Results of riverine macroplastics sampling with the Waste Free Waters sampler.

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figure 1: Trawled WFW-sampler Mk-I in the Meuse

1 Introduction

Waste Free Waters is an independent foundation that focuses on the issue of litter flowing from land to seas by means of rivers. Started in 2011, the foundation has developed a method to sample litter in riverine conditions on the surface and simultaneously in the watercolumn. With the developed sampler (Mk-I) measurements have been done in the Meuse in the Netherlands and in a number of rivers in Europe (the Rhine in the Netherlands, the Po in Italy, the Danube in Romania and the Dalålven in Sweden). Based on these experiences a lot of knowledge is gained about sampling in riverine conditions.

figure 2: Waste Free Waters sampler (Mk-I)

In this report some of the specific aspects of sampling macrolitter in rivers are highlighted, the results of a sampling program in the Meuse (Oct. 2013) are presented and a preferable way to measure riverine macrolitter based on the previous experiences is outlined.

This study in 2013 was commissioned by Rijkswaterstaat and Gemeente Schoon. The sampling and measuring equipment was sponsored by PlasticsEurope Nederland.

Rijkswaterstaat Ministry of Infrastructure and the Environment

Gemeente Schoon

Plastics Europe

2 Methodological approach

2.1 Why do we need a different approach between macroplastics and microplastics?

Political and scientific attention focuses ever more on microplastics (particles < 5 mm) because of the potential ecological harmful impact, but for the public larger macroplastics are the most visible part of plastic waste. Larger plastic particles can disintegrate in smaller plastic particles due to UV-light and elevated temperatures, which happens mostly on land. One plastic bag (500 mm long and 2 x 400 mm wide) can fragment in over a million particles with a dimension of 0,5 x 0,8 mm. The number of ever smaller microplastics coming from one piece of macroplastic show an exponential growth. Microplastics are relevant because of the negative effects they can have on biota low in the food chain, macroplastics are relevant because they cause harm to larger creatures. They represent most of the weight and might be managed and controlled easier than microplastics (e.g. with clean-up activities and improved waste management systems). Understanding the abundance of macroplastics and the way they are transported in rivers can help to develop effective mitigating strategies and support public actions for mitigating the problem of marine debris.

2.2 Why is the WFW-sampler a relevant sampling device for macroplastics?

The WFW-sampler is designed to sample macroplastics in riverine conditions and in two compartments: on the surface and in the water column. Most available data about the presence of litter in aquatic environments is gathered with neuston nets, having a mesh smaller than 1 mm, mostly 300 micron. These nets clog very fast in riverine conditions and can only be applied for short periods. With neuston nets in riverine conditions only 500 to 1000 m^2 can be sampled. To collect the larger, more widely spread macroplastics, a larger mesh is needed. The WFW-sampler has a mesh of 3,2 mm and can sample over 10.000 m^2 on the surface and over 5.000 m^3 from the water column.

2.3 Why sampling in two compartments, surface and suspension?

Plastics have a specific weight close to 1. The lighter plastics will rise to the surface, the heavier plastics will sink to the bottom in accordance to Archimedes' law. When particles move through the water a drag force occurs in the opposite direction, related to the wetted surface of the particle. This means that the terminal speed in water relates to the surface-to-volume ratio (s/v ratio) of the particle. If in turbulent conditions the upward or downward speed of the water exceeds the terminal speed of the particle, the particle will be kept suspended. Particles with a small s/v ratio will quickly sink or float, particles with a large s/v ratio will remain suspended, depending on the turbulence of the water. Rivers are always turbulent, so a part of the total plastic load will be transported suspended in the water column. Especially foils will stay in the water column, granules and other thick walled products like bottle caps will float, heavy products like rubber products will be found close to the bottom. For technical (nautical) reasons, the WFW-sampler only takes samples at the surface and in the higher part of the water column.

