contribution to plastic litter in North Sea, project 1205955, Deltares, Delft

[38] Gurnell, 2007 Analogies between mineral sediment and vegetative particle dynamics in fluvial systems

[39] Tweehuysen, G. (2012) Incatieve resultaten van 5 metingen in oktober 2012, River Litter Foundation

Figure 60: A Conceptual illustration of Riverine Litter Emission, Transport and Storage[40]



The different emissions and storage locations are indicated in Figure 60:

- E1 is an emission directly into the river, like the emission from a waste water treatment plant (WWTP), a ship or a city;
- E2 is an emission in a water basin that is connected to the river. It can be a harbour basin or a connected lake;
- E3 is an emission into a tributary;
- E4 and E5 are emissions on a floodplain, waiting to be transported with a high water period (e.g. litter discarded by tourists or by illegal dumping);
- E6 is an emission outside the floodplain, but litter is transported by waterways, wind and sewerage systems into the river;
- S1 is litter stored in basins that have a connection with the river and consists of litter input either from an emission or it has been pushed in the basin by wind or high water;
- S2 and S3 is litter deposited on a riverbank, waiting to be transported by a high water wave or a change in wind-direction; and

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[40] source: Waste Free Waters

- S4 and S5 is litter stored in a floodplain of the river or from tributaries in the whole watershed, either by direct emission or by deposition at a previous high water period.

A.8.2.2 River Mouth

In a river mouth with a tidal motion and complete mixture of fresh and salt water, the flow direction might change during flood. In a well-mixed estuary the flow in the whole water column can change direction depending on the strength of a tide. However, in a stratified estuary the flow of a saline wedge under the fresh water layer is often in the opposite direction to the flow of fresh water. Therefore the measurements of plastic litter in a river mouth can be influenced by the type of estuary and the amount of plastic litter present in seawater.

A.8.2.3 Measuring

Measuring the riverine input of plastic litter from a river into a sea is basically measuring the litter load at the mouth of a river, where it discharges into a sea. Often this location is an area and not a well specified location where ‘the river’ enters a sea. Many rivers flow in a delta with multiple parallel channels connected to a sea.

A.8.2.4 Approach

The process of transport, storage and release of emitted and stored items is hard to predict or to trace back to an individual emission, so linking the presence of litter at a river mouth to a specific emission point somewhere in the watershed is only approachable by relating the characteristic properties of a plastic litter particle to its possible source in a river basin. This requires a detailed analysis of collected plastic particles to determine size, density, chemical composition and other parameters to identify a probable source of plastic litter. This approach has been applied in this project.

A.8.3 Monitoring Methods of Litter in Seas and Rivers

Monitoring of floating macrolitter in the marine environment is usually performed via visual ship-based observation. There are several protocols, with minimal differences, based on visual observation, used by HELMEPA, ECOOCEAN, Chile/Germany, UNEP, NOAA and by scientific research groups. In respect of rivers, no published study on the theme of visual monitoring of floating macrolitter is available.[41]

[41] Exept a yet unpublished study from University College Cork (T. Doyle) : Cork Riverine Inputs project

Seawater samples are mostly taken by nets. Most studies from surface waters have used Neuston nets and from the water column, zooplankton nest. The main advantage of nets is that large volumes of water can be sampled quickly. Nets differ between each other in the mesh size and the opening area. In the most studies mesh size was in range from 0.30 to 0.39 mm. The net aperture for rectangular openings of neuston nets ranges from 0.03 to 2 m^2. For circular-bongo nets the net aperture ranged from 0.79 to 1.58 m^2. The length of the net for sea surface samples has varied from 1.0 to 8.5 m, with most nets being 3 to 4.5 m long. One recently developed technique in the marine environment at the moment is the Manta net, which is also discussed by the JRC (Hanke et al., 2013) as a potentially good technique for the monitoring of floating litter within the EU.

Another instrument that is deployed on a global scale and that has also been used for microplastic sampling is the continuous plankton recorder (CPR).

The third option is pumping the water through the a filter on-board a ship. This method is being developed for example by CEFAS, using the ship's water inlet, collecting seawater from the side at specified depths, mostly ranging between 4 m and 1 m.