

## Characterization of urban microplastics discharges for the Paris megacity

### Caractérisation des rejets urbains en microplastiques dans l'agglomération parisienne

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## RÉSUMÉ

Les microplastiques (MPs), particules de plastique de taille inférieure à 5 mm, soulèvent de plus en plus de problématiques environnementales, et la concentration d'activités humaines font des milieux urbains une source majeure de pollution microplastique. Les MPs générés dans les zones urbaines peuvent contaminer le milieu naturel via une grande diversité de voies de transfert (déposition atmosphérique, eaux usées, eaux pluviales, ...). Cette étude examine la contribution relative de différentes voies de transfert au flux de MP dans la Seine le long de l'agglomération parisienne, ainsi que les caractéristiques temporelles des transferts et rejets de microplastiques. Pour cela, des échantillons sont collectés dans trois différents compartiments environnementaux : (i) dans les influents et effluents de stations d'épuration en temps sec et en temps de pluie (ii) en sortie de déversoir d'orage par temps de pluie (iii) dans le ruissellement pluvial de secteurs drainés dans un réseau séparatif. Les échantillons seront préparés avec un traitement à l' $H_2O_2$  et une séparation densimétrique des MPs avec du NaI, puis analysés par spectroscopie  $\mu$ FTIR, pour identifier les MPs de taille (25 – 5000  $\mu$ m). Les campagnes d'échantillonnage n'ont pas encore eu lieu, mais des cas d'études antérieurs menés sur l'agglomération parisienne peuvent permettre des premières estimations.

## ABSTRACT

Microplastics (MPs), plastic particles smaller than 5 mm, raise increasing environmental concerns, and the concentration of human activities make urban environments a major source of microplastic pollution. The MPs generated in urban areas can contaminate the natural environment through a variety of pathways (atmospheric deposition, wastewater or stormwater discharge, ...). The present study investigates the relative contribution of different pathways to the MP flux in the Seine River as it flows through the Paris megacity, as well as the temporal characteristics of MP transport and discharge. To achieve this, samples are collected in three different environmental compartments: (i) in the influents and effluents of wastewater treatment plants during dry and wet weather (ii) in untreated stormwater runoff in areas drained by a separate sewer system (iii) in combined sewers overflows during rain events. Samples will be prepared with  $H_2O_2$  treatment and NaI density separation of MPs, then analyzed with  $\mu$ FTIR spectroscopy to identify MPs within the size range (25 – 5000  $\mu$ m). The sampling campaigns have not yet taken place, but previous case studies in the Paris megacity can give first estimates.

## KEYWORDS

CSO (Combined Sewer Overflow), microplastics, stormwater, urban, WWTP (Wastewater treatment plants)

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## 1 INTRODUCTION

Plastics are a major source of pollution. Small size (typically <5mm) plastic particles, known as microplastics (MPs), have been under increased scrutiny for the past few decades, due to their ubiquitous presence in the environment and the potential risks they pose for environmental and human health. Early microplastics research focused mainly on MPs in marine and riverine environments, but there is now growing interest in urban environments as potential MP sources (Thompson et al. 2024). Concentrated human activities in urban areas generate important quantities of microplastics (e.g., road circulation, littering, laundry, industrial activities, ...) (Zhou et al. 2023). These microplastics can be discharged into the natural environment through a variety of complex pathways (atmospheric resuspension and deposition, runoff, contamination of wastewater, ...), making their behavior and fate difficult to characterize.

The Paris megacity is an important source of microplastics into the Seine River, main recipient of the city's water discharge (Treilles et al. 2021). MPs carried in wastewater and stormwater can be discharged into the Seine River in three ways: (i) in treated wastewater, mixed with stormwater in certain cases, discharged by wastewater treatment plants (WWTP) (ii) in untreated stormwater runoff drained by a separate sewer system (iii) in stormwater mixed with wastewater in combined sewer overflows (CSOs) during rain events.

The fate of MPs in some cases is well-documented, and some investigations focused on the Paris megacity have already taken place. However, knowledge gaps remain regarding some other pathways (Nguyen et al. 2024). Furthermore, the great diversity and fast development of analytical methods (sample preparation protocols,  $\mu$ FTIR spectroscopy, Raman spectroscopy, manual counting, ...) and scope of studies (size range of detected MPs, considered polymers, consideration of microfibers or tire and road wear particles, ...), limit inter-comparability between studies.

