Guidelines for the BLASTIC riverine plastic litter monitoring method

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Project	BLASTIC - Plastic waste pathways into the Baltic Sea
Work package	WP3 Results from plastic litter monitoring in the pilot areas
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Contents

1. Executive Summary

This document is prepared within the BLASTIC project (Plastic waste pathways into the Baltic Sea). The project was supported by EU Interreg Central Baltic (2016-2018). The overall aim is, by mapping and monitoring marine plastic litter, to facilitate the reduction of the inflows of plastic litter and of hazardous substances into the Baltic Sea.

Plastic litter is a prominent environmental problem as almost everywhere, not only in urban environments, you can find plastic debris in some form. Marine plastic litter is anthropogenic plastic waste that has been discharged into the coastal or marine environment. Marine plastic litter have been shown to have a great potential to harm marine wildlife and ecosystems. Its negative effects on the marine environment have prompted not only governments but also, environmental groups and citizens to take action.

The monitoring of marine plastic litter is important not only in order to acquire knowledge about know how much plastic is already in the marine environment but it is also important in order to know how much plastic is being discharged into the oceans. The idea within BLASTIC was to develop a cost efficient, flexible and scalable method for monitoring of riverine plastic discharge. The method of floating litter booms was chosen as litter booms are flexible in both size and positioning and that they collect the floating litter which then can be quantified, categorised and analysed, which is considered to be a major strength of this method. It was designed with the intention of producing high quality, robust data sets while being flexible in regards to the purpose of the monitoring. The methodology for riverine litter monitoring was developed and tested at four different pilot areas within the BLASTIC project. The methodology and experiences gained from the pilot testing of the methodology are described in this in this document.

The three project partners that reported results (IVL, SEIT and SYKE) had different experiences and the floating litter booms worked better in some sites than others. The physical conditions of the monitoring site are of great importance when monitoring with floating litter booms. All monitoring was in some way affected by either the width of the river, weather conditions such as wind and/or water flow rate/direction. Based on the experiences from the monitoring in the pilot areas the conclusion by the project members is that the floating litter boom methodology is suitable in narrow rivers with a continuous water flow and a high frequent sampling rate is recommended to obtain high quality data sets.

2. Background and aim of monitoring plastic macrolitter in BLASTIC

The monitoring of plastic litter or litter in general, can have multiple purposes. Monitoring can for example be carried out as a mean of verifying the sources and pathways identified as "hot spots" from a desktop study. It could also have the purpose to control if implemented measures to decrease littering have had the desired effects and/or it can be used for awareness-raising means. The awareness-raising purposes could for example be to demonstrate how much plastic litter or litter in general that originates in general or from specific areas or events in the city during a given period of time.

Monitoring of plastic litter in BLASTIC plastic was carried out in Work Package 3: Monitoring of plastic litter. The aim of monitoring macroplastic litter in BLASTIC was twofold:

1. To develop and practically test a monitoring methodology suitable for the Baltic Region.

2. To monitor the pilot areas contribution of plastic marine plastic macro litter in to the Baltic Sea.

3. Monitoring methodology development

A literature screening review of existing methodologies for monitoring marine plastic macro litter was conducted in or order to see where the methodology development in BLASTIC could fill some gaps.

It has been estimated that the annual input of plastic waste from rivers to the oceans is between 1.15 and 4 million tonnes. with the majority of these emissions occurring between May and October (Lebreton, Van der Zwet et al. 2017, Schmidt, Krauth et al. 2017). However, even if it's well known that rivers are a major pathway of the plastic input to the world's ocean, not much actual monitoring has been performed. Most studies have focused on measuring microplastics (<5mm) by either using manta trawls (Yonkos, Friedel et al. 2014, Dris, Gasperi et al. 2015, van der Wal, van der Meulen et al. 2015), stationary drift nets, Neuston nets (Lechner, Keckeis et al. 2014, Rech, Macaya-Caquilpán et al. 2015, Vianelloa, Acrib et al. 2015) or by pumping water through a fine mesh filter (Zhao, Zhu et al. 2014). All these methods are limited by the volume of water that can be sampled which becomes an issue when sampling for macroplastics. The concentration (item / dm^3) of macro plastics has been shown to be significantly lower than the concentration of microplastics (Lebreton, Van der Zwet et al. 2017), hence it is important to be able to sample a large volume of water to get good quantitative results. The area of macroplastic riverine monitoring is not well explored and as all pilot areas (Södertälje, Turku, Helsinki and Tallinn) in the BLASTIC project have rivers flowing through them the project group decided to focus on the development of a method for riverine plastic litter monitoring.