2.4 How are the samples categorized?

With the aim to gain insight in the numerical abundance, shape and weight of plastic debris in rivers, the samples are split in three shape categories (compact, flat and long) and three size categories (< 5 mm, 5 - 25 mm and > 25 mm). These categories relate to the suspected behaviour of particles in turbulent riverine conditions. Only the > 5 mm and > 25 mm categories are used for further analysis. While manually categorizing, compact particles "feel" rigid and have three dimensions that are in the same order of magnitude. Flat particles "feel" flexible and have one dimension significantly smaller than the other two. Long particles have one dimension significantly larger than the other two and "feel" flexible. This categorization can be done by relatively untrained staff and requires no laboratory equipment (except a drying stove). Samples are counted and weighed. This simplified categorization protocol is aimed at determining the most relevant data for assessing the particle load that is present in a river and can easily be applied in other (European) rivers and aggregated to determine the total land based origin of litter flowing into the marine environment.

figure 3: typical compact particles typical flat particles

2.5 Why is dynamic sampling necessary?

Sampling can be done from a static position, like from the riverbank or from a bridge. But conditions at the river surface can vary substantially, e.g. caused by the effect of wind pushing floating materials across the river surface, or by the presence of moving patches of litter that were released at a rising water level or by the effects of an uneven distribution of water flowing in from an upstream tributary or installation.

figure 4: litter pushed to downwind shore

figure 5: litter caught in eddy

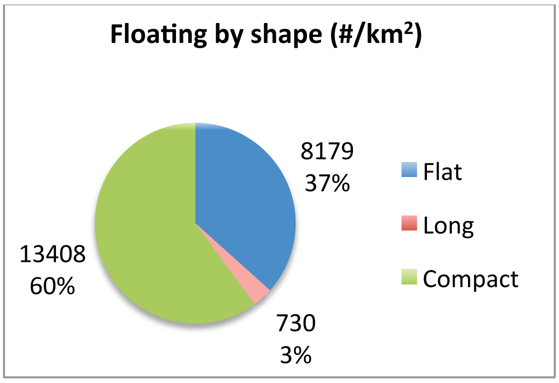
figure 6: tributary upstream sampling location

Dynamic sampling on the whole width of a river assures that these local phenomena do not dominate the sampling results. Dynamic sampling also assures that there is a constant speed with which the samples are taken and that samples can be taken from water bodies with very low or absent currents. The samples as discussed here are taken by trawling a sampler along the side of a boat.

3 Results

Reported here are the results of research in the Meuse in October 2013 near Eijsden[1], close to the city of Maastricht in the Netherlands. In a period of two weeks, 8 sampling runs were done. At the time of sampling the discharges were rather low and riverine conditions were calm.

3.1 Numerical presence and concentration in numbers by compartment and shape:



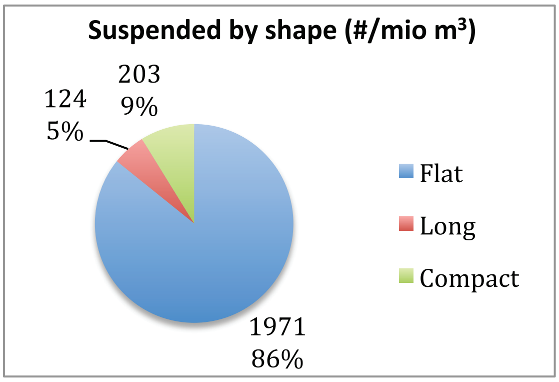


figure 7: average presence on surface by shape, average concentration suspended by shape

These pie charts show the average normalized presence of macroplastics on the surface and the concentration of macroplastics in suspension in units that are frequently used in reports on the presence of particles in marine environments. For a meaningful assessment of riverine transport, these units are not practical to use because they cannot be added or compared.

By relating the amount of suspended particles to the discharged volume of the river during a day[2] and the amount of floating particles to the size of the surface layer that passes the riverine cross-section during a day[3], more meaningful units become available.

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1 Tweehuysen, 2013, Onderzoek naar de aanwezigheid van grof en fijn rivierafval in de Maas.

2 [daily load of suspended particles (#/day)] = [measured concentration in suspension (#/m^3)] x [discharge

2 [daily load of suspended particles (#/day)] = [measured concentration in suspension (#/m^3)] x [discharge (m^3/s)] x 3600 x 24

3 [daily load of floating particles (#/day)] = [measured presence on surface (#/m^2)] x [river width (m)] x [river velocity (m/s)] x 3600 x 24

3.2 Daily load in numbers by compartment and shape:

For riverine environments a representation in daily loads as described in the table below is more relevant.

