Abundance, composition and fluxes of plastic debris and other macrolitter in urban runoff in a suburban catchment of Greater Paris

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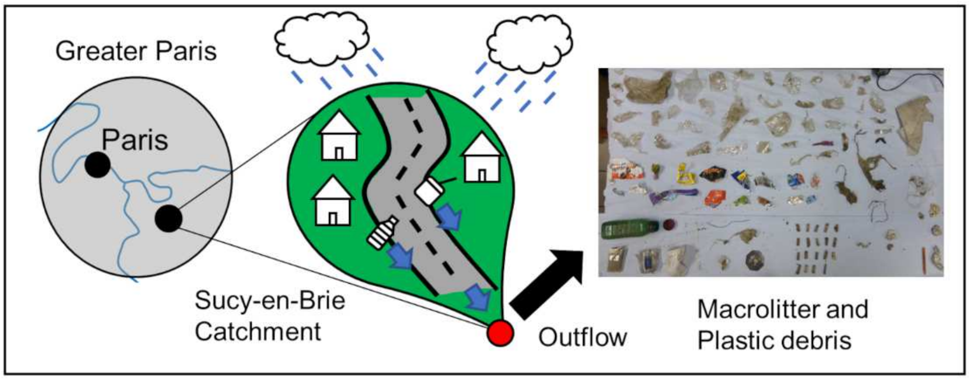
Abstract

Stormwater possibly represents a significant input for plastic debris in the environment; however, the quantification and composition of plastic debris and other macrolitter in stormwater are not available in literature and the amounts discharged into freshwater have been poorly investigated. To obtain a better understanding, the occurrence, abundance, and composition of the macrolitter in screened materials from stormwater were investigated at a small residential suburban catchment (Sucy-en-Brie, France) in Greater Paris. The macrolitter, particularly the plastic debris, was sorted, weighed, and classified based on the OSPAR methodology. On average, plastics accounted for at least 62% in number and for

53% of the mass of all the anthropogenic waste found in the screened materials. The most common items were plastic bags or films, crisp or sweet packets, cigarette butts, plastic fragments of unknown origin, garbage bags or garbage bag strings, foil wrappers, tampon applicators, plastic cups, and medical items such as bandages. Plastic debris concentrations in runoff water ranged between 7 and 134 mg/m^3 (i.e. 0.4–1.7 kg.yr^{-1}.ha^{-1} or 4.8–18.8 g.yr^{-1}.cap^{-1}). When extrapolated to the Greater Paris area, the estimated amount of plastic debris discarded into the environment through untreated stormwater of separate sewer systems ranges from 8 to 33 tons yr^{-1}.

KEYWORDS: macrolitter, plastic debris, stormwater, urban inputs

Graphical abstract



1. Introduction

For several years, studies have demonstrated the strong environmental impacts of plastic debris on marine (Barnes, 2002; Derraik, 2002; Gall and Thompson, 2015) and freshwater (Blettler et al., 2017) ecosystems. However, recent field studies (van Emmerik et al., 2018) and models (Lebreton et al., 2017; Schmidt et al., 2017) have shown that rivers originating from populated metropolitan areas represent a major source of the plastic pollution in oceans. Additionally, the existence and performance of solid waste management practises and sewer systems play a key role in plastic waste discharge (Blettler et al., 2018; Jambeck et al., 2015).

Most plastic pollution studies focus on microplastics (<5 mm) which correspond to the most numerous debris discarded in the environment. However, macroplastics (>5 mm) account for the most significant fraction in terms of mass (Van Sebille et al., 2015). In this study, plastic debris only includes macroplastics. The understanding of macrolitter and plastic debris is still inadequate (Blettler et al., 2018) and discrepancies between plastic emission models and field data have been reported in several studies (Blettler et al., 2018; González-Fernández and Hanke, 2017; Schöneich-Argent et al., 2020; Tramoy et al., 2019b); therefore, additional field data in urban areas should be collected to reduce these discrepancies. The role and importance of urban areas in the generation and transfer of plastic debris have been identified and frequently mentioned in previous studies; however, studies and data that precisely assess the role of these complex sources on plastic pollution are minimal.