3.1. Methodology

Measuring riverine plastic can be performed in several different ways and depending on where in the river (water column, river bank or riverbed) the plastic is to be measured; the monitoring methods will differ greatly. Another factor that affects the monitoring method is what size fraction (micro. meso or macro plastics) is to be measured.

The idea was to develop a cost efficient, flexible and scalable method that could monitor a large volume of water in order to get quantitative results of the abundance and composition of macroplastic litter in the water column of a flowing river. As visual observation methodology protocols for floating plastic litter and beach litter already exist (Cheshire and Adler 2009, Ryan, Moore et al. 2009, Directive 2013) and as seabed monitoring was considered by the project group not to be cost efficient, it was decided to develop a method to monitor the water surface and

column. The method with floating litter booms was chosen as litter booms collect all the floating litter which then can be quantified, categorised and analysed, which is considered to be a major strength of the litter booms. It is designed with the intention of producing high quality, robust data sets. The method is flexible in regards to the purpose of the monitoring, it can be for scientific purposes if standardizing the sampling or it can be simplified to work in e.g. awareness projects. Also, the litter booms stops the litter from reaching the ocean, in contrast to e.g. visual surveys. Litter/trash/debris-retention booms are already being used in some rivers to prevent litter from reaching the ocean. The debris-retention systems that are made for collecting floating litter are often large, expensive, not very flexible in regards to moving them around and they are used in rivers with a high load of floating litter such as Seine and Thames (Gasperi, Dris et al. 2014, Morritt, Stefanoudis et al. 2014). The floating litter boom methodology described within BLASTIC is less expensive, easy to deploy, easy to scale in size, flexible in regards to where it can be placed and easily moved. The original idea was to monitor upstream and downstream the city centres in all pilot areas to get an indication of the contribution to marine plastic littering from urban areas. This was not practically possible in pilot areas.

The main task in work package 3 of the BLASTIC project was to develop and test a method for riverine plastic litter. The floating litter boom method was chosen. The various partners in the project did perform the monitoring in a few different ways as the physical characteristics of the different sites differ in several ways such as river width, flow rate, depth, changes in current direction, exposure to wind etc.

3.2. The floating litter boom

The floating litter boom creates a barrier where floating litter is captured (Figure 1). As over 2/3 of all produced plastics have lower density than water (Yeo, Muiruri et al. 2017) it has the potential to float. However both the shape and density of the plastic will affect the plastic items buoyancy and hence affect where in the water column of the river that the litter will be. For example flexible, film-like litter, tends to stay mixed in with the water column while more dense plastics without trapped air pockets may sink and travel along the river bottom if not completely embedded in sediment. However if the more dense plastic package has air trapped in it (like a PET bottle) then it may float on the surface. The floating litter boom method focuses mainly on measuring the surface water (top 0.5m) but the boom can advantageously be supplemented with different net curtains (Figure 2) to increase the sampling depth. In the BLASTIC project different kind of set-ups where tested.

The floating litter booms used within BLASTIC were modified cylindrical containment booms (Sjuntorp C500). The general area of use for these booms is to contain oil and/or chemical spills or protect areas against floating contamination agents. As the C500 was designed for rapid and easy deployment and several booms could be connected to get a desired length they were chosen for the project. The booms were modified so that net curtains easily can be connected to them.

The litter booms can be moored either by using some kind of anchors (Figure 2) that are placed in the water or they can be attached to fixed structures either at the shoreline or if there are any out in the water. Both types of moorings were tested within the project.

