

## Exploring (micro)plastic pollution in European ports: Antwerp and Rotterdam case studies

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### Introduction

Plastic pollution has emerged as a major global environmental issue due to the high abundance of microplastics in the ocean, and the potential negative effects to organisms and ecosystems. Plastic items and particles which have been accidentally introduced in waters start to degrade, followed by fragmentation, due to the action of weather and physical-chemical stressors. This results in the introduction of macro- (> 2.5 cm), meso- (5 mm – 25 mm), micro- (1 µm – 5000 µm), and nanoplastics (1 - 1000 nm) in the ocean and in the environment<sup>1,2</sup>. Although awareness on this matter is increasing, there still is an urgent need to expand the knowledge on the abundance, distribution and fate of these plastics, specifically in places such as estuaries and ports, where plastic litter tends to accumulate<sup>3</sup>. In addition, it is estimated that the number of plastic particles in the ocean will triple in the next twenty years, if no action is taken<sup>4</sup>. In this context the project “Innovative solutions for plastic free European rivers” (INSPIRE) [Horizon Europe] aims to contribute to the Green Deal targets and the European Commission Mission to restore the ocean and inland waters by 2030<sup>5</sup>.

INSPIRE is a four-year project (2023 – 2027) with the goal to develop, implement, test and validate a set of solutions to assist in mitigating the increasing aquatic plastic pollution<sup>5,6</sup>. It brings different technologies and actions together with a focus on three main aspects: detection, collection, and prevention. Detection is about identification, quantification and characterization of litter pollution in rivers and transitional waters, such as finding the type and number or mass of macro-, meso-, and microplastics that are present in the water or sediment. Collection covers retrieval of litter and plastic from rivers. This results in a minimal lifetime of this pollutant in the river, preventing further fragmentation of these particles. Finally, prevention is about implementing different strategies that reduce the inputs of litter, macro-, meso-, and microplastics being introduced in the aquatic environment. This includes research towards technologies that enable the collection of litter before it reaches rivers, ports and estuaries or the development of alternatives for the currently used products that are responsible for plastic pollution. The INSPIRE project makes use of six rivers (demo cases) across Europe to conduct research on this topic: the Rhine, Scheldt, Danube, Kamniska Bistrica, Po, and Douro<sup>5</sup>. In the context of the INSPIRE project, the objective of this study was to assess the microplastic,

mesoplastic, and litter abundance from Doeldok (port of Antwerp; Scheldt, BE) and Londenhaven (port of Rotterdam; Rhine, NL), and to characterize the particles diversity.

## Methods

The samples used for analysis were obtained using different sampling methods. The first method relied on sampling using a Ferrybox (Fig. 1.a)<sup>5</sup>, a semi-automated device that collects (sea)water and retains microplastics and other microlitter, at a specific water depth. It consists of a collection module that uses a series of sieves to sort the plastics within different size fractions, which is then connected to the Ferrybox system itself that is onboard a research vessel or connected to a submerged pump. In addition, the volume of filtered water and flow rate within the collection module can be recorded<sup>5</sup>. A second sampling method used was the manta net (Fig 1.b)<sup>5</sup>, a device designed to sample plankton, but now adapted for the collection of microlitter and microplastics that are floating or are within the first few centimeters of the water column. The microplastics were extracted from the obtained samples using established standard operating procedures<sup>7</sup> and the analysis of the particles was performed using an automated decision-making model, that detects and identifies plastic particles using images taken with a fluorescent microscope under different filters<sup>7,8</sup>. Following this, the microplastics presence and the polymer identification were verified using  $\mu$ -Fourier transform infrared (FTIR) spectroscopy<sup>7</sup>.