Past studies have examined MPs discharged by WWTP around Paris. An extrapolation from fourteen WWTPs in the literature, based on per capita MP load, estimated the annual MP flux discharged via WWTP effluents into the Seine River within the Paris megacity between  $2.4 \times 10^{11}$  and  $2.3 \times 10^{13}$  particle/year (Nguyen et al. 2024). However, the literature data is based on different analytical methods that are hardly comparable and target different microplastics (sizes, shapes and polymers). Moreover, the context (WWTP size, environmental conditions, activity type and intensity) is not specific to the Paris megacity. The only data available for the Paris Mega City are from Dris et al. (2016) but are focused on microfibers only, making comparison with more recent works and other compartments irrelevant.

Treilles et al. (2021) conducted a study on the Sucy-en-Brie urban watershed (228ha), located in Val-de-Marne department (part of the Greater Paris area). This watershed is connected to a separate sewer system, making it possible to study stormwater runoff for the entire area by sampling at the catchment outlet. The observed MP concentrations ranged between 3 to 129 item/L, with a median value of 29 item/L. The methodology was designed to only analyze microplastics over 80  $\mu$ m, which make comparison difficult as smaller MPs are often found more abundantly. Besides, the Sucy-en-Brie catchment might not be representative of the entire Greater Paris area, as it is mostly residential. Therefore, it does not provide any data on areas with a different land occupation such as commercial or industrial activities. Finally, Treilles et al. (2021) study begins to identify possible trends between flowrate and MP concentration but highlights the need for more data to confirm those hypotheses regarding the temporal aspects of MP concentration in stormwater.

Nguyen et al. (2024) recently conducted a study on the CSOs of Clichy and La Brèche and found that CSOs could be a major contributor to MP discharge into the Seine River. For MPs within the size range (25-500  $\mu$ m), concentrations between 67.7 and 391.5 item/L were observed, with polyethylene (PE), polypropylene (PP), and polyester (PEST) being most represented. Based on yearly volumes discharged from the Parisian sewer system via CSOs, the study estimated a yearly MP discharge ranging from  $1.4 \times 10^{12}$  to  $8.2 \times 10^{12}$  item/year, which could contribute up to 70 % of the MP flux level in the Seine River based on extrapolations from literature data.

The present work aims to build upon these past results and characterize as globally as possible MP discharge throughout the Paris megacity:

- By providing recent data specific to the influents and effluents of Paris megacity WWTPs in both dry and wet weather and give insight into the processes involved (temporal trends, stormwater contribution, ...), to enable more precise estimates of year-round MP discharges into the Seine River at WWTP outlets.
- By considering rainfall characteristics during rain events to better understand the temporal behavior of

microplastic discharge via CSOs and stormwater outlets and refine estimates for MP fluxes in wet weather.

- By gathering comparable data, over a reference year, on microplastics discharged for all three identified types of discharges, to determine which ones present the most significant risks of microplastic pollution in the Seine River

This work is the first part of a PhD project, funded by European program UrbaQuantum, that aims to develop new approaches for sustainable and resilient urban water management. Collaborators in Paris focus on monitoring the river water quality, as well as all wastewater inputs to the river (from CSOs and wastewater treatment plants), with a particular focus on microplastics.

## 2 MATERIALS AND METHODS

### 2.1 Study site – Paris megacity

As both Paris city and its surroundings are densely urbanized, and share certain drainage infrastructure, the Paris megacity is chosen for this case study. This broadly refers to Paris city, the three bordering department Hauts-de-Seine, Seine-Saint-Denis, and Val-de-Marne, as well as some neighboring municipalities, making up an area of approximately 1800 km<sup>2</sup> across 284 municipalities for a population of about 9 million inhabitants (Nguyen et al., 2024 ; Lotfi et al., 2016). Its drainage system is managed on three levels. Storm and wastewater is collected by municipalities, then conveyed to department networks and finally to an inter-department network operated by the Greater Paris Sanitation Authority (SIAAP), responsible for treatment. In total, the SIAAP manages 2.5 million m<sup>3</sup> of wastewater each day. Part of the network is made of combined sewers (wastewater and stormwater are treated together), but some parts use separate sewers, especially in the most recent additions.