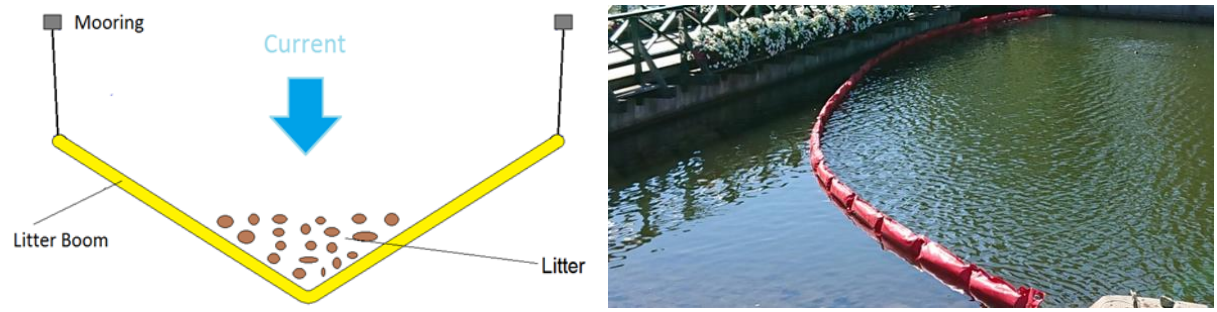

Figure 1. Set-up of the floating litter boom.

Figure 2. Litter booms with net curtains and grapnel anchors used to moor the litter boom.

3.3. Net curtains

Net curtains with different mesh size can be connected to the booms which allows for monitoring of different size fractions of plastic litter. In the BLASTIC project the mesh size of about 8 mm was chosen so that the nets would catch cigarette buds and that mesh size was not expected to clog too fast with organic material. That mesh size was proven to be adequate to catch a good sample of cigarette butts, candy wrappers etc. while allowing a longer sampling time than a net with smaller mesh size. The height of the net curtain can be modified to suit the monitoring site.

3.4. Sample size

Depending on what the results of the monitoring are to be used for e.g. quantitative scientific data, monitoring the results of implemented measures towards reducing riverine litter or public awareness, the set-up may vary greatly. The more variable the data is the more repetition is needed to achieve an acceptable level of accuracy and precision. If the monitoring is to be used for a scientific publication or to monitor the effects of implemented measures against litter, then multiple sampling sessions are needed in order to produce high quality data. The sampling should cover seasonal variation and short term variation. As plastic litter is not spread homogenously in the water, the result of short time sampling (for example one day) will only provide a snapshot that shows how the plastic litter discharge was that particular day. To in order to find out about the variation in the discharge, repeated sampling is necessary. But if the monitoring is to be used to raise awareness in an environmental campaign then fewer samples may suffice.

When starting to monitor in a specific area that has no prior monitoring, the general lack of quantitative data regarding litter quantities makes it difficult/impossible to predict how long sampling duration and sampling repetition is needed to obtain high quality results. The needed sampling repetition and sampling duration will be site specific which means that pilot sampling is recommended. Frequent sampling is recommended to increase the representativeness of monitoring.

3.5. Assessment and documentation

The collected litter can be counted, weighed and categorized according to the BLASTIC protocol (

) for categorization of marine plastic litter. This includes the specific information about the dates of the monitoring, number of collection days, weight of the total collected amount litter, weight of the collected amount of plastic items and total number of items collected. The data should, if possible be reported as the number of items per volume of water passing the litter boom. The categories for plastic litter include 37 types of floating plastic litter.

3.6. Necessary resources

The floating litter boom is a low-tech and relatively low-cost monitoring option. However an initial cost for the boom is required. Cylindrical containment booms can be used with success. These booms might need some modification depending on the initial design and if net curtains are to be used on the booms. Other costs depend on the deployment and retrieval of the booms and the collection and categorization of the collected litter. The deployment and retrieval of one boom requires 2 man-days, excluding the travel time. The monitoring does not require any specific skills, although some experience in the field is recommended.

A variety of equipment is needed to support the floating litter boom method. Equipment needed:

- Floating litter booms
- Net curtains (e.g. fishing nets)
- Mooring equipment (ropes, anchors and marking buoys)
- Transport, trailer
- Laptops
- Boat for deployment
- GPS
- Flowmeter
- Instrument to measure water depth (e.g. a plummet).