	Flat	Long	Compact	total
av load suspended (#/day)	26902	1210	2696	30808
av load floating (#/day)	31084	2743	51820	85648
Total	57986	3954	54516	116455

table 1: daily load in numbers by compartment and shape

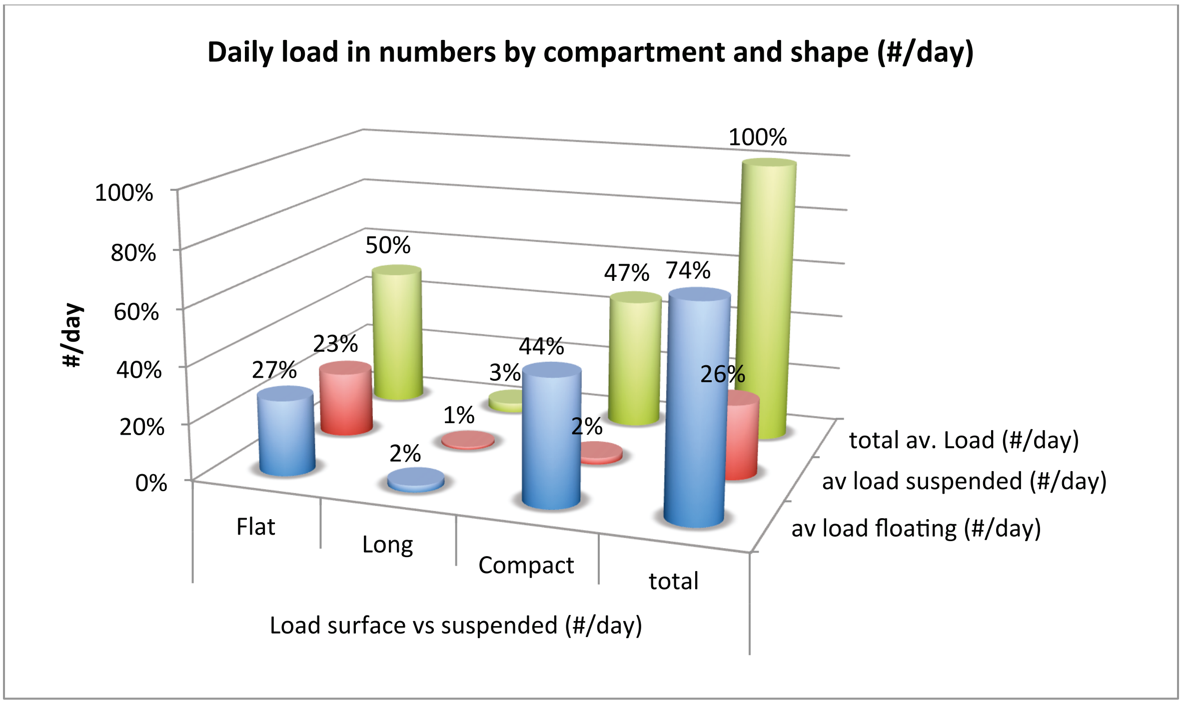

figure 8: daily load in numbers by compartment and shape

From the total amount of 116,455 (100%) particles transported daily by the river, 74% is transported on the surface, of which 3/5 is compact and 2/5 is flat. In suspension 26% of the daily load is transported, almost exclusively with a flat shape. Long particles are rare. The relative high presence of flat particles on the surface has to do with the calm riverine conditions. When discharges rise and the river gets more turbulent, this category is expected to shift more into suspension.

3.3 Daily load in numbers by compartment and size:

An analysis of the different size fractions of the caught macroplastics give the following picture:

	< 25 mm	>25 mm	total
average load floating #/day)	75878	9769	85648
average load suspended (#/day)	29927	881	30808
total floating + suspended (#/day)	105806	10650	116455

table 2: daily load in numbers by compartment and size

From the total number of 116,455 particles, 91% is smaller than 25 mm and are mostly found floating on the surface. Only 9% of the particles is larger than 25mm and they are mostly floating (> 90%).