Plastic debris, primarily microplastics, has been reported in every type of urban water source including the atmosphere and rainwater (Chen et al., 2020; Dris et al., 2016), drinking water (Mintenig et al., 2019; Pivokonsky et al., 2018), wastewater entering treatment plants (WWTPs) and in effluents (Magni et al., 2019; Talvitie et al., 2015), sludge (Li et al., 2018; Mintenig et al., 2017), and stormwater (Dris et al., 2018; Liu et al., 2019; Piñon-Colin and al., 2020). However, the effects of the dynamics, abundance, and composition of macrolitter on an urban scale and its consequences on the receiving hydrosystem are poorly understood. No comprehensive approach can precisely describe the plastic debris in urban environments or facilitate the design of a conceptual quantitative model of plastic fluxes in urban areas. The high variability of the results and the lack of clear explanatory factors impede the ability to derive definitive conclusions on macrolitter, particularly plastic debris fluxes (Blettler et al., 2018). This study focused on the plastic debris fluxes in the urban runoff at the outlet of a small urban catchment in a Paris suburb.

This study aims to (i) provide data on the composition of the macrolitter in the runoff water of a small urban catchment; (ii) assess the mass percentages of macrolitter, particularly plastic debris; and (iii) estimate the plastic debris mass fluxes per hectare of impervious area and per capita and extrapolate those figures to the scale of Greater Paris.

2. Materials and methods

2.1. Sampling site

Samples were collected at the outflow of the Sucy-en-Brie watershed, which were located in a suburban environment in the southeast portion of the Paris agglomeration (Figure 1). It has a surface area of 228 ha with an impervious area of 62 ha, which represents 27% of the catchment (Gasperi et al., 2017). The population of the territory is approximately 5,700, which is mostly residential, with an individual household density of approximately 25 $cap.ha^{-1}$ that corresponds to a moderately dense urban area in France (Gasperi et al., 2017). Commercial and professional activities are limited. The sewer system in this catchment is a separated one, *i.e.* wastewater and stormwater are collected separately. A stormwater treatment structure is located at the catchment outflow, which consists of a stormwater retention pond and a lamellar settling tank. To block larger debris from entering the treatment structure, a 6 cm screen (S_{6cm}) and a 1 cm screen (S_{1cm}) are installed in upstream retention ponds. This type of stormwater treatment structure of separate sewer system is rare in Greater Paris and crucial for our experiments as it traps macrolitter from Sucy-en-Brie catchment. Debris collected by these screens is automatically deposited into trash containers (one container per screen), which enables the screened materials to be differentiated by the type of screen. The accumulated debris on the two screens was used in this study to investigate macrolitter abundance and composition. Additionally, the stormwater treatment structure is well-instrumented for urban water study. Stormwater flow rates and volumes through the screens were measured by utilizing flowmeters (DRUCK-PTX1830 and DRUCK-PTX5032) and provided by the Val-de-Marne Environmental and Sanitation Services Directorate (DSEA); these measurements were utilized to estimate the macrolitter concentrations.