3.7. Monitoring recommendations

Based on everyone's experiences, we present some basic recommendations regarding the monitoring.

3.7.1. Pre-monitoring recommendations

Before starting to monitor in a specific area there are several factors that needs to be considered when defining the monitoring sites in order to succeed with the monitoring. The physical conditions of a monitoring site are of great importance when monitoring with floating litter booms. The monitoring is affected by the width of the river, weather conditions such as wind and/or water flow rate/direction. Based on the experiences from the BLASTIC project the recommendations for site selection are:

- A site where relevant authorities allow monitoring.
- A site with minimal influence of the tidal currents or counter currents as these can push away already captured litter and compromise the moorings of the boom. Examine the flow pattern and speed of the water before performing any monitoring. If the flowrate is too slow or the flow direction is unstable then another site or method should be considered.
- The method (boom/net collection) is more suitable for narrow rivers. Chose a narrow river or a site that is located at a narrow part of the river.
- A site where a large part (preferably the entire width) of the river can be blocked by the boom. If this is not possible due to e.g. boat traffic then it’s recommended to sample both sides of the river. The more of the river that is blocked the more reliable results can be obtained.

- A site where the litter is not exposed to wind, as captured litter can be blown away and the shape of the litter boom can be changed in a negative way, see Figure 3.
- The site selection also could depend on available information on potential litter emitters or convenience of the sampling locations.
- A site with easy access to simplify both deployment/retrieval of the boom and litter collection.
- A site where at least one fixed mooring point is available is recommended.

Figure 3. Strong winds resulted in a deformation of the litter boom. It was not able to capture any litter.

3.7.2. During monitoring recommendations

While performing the monitoring there are several things to consider in order to simplify the monitoring and in order to save as much time as possible when preparing and deploying/retrieving the booms.

- Define the monitoring sites in advance (see 3.7.1.).
- Prepare as much as possible on land (if the boom is to be deployed off shore). It is more time efficient to attach net curtains, grapnels, marking buoys etc. on land where space is available.
- A minimum of two persons are recommended to prepare and handle the booms. If deployed and retrieved with a boat then three persons are recommended: two to handle the booms and a third person maneuverer the boat.
- If anchors are be used to moor the booms to the river bed, make sure they are securely fastened to the bottom. If an anchor is not secure then both winds and currents can change the position of the boom. Booms have to be fixed and set-up in a proper way (preferably by anchoring the middle of the boom as well).
- Investigate the upcoming weather conditions. Strong winds increase the risk of changing the shape and position of the booms and litter can be blown away from the boom. Rain and other precipitation can affect the results if there is an increased flow of storm water. Rough weather might also limit the possibility to deploy and retrieve the booms.
- Timing: periods with heavy water discharge (early spring an autumn) are associated with much organic material in the water. Leaves, branches and other organic material will get trapped in the boom and might clog net curtains. This could overflow the litter booms and it can result in difficulties to separate the litter from the organic material. However, frequent litter collection from the booms can reduce this issue.
- Use a landing net to capture floating litter
- When retrieving the booms from the water one must be careful that litter doesn't come loose and float away with the current. If a net curtain is used it is preferably folded over the boom to capture the litter.

3.7.3. Post monitoring recommendations

After the monitoring has been performed there are a few things to consider when quantifying data. It is very important to separate absolute and relative results. A high quality data set will be more comparable between repeats, seasons and other sites. In addition, we would like to assess in real terms, what is the contribution of different sources to riverine litter. Doing this with compositional data alone and acquiring any degree of accuracy is impossible as it is not standardized in any way to litter abundance. For this reason, the preferred method is to characterize, weigh and count the litter sampled in the river; use the protocol developed in BLASTIC (

) when doing this. The litter should be dried before weighing, and any significant silt or algae deposits should be removed.

An absolute result is the total litter captured in the litter boom, regardless of flowrate of the river and the duration of the sampling. Absolute values e.g. litter abundance cannot be compared between repeats, seasons and other sites as the sampled volume of water can vary greatly, even between repeats at the same site. A relative result tells us how much litter (number of items and/or weight) there is per sampled volume of water (e.g. items or weight per m^3 water). The relative result is an estimation which requires information about the flowrate, the total area (m^2) in the water column where litter is captured, sampling duration and the absolute results of litter captured.