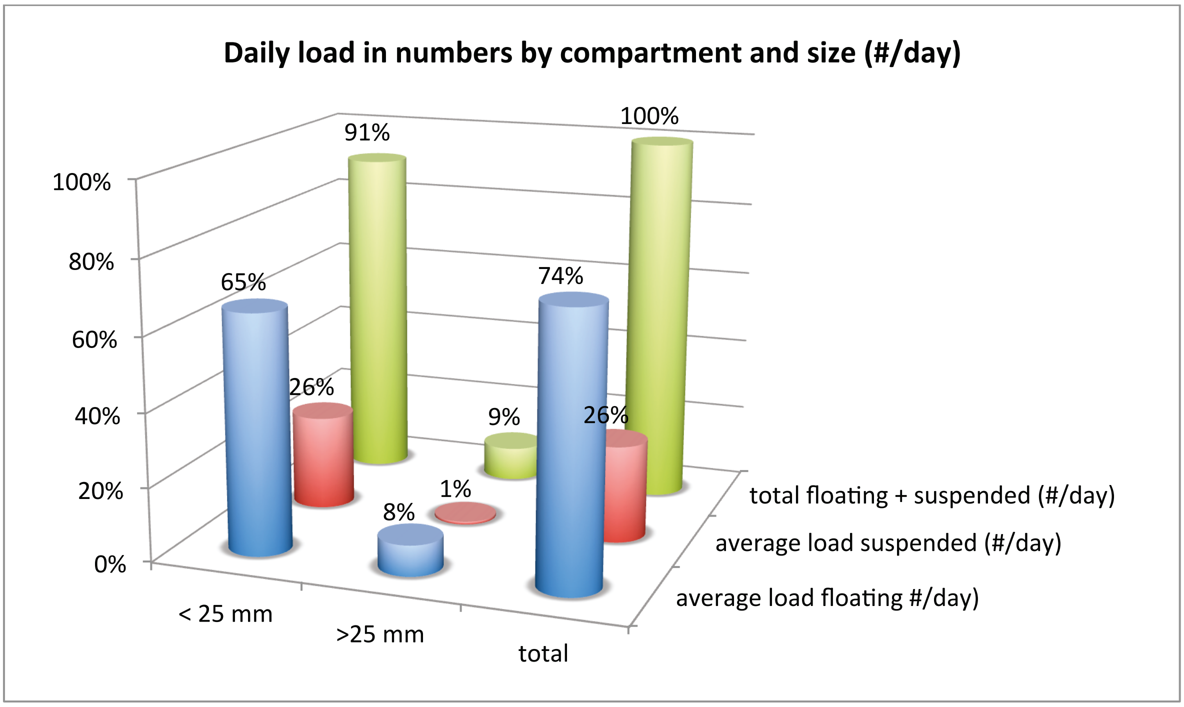

figure 9: daily load in numbers by compartment and size

3.4 Daily load in weight (grams/day) by compartment and size:

For assessing the load of plastic debris carried by a river to the sea, not only the numerical presence is relevant, but certainly also the load in weight terms. The table below shows the weight per size category and per compartment.

	< 25 mm	>25 mm	total
average load floating (g/day)	3175	9591	12766
average load suspended (g/day)	332	162	493
total floating + suspended (g/day)	3506	9753	13259

table 3: daily load in weight by compartment and size

It is remarkable to notice that the 9% of the amount of particles which are larger than 25 mm represent 74% of the weight, mostly transported on the surface. The large amount of smaller macroplastics represent in weight terms "only" 24% of the total load. The suspended fraction represents a minor share of the total load in weight terms (4%).