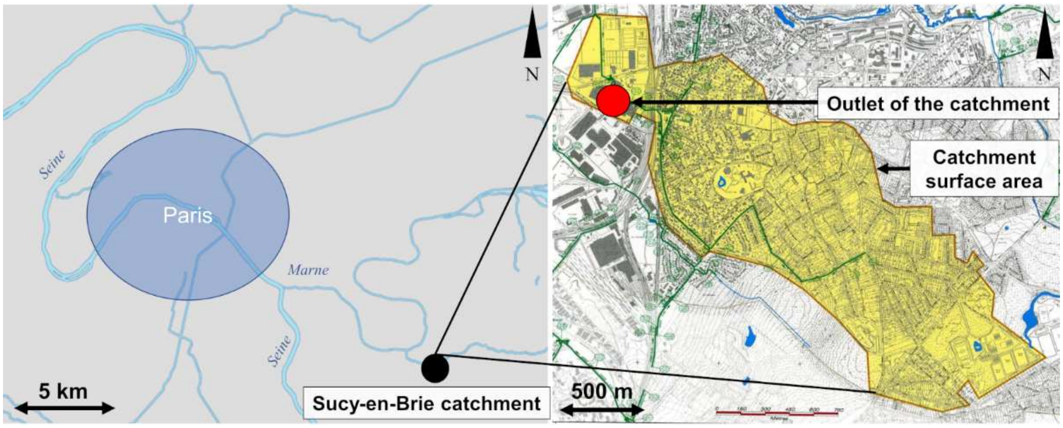


Figure 1: Location of the Sucy-en-Brie catchment. The outlet and stormwater retention pond are located in the western portion of the catchment.

2.2. Sampling method

Eleven sampling campaigns were performed between April 2018 and April 2019 to collect the screened materials from S_{6cm} and S_{1cm} under different hydrological conditions (Figure 2). During each campaign, samples of the screened materials accumulated in trash containers of each of the screens were collected and weighed, and the initial waste volume for each trash container was estimated before and after sampling. The densities of the samples were then estimated using volume and weight. The samples were homogenised, and a subsample was randomly collected and weighed (~10% of the initial sample mass, which corresponds to 3–6 kg). The subsamples were then dried and sorted to study the variations in the macrolitter and plastic compositions (see Section 3). The last two campaigns were performed in triplicate to study intra-sample variability and to assess the robustness of the analytical procedure.

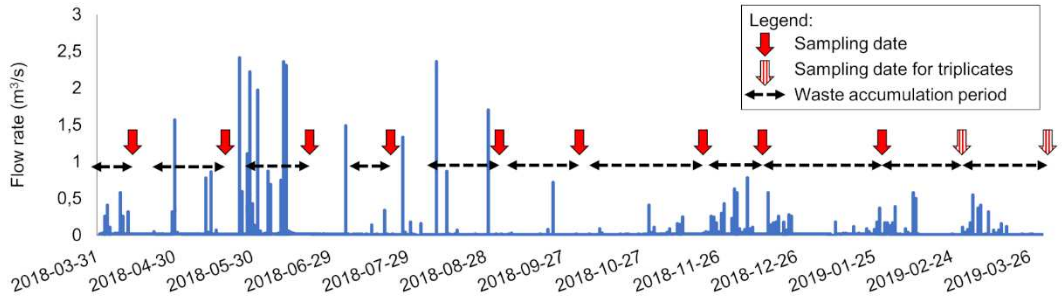


Figure 2: Stormwater hygrogram of the Sucy-en-Brie catchment and sampling dates. Waste accumulation period for each sample is indicated.

2.3. Analytical procedure

The collected debris had a high water content (>70% of the initial mass); therefore, the subsamples were dried in an oven at 40°C for at least 10 d, after which the dry debris was weighed and visually sorted. The first four campaigns focused only on plastic waste and cigarette butts; however, all during the following campaigns other anthropogenic items (aluminium cans, healthcare waste, etc.) larger than 5 mm were classified using the OSPAR classification (OSPAR Comission, 2010). Additionally, items were weighed according to their waste category: plastics, metals, sanitary and medical waste, and other anthropogenic waste (composite waste, glass, cardboard, etc.). In this study, sanitary and medical waste included items in OSPAR classifications 97, 98, 99, 100, 102, and 105. For the plastics category, only synthetic materials were considered. Artificial and composite materials were considered separately to enable a better distinction between materials; therefore, cigarette butts were not included in the plastic category. An additional category; “non-plastic anthropogenic waste” has been defined as all anthropogenic waste excepted plastic items which combines metals, sanitary and medical waste, and other anthropogenic waste.

Using the stormwater volumes, the mass percentages of the different subsamples were extrapolated to the initial debris volume to estimate plastic debris concentrations in the stormwater.

2.4. Calculation of plastic debris flux in stormwater

Two methods were used to estimate the annual plastic debris mass in the screened materials, namely, (i) using the estimated plastic debris concentration in stormwater and the annual stormwater volume ($method_{Concentration}$) and (ii) using the mean tonnage of the screened materials accumulated from 2015 to 2019 and the mean plastic mass percentage estimated by this study ($method_{Annual\ Mass}$).