### 2.2 Sampling methodology

#### 2.2.1 Wastewater treatment plants (WWTPs)

The SIAAP manages six wastewater treatment plants (WWTPs). Three of them receive water from combined sewers: Seine Aval, Seine Centre, and Seine Grésillon. Three of them are designed to only treat wastewater: Seine Amont, Marne Aval, and Seine Morée. The most important one is Seine Aval, that manages alone 1.5 million m<sup>3</sup> water per day in dry weather (Nguyen et al., 2024). The goal is to sample both influents and effluents, which should provide information on MP removal, as well as overall microplastic discharges into the Seine River from WWTPs. Some samples will be collected during dry weather to study the impact of wastewater alone. Some samples will be collected during rain events to study the relative contribution of stormwater to MPs in WWTPs.

#### 2.2.2 Separated stormwater runoff

Some areas of the sewage network of the Paris megacity separate wastewater and stormwater. In these cases, stormwater is discharged into the Seine River without treatment to remove MPs that can be carried in the stormwater from wet atmospheric deposition and runoff on urban surfaces. To estimate the impact of such discharge, samples should be collected at the outlet of catchments that function with a strictly separate sewer system. This is an ideal scenario as misconnections of sewers are common in separate sewers systems. Information about land occupation within the studied catchments is also important, as it can help explain runoff characteristics. The identification of suitable sampling sites is still under process.

#### 2.2.3 Combined sewers overflow (CSOs)

During intense rain events, the volume of water in combined sewers is too important to be treated in WWTPs. The excess water (mostly stormwater, mixed with wastewater) is then discharged directly into the river with little to no treatment through combined sewers overflows (CSOs). Sampling will be conducted at two major Paris CSOs: Clichy and La Briche. They are equipped with pre-treatment infrastructures that stop the bigger debris, but no microplastic removal technologies. Despite an important number of CSOs in the area, it is estimated that those 2 sites are responsible for about 80% of the volume of all CSO discharges in the network (Lotfi et al. 2016). Samples of CSO discharge, combined with data on discharge volume and frequency, can lead to estimating microplastic fluxes via CSOs.

In cases where stormwater and wastewater are mixed, conductivity can be monitored to estimate the wastewater to stormwater ratio. When possible, several samples will be collected for each considered storm event to examine the temporal trends of MP discharge during such events.

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## 2.3 Analytical procedure

### 2.3.1 Sample collection and preparation

Appropriate sample collection methods must be established for each type of sampling site, considering the properties of the sites, and use non-plastic containers. Organic matter will be removed from the samples with a H<sub>2</sub>O<sub>2</sub> 30% treatment. The samples will then be concentrated on a 10 µm metallic filter. MPs will then be separated from other suspended solids through density separation using NaI. The sample will then be deposited onto Anodisc filters (Ø25 mm, pore size of 0.2 µm, Whatman®) and stored in a petri dish until analysis. To mitigate contamination risks, samples are handled under a laminar flow and covered with aluminum foils whenever possible, and several procedural blanks can be carried out.

### 2.3.2 Analysis using µFTIR spectroscopy

Samples will then be analyzed using µFTIR (Fourier Transform InfraRed) spectroscopy. The detector has a limited resolution, with a pixel size of 25×25 µm, therefore the size detection limit of the technique is 25 µm. Maps acquired by µFTIR are then analyzed using the MP analysis software siMPle, developed at Aalborg University, Denmark, and the Alfred Wegener Institute, Germany. (Liu et al. 2019) This analysis estimates particle number as well as mass, size, and polymer composition for each detected particle.

## 3 CONCLUSION AND PERSPECTIVES

Previous studies have demonstrated the relevance of different types of urban discharges to the MP flux in the Seine River. This project aims to add to these results by:

- Gathering additional data on microplastic discharge, using a unified methodology between compartments, over a consistent period
- Providing insight into the spatial and temporal characteristics of urban MP discharges, especially during rain events. Using available data on total discharged volumes currently monitored by SIAAP, a modelling approach could be considered to develop a map of MP discharges (concentration, flow).
- Estimating the relative contribution of each pathway and prioritize the sources according to their annual contribution to the total microplastic load. For the first time, a global budget will compare and prioritize different urban effluents at the scale of the same megacity (Paris).

This project started in October 2025. Therefore, sampling sites choice and methodology are not completely definite, and no sampling campaign has yet been conducted. Because of the importance of meteorological context in this study, the first campaigns will start during winter 2025-2026, and first results will be obtained during the first quarter of 2026.

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