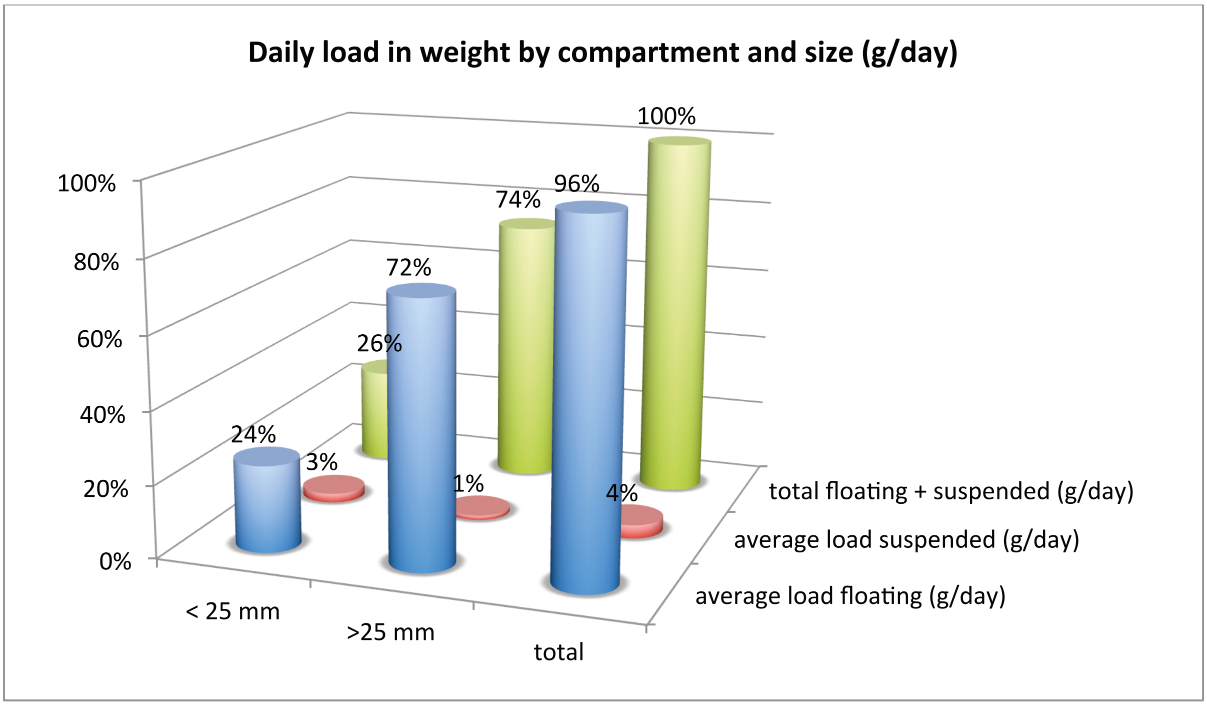

figure 10: daily load in weight by compartment and size

In total the Meuse transports on a daily basis a load of 13,25 kg, of which 12.8 kg floating on the surface.

4 Conclusions

Sampling in two compartments and categorizing to shape and size offers a recognisable view on the presence of macroplastics in a river and the way they are transported to the sea.

The results indicate that the numerical presence shows a different picture than the presence in weight terms. It also indicates that most of the riverine load is transported on the surface and that it consists of mostly compact shaped particles. Still the amount and weight of flat particles (films and sheet) are not negligible, mainly because they are transported in suspension and are out of reach of floating collection devices. Flat particles are also the most probable source of secondary microplastics.

Compact particles which are floating will be temporarily stored at riverbanks and when they are larger than 25 mm they might be the only category that can be removed from the environment by clean-up activities.

The categories flat, long and < 25mm are difficult to remove from the riverine environment once they are in there and require mitigation strategies aimed at prevention at source.
It is not known yet which portion of the flat particles are caught in vegetation and can be removed from there.

The WFW-sampler is not capable of sampling materials that are transported on the river bottom. It can be assumed that only compact heavy particles will remain on the bottom and that flat heavy objects will also be present in suspension in turbulent conditions. Since the majority of plastic debris consists of products made from polyolefins like PE, PP or PS, the results of the sampler might cover most of the spectrum of discarded products.

figure 11: heavy particles on dry river bed

Extrapolation of daily values to yearly values is not possible based on the results of this study. The total yearly riverine discharge is most probably concentrated in short periods of significantly higher discharge values than normal. In those high discharge events the river basin gets "flushed" and it is expected that at those moments most of the yearly riverine load of debris is transported. The data discussed in this report can best be regarded as the average baseload of litter transported in the Meuse river.