Figure 1. Sampling methodologies used in this study, to assess microplastics abundance in various matrices: (a) the Ferrybox sampling system, (b) the manta net, (c) the riverbank quadrat. (source: INSPIRE)

Additionally, quadrat (20 x 20 cm) sampling along a transect was performed to collect larger microplastic (1 - 5 mm), mesoplastic particles, and litter in general, in the riverbanks of the selected sampling locations (Fig. 1.c), using metal tweezers<sup>5</sup>. At both sites, sampling was performed at the beginning, middle and end of three different transects of 100 m (Doeldok, BE) or 30 m (Londenhaven, NL). The collected pellets were counted to determine the particle concentrations at each transect, followed by analysis using Fourier transform infrared/attenuated total reflection (FTIR/ATR) spectroscopy, after a cleaning step using ethanol and miliQ-water.

## Results

The mean concentration of particles and litter items was estimated after using both the automated model and FTIR analysis, and the mean abundance of items varied between 0.47 and 19.63 particles / m<sup>3</sup> (Table 1). When comparing the decision-making model to the FTIR analysis, we observed that the model underestimates the number of particles for all measurements. We have further observed that the manta net samples show lower particle concentrations than the Ferrybox samples. The Ferrybox measurements indicated a higher particle abundance for Doeldok than for Londenhaven.

Table 1. Mean ( $\pm$  SD,  $n = 3$ ) plastic particle concentrations with standard deviations, as observed by the decision-making model and FTIR analysis.

	Automated model: (particles / m <sup>3</sup> )	FTIR: (particles / m <sup>3</sup> )
<b>Doeldok (Port of Antwerp) - Ferrybox</b>	16.58 $\pm$ 21.53	19.63 $\pm$ 22.59
<b>Doeldok (Port of Antwerp) - Manta net</b>	0.47 $\pm$ 0.31	1.87 $\pm$ 1.35
<b>Londenhaven (Port of Rotterdam) - Ferrybox</b>	5.36 $\pm$ 4.48	9.34 $\pm$ 5.99

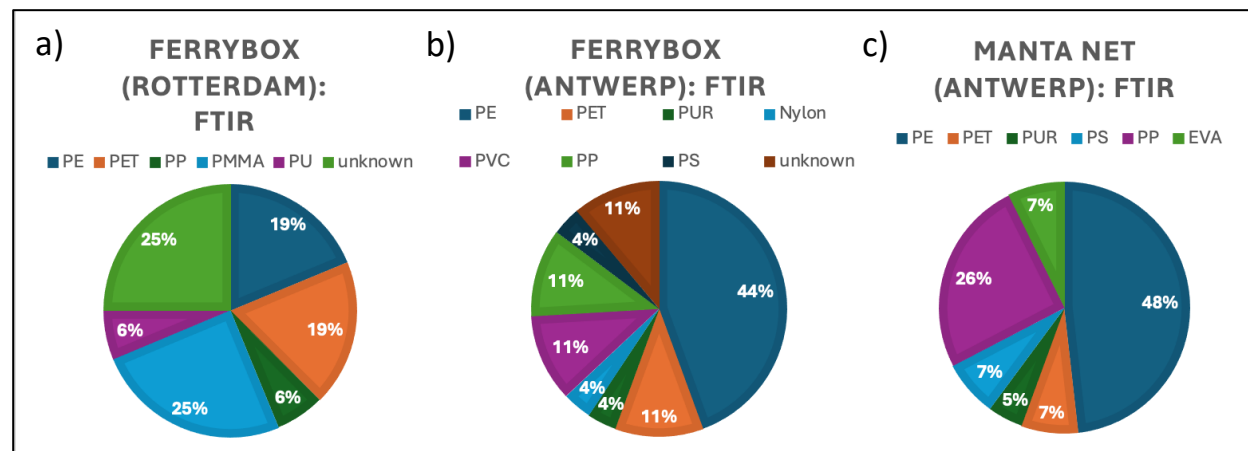


Figure 2. Proportion of particles observed from each polymer type at the different sites: (a) Ferrybox samples collected in Rotterdam, (b) Ferrybox samples collected in Antwerp, (c) manta net samples collected in Antwerp.