With these variables we can first estimate the water throughput of the net:

> *Water throughput (m^3) = (Average flow velocity) (m/s) **x** submerged area of the boom/net (m^2) **x** sample duration (s)*

Then we estimate the litter load:

> *Litter load (kg/m^3) = sum of the weight of the litter captured (kg) / Water throughput (m^3)*

If we're at a site where we don't know the total water discharge of the river then we can estimate it:

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

Finally we can use these numbers to estimate the total litter load of the river, i.e. the amount of litter passing by a particular point in one day or for longer periods:

> *Total Litter (kg/time) = Litter load (kg/m^3) x Discharge (m^3/s) x time (s)*

These calculations are rough estimations. The biggest issues are that the flowrate is not constant, not over time and not throughout a cross section of a river (Figure 4) and that the litter load is not constant. So depending on where in the river the flowrate is measured and depending on the specific litter load during the sampling duration, the results may differ greatly. This is why a high frequency of sampling and multiple flowrate measurements are recommended. Also it is important to know that there are quite a few items that because of their weight will sink to the bottom and are unlikely to be sampled by this method.

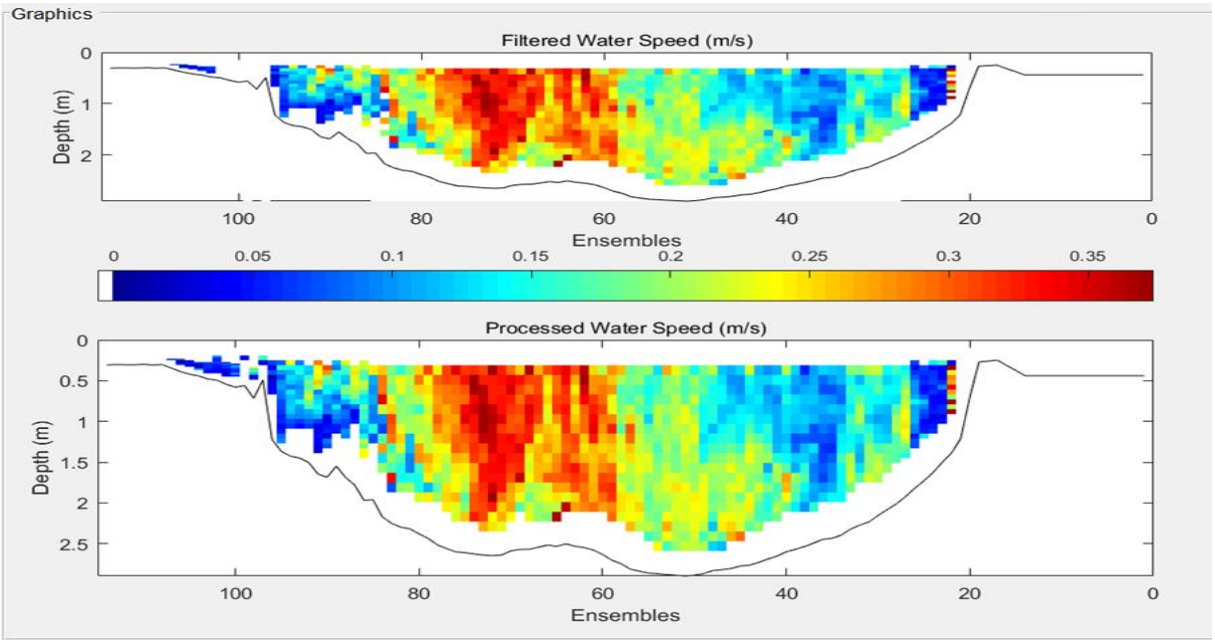

Figure 4. ***Example of the water flow profile at the Kerava River (Finland) that was monitored in the BLASTIC project by SYKE.***

3.8. PROS & CONS of floating litter boom litter monitoring

Advantages

- Cost effective and simple monitoring option for floating litter;
- Simple and direct method that can be used for several different purposes such as scientific measurements, measuring the result of implemented litter actions and used in awareness projects;
- Collects litter so that it can be counted, weighed and categorized;
- Submerged litter items can be captured by net curtains.