5 Perspective

The sampling methodology described in this report appears to be valuable for determining the presence and behaviour of macroplastics in a riverine environment. Also the limited choice of categorization criteria still gives valuable insights and has the advantage that it can be performed with very limited laboratory facilities. But when required the samples can always be further divided in subcategories e.g. in accordance with the Masterlist of Categories of Litter Items (TG-ML) or the list used by OSPAR for beach clean-ups.

More experience now should be gathered in different rivers and in different conditions to test the validity of the results in the Meuse. A new sampler must be developed which is self-propelled and transportable and which makes it possible to sample in rivers and lakes all over Europe.

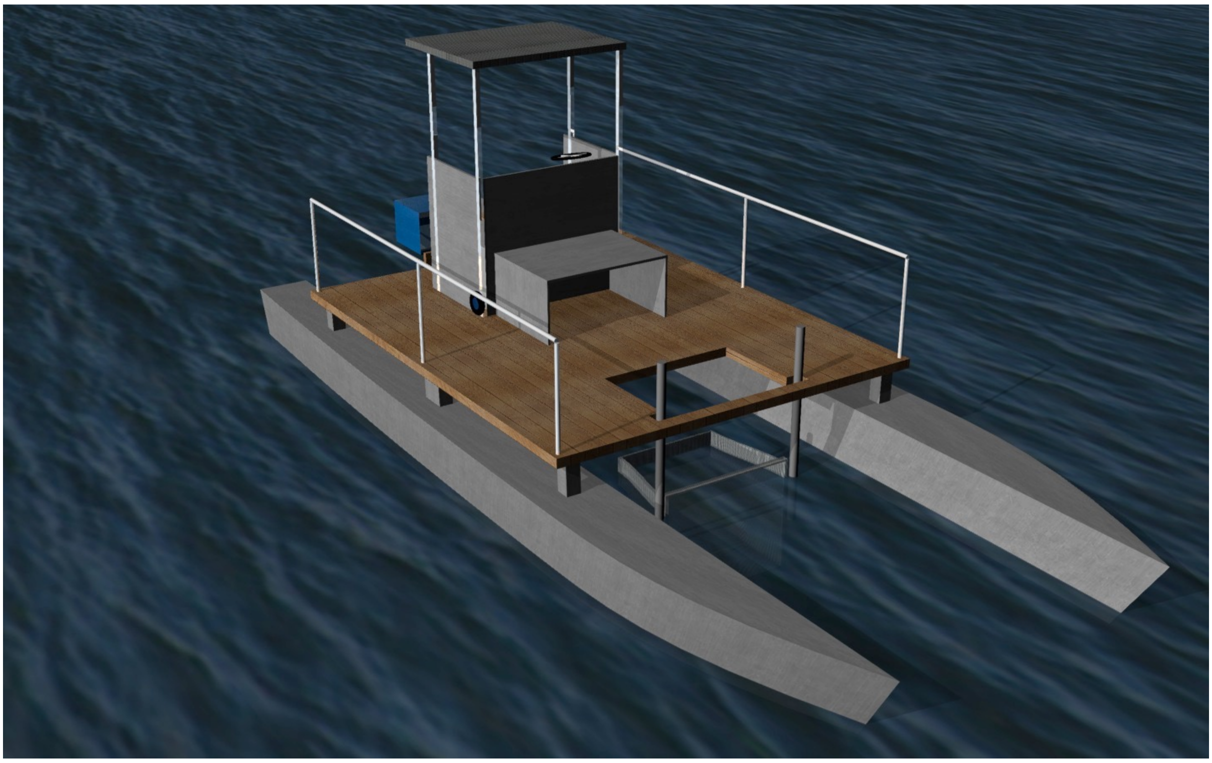

figure 12: artist impression of WFW-sampler Mk-II

More scientific tests are necessary to support the validity of the assumption that the results of the suspension net are representative for the rest of the water column.

Also more research is needed to understand the phenomena that occur in tidal estuaries, where fresh water from rivers mix with the salt water from the sea and which can be regarded as system boundaries to establish the scale of landbased input in the marine environment

A particular challenge is to assess the transported load of litter during high discharges events and to find ways to relate observational methods (like camera observations) to the actual presence as determined with the WFW-sampler.