The most common polymer type observed varied between compartment sampled: PMMA was the most common polymer observed in samples acquired in Rotterdam using the Ferrybox, while PE was the most common polymer observed for samples acquired both using the Ferrybox and manta net in Antwerp (Fig. 2). For the Ferrybox samples at both sites, the polymer types of some

particles remained unknown, as the FTIR results did not have a sufficient correlation to the spectrum of a certain polymer type. This can be an indication that the material was not a plastic but cannot be confirmed as such.

Table 2. Overview of the collected litter particles in Doeldok (port of Antwerp, BE) and Londenhaven (port of Rotterdam, NL), using 20 x 20 cm quadrats.

	Doeldok: particle number per sample	Doeldok: concentration (particles / m <sup>2</sup> )	Londenhaven: particle number per sample	Londenhaven: concentration (particles / m <sup>2</sup> )
<b>Transect 1: beginning</b>	20	500	257	6425
<b>Transect 1: middle</b>	10	250	218	5450
<b>Transect 1: end</b>	5	125	94	2350
<b>Transect 1: 15m</b>	71	1775	NA	NA
<b>Transect 1: weighted mean</b>	31.6	790	279.67	4741.67
<b>Transect 2: beginning</b>	2	50	NA (sample too large, and so not quantified)	NA
<b>Transect 2: middle</b>	2	50	208	5200
<b>Transect 2: end</b>	4	100	40	1000
<b>Transect 2: weighted mean</b>	2.67	66.67	> 124*	> 3100*
<b>Transect 3: beginning</b>	0	0	15	375
<b>Transect 3: middle</b>	4	100	19	475
<b>Transect 3: end</b>	1	25	473	11825
<b>Transect 3: weighted mean</b>	71	1775	169	4225

\*The sample at the beginning of transect 2 was too large, it was not counted and not considered when calculating the average.

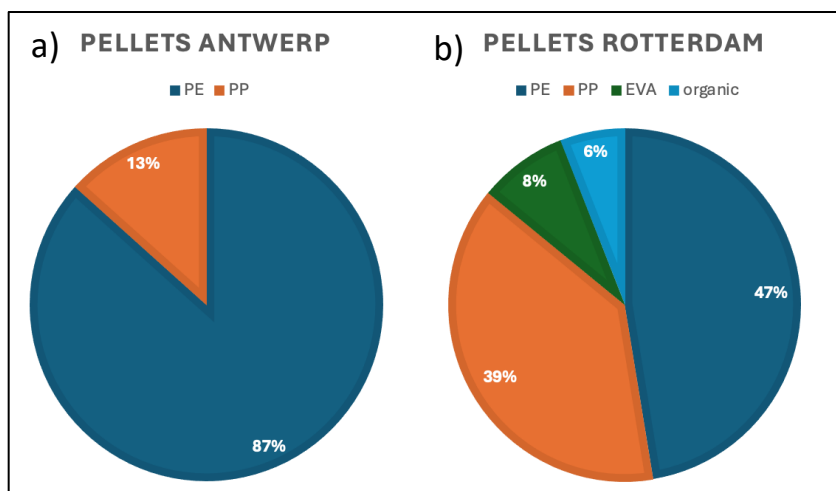


Figure 3. Proportion of pellets from each polymer type observed at the different sites: (a) Doeldok (port of Antwerp, BE), (b) Londenhaven (port of Rotterdam, NL).

The highest concentration of litter was observed in the Port of Rotterdam (11,825 particles / m<sup>2</sup>), exceeding the highest concentration observed in the port of Antwerp (1,775 particles / m<sup>2</sup>) (Table 2). The polymer types of the pellets in both sampled locations were mainly PE and PP, with the former being most common polymer type.