Disadvantages

- Frequent observations are recommended for representative monitoring;
- The monitoring is easily influenced by external circumstances such as weather conditions (wind and precipitation) and flowrate/direction;
- Not suitable in wider rivers or in rivers with boat traffic as it is recommended to block the entire width of the river;
- Monitoring can be affected by the discharge of organic material. Monitoring during spring and autumn floods is not recommended.

4. Conclusions

The three project partners that reported results (IVL, SEIT and SYKE) had different experiences and the floating litter booms worked better in some sites than others. The physical conditions of the monitoring site are of great importance when monitoring with floating litter booms. All monitoring was in some way affected by either the width of the river, weather conditions such as wind and/or water flow rate/direction.

While the litter boom monitoring method is relatively low tech and doesn't require much experience from the personnel handling the booms and retrieving the captured litter, there are still some variables that need to be considered if the monitoring is to produce a high quality data set. If the results are to be compared between e.g. different repeats, seasons and other sites then it's important to calculate the relative results (e.g. kg/m^3). To obtain good relative results frequent samplings and multiple flowrate measurement are recommended. The flowrate measurements might be the most complicated part of the monitoring, however depending on the purpose of the monitoring the flowrate measurements can be scaled accordingly.

Before monitoring with litter booms is considered it is important to examine if there are sites with suitable physical conditions where the monitoring can be performed, as this is crucial for successful measurements with the floating litter booms. Based on the experiences from the monitoring in the pilot areas the conclusion by the project members is that the floating litter boom methodology is suitable in narrow rivers with a continuous water flow; however in wide rivers river this monitoring method might not be the best option. Being able to block the entire width of the river is recommended, find sites that are easily accessed and check with the relevant authorities if monitoring is allowed at the site.

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Appendix 1: Protocol used for the collected litter items

BLASTIC: PROTOCOL FOR CATEGORISATION OF MARINE PLASTIC LITTER		
The categorisation is based on the master list of categories of marine litter found in the European guidelines, "Guidance on monitoring of marine litter in European Seas"		
The categorisation is used for litter collected by booms and net curtains.		
Date for placing the booms in the water:		
Date for picking up the booms:		
Number of collection days:		
Weight of the total collected amount:		
Weight of the collected amount of plastic items:		
Total number of items collected:		
Number of plastic items collected:		
CATEGORY	**Weight (g)**	**Number of items**
Plastic items		
4/6-pack yokes, six-pack rings		
Buckets		
Carrier bags		
Cigarette butts and filters		
Cotton bud sticks		
Crisps packets/sweet wrappers		
Cups and cup lids		
Cutlery and trays		
Diapers		
Dog faeces bags		
Drink bottles		
Fishing equipment		
Flower pots		
Food containers		
Jerry cans (square plastic containers with handle)		
Lolly sticks		
Miscellaneous plastic items		
Other plastic bags (e.g. freezer bags incl. pieces)		
Other plastic containers		

Pens and pen lids
Plastic caps and lids
Plastic fragments < 5 mm
Plastic pellets
Strapping bands
Straws and stirrers
Synthetic ropes
Toys and party poppers
Unidentified plastic film > 50 cm
Unidentified plastic film 2.5 cm ><50 cm
Unidentified plastic film 5 mm-2.5 cm
Unidentified polystyrene pieces > 50 cm
Unidentified polystyrene pieces 2.5 cm ><50 cm
Unidentified polystyrene pieces 5 mm-2.5 cm
Unidentified rigid plastic pieces > 50 cm
Unidentified rigid plastic pieces > 50 cm
Unidentified rigid plastic pieces 2.5 cm ><50 cm
Unidentified rigid plastic pieces 5 mm-2.5 cm

Other items
Food waste
Leafs and sticks
Metal
Miscellaneous
Newspapers/magazines
Paper/cardboard
Shoes
Textiles
Wood