## Discussion

High concentrations of litter particles were recorded in Doeldok and Londenhaven, across all sampling methods, with mean concentrations ranging from 0.47 particles / m<sup>3</sup> to 4,741.67 particles / m<sup>3</sup>. Manta net and Ferrybox sampling indicated the presence of microplastics in both the water surface and on the water column, which varied between 0.47 particles / m<sup>3</sup> and 19.63 particles / m<sup>3</sup>, respectively. Furthermore, micro- and mesolitter collection using quadrat sampling revealed a high concentration of plastics and other litter at both sites, with concentrations ranging from 0 particles / m<sup>3</sup> (Doeldok; BE) up to 11,825 particles / m<sup>3</sup> (Londenhaven; NL) being reported.

The analysis of the abundance of particles revealed a large variation depending on the location and sampling method (which reflects the sampling depth in the water column). The lowest concentrations observed correspond to manta net samples (0.47 particles / m<sup>3</sup>). As the manta net samples were taken at the water surface, this is an indication that more particles were located in the water column, where Ferrybox samples were taken. This suggests a moderate to high flux was occurring during sampling. In contrast, a low flux typically associated with the turn of the tide would lead to accumulation of particles at the surface, resulting in a higher abundance of particles in the manta net samples. Furthermore, the concentration of particles sampled using the Ferrybox was higher in Doeldok (BE) than in Londenhaven (NL), and therefore we suggest that these results should be further investigated by additional sampling over multiple time points, to analyze if there is a specific trend linked to this observation.

Polyethylene (PE) and polypropylene (PP) were amongst the most abundant polymers observed in the microlitter for both Antwerp and Rotterdam. In addition, Rotterdam showed a remarkable 25% share of polymethylmethacrylate (PMMA). In contrast to these results, the microplastics collected using the manta net were almost exclusively PE and PP particles. The polymer types from the Ferrybox samples indicated that different locations contain a diverse range of categories, with certain polymers occurring exclusively at one of the two sites, such as polyvinylchloride (PVC) and polystyrene (PS) for Doeldok, and the abundant PMMA for Londenhaven. Furthermore, the results suggest turbulence was present during sampling, as low-density polymers, such as PE and PP, were detected in the Ferrybox samples. Additionally, the presence of high-density polymers, such as polyethylene terephthalate (PET), in the manta net samples further supports this observation. These are important observations, as these unique

patterns for the different sampling sites establish new developments towards finding the origins of these different types of microplastics.

The abundance of large micro- and mesolitter by the riverbank quadrats showed high concentrations at both sampling sites, with substantially higher levels observed for Londenhaven, where concentrations reached up to 11,825 particles / m<sup>2</sup>. From the observed litter types, pellets were the most abundant at both sites. This indicates that these materials are within the most important sources of plastic pollution in the riverbanks around these large port areas. Furthermore, the pellets predominantly are PE and PP, with PE being more abundant than PP on both sites. In Rotterdam, NL, some pellets were categorized as organic material, and several pellets were ethylene/vinyl acetate copolymer. The results of this study provide a first step towards monitoring the origin of these pellets, indicating whether the pellet loss is related to production and an important mismanagement of transport in the port areas or transport.

## Conclusion

In this study, the particle abundance of micro- and mesolitter has been assessed at the ports of Antwerp (BE) and Rotterdam (NL), the two largest industrial and commercial ports in Europe. The Ferry box and manta net sampling methods were used, and our samples have indicated the presence of a variety of microplastics within the water column (largest concentrations) and at the water surface. Furthermore, we used quadrat sampling along transects in riverbanks, and our observations indicate a very high abundance of large microlitter and mesolitter, with the concentrations for Londenhaven (NL) being significantly higher than for Doeldok (BE). The FTIR analysis on the different litter particles contributed to a deeper insight on the polymer types present at both sites, indicating a unique variety of compositions at the different locations, with the most abundant polymers observed being PE and PP. The results of this study have produced key data that will be incorporated into the analysis of plastic particles transport and fate, and will be incorporated into baseline analysis on prevention actions.

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