For $method_{Concentration}$, the results of the analytical procedure presented in Section 3 were used to calculate the plastic debris concentrations in the stormwater (N = 11). The mean and median values were then multiplied by the annual stormwater volume filtered through the screens (from April 2018 to April 2019); consequently, the plastic debris mass in the screened materials was obtained.

For $method_{Annual\ Mass}$, waste mass percentages in the subsamples were directly applied to the annual tonnage of the screened materials collected by a company responsible for its incineration. For this study, it was assumed that the plastic mass percentage was constant over the last five years and the DSEA provided screened materials tonnage estimations from 2015 to 2019.

The plastic debris masses determined by both methods were then normalised to the impervious surface area of the catchment and population, which yielded two different ratios, $ratio_{Area}$ and $ratio_{Cap}$ expressed in $kg.yr^{-1}.ha^{-1}$ and $g.yr^{-1}.cap^{-1}$, respectively.

3. Results

3.1. Macrolitter composition in screened materials

Figure 3 illustrates the different waste types and categories that were collected during the campaigns. The anthropogenic macrolitter composition of the screened materials is presented in Figure 4. All items found at each screen are presented in the supplementary data (Table S1 and S2). In this paragraph, percentages will only refer to percentages in numbers and not in mass.

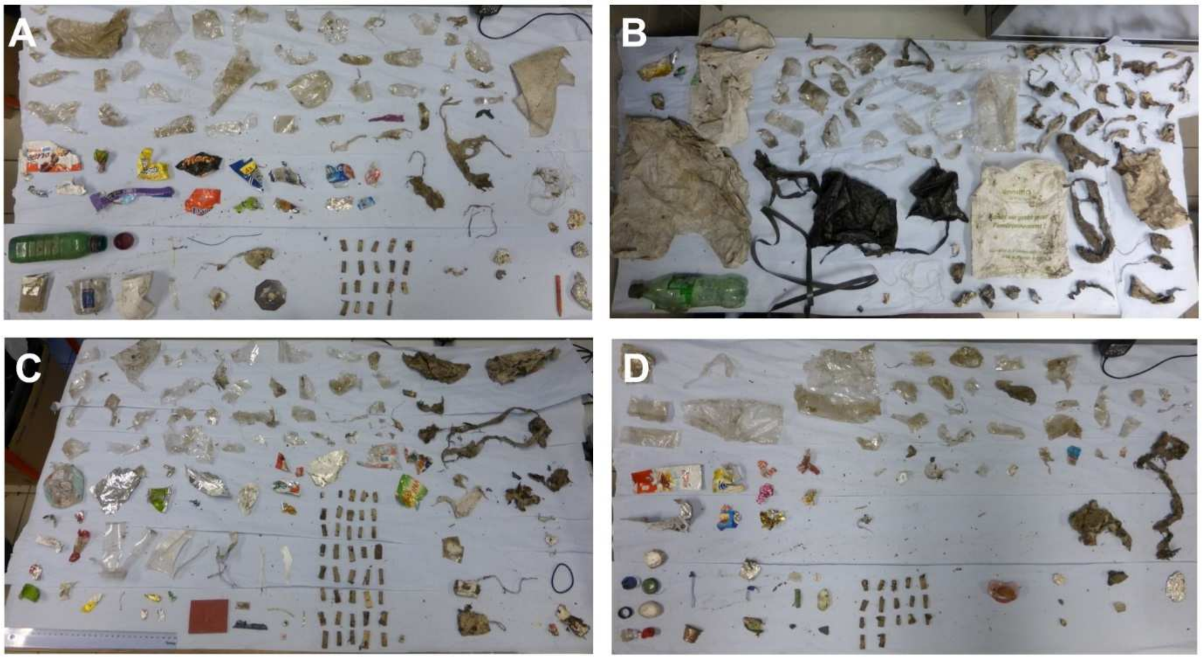


Figure 3: Common waste found in S_{6cm} (A and B) and S_{1cm} (C and D)

Only anthropogenic waste was included in Figure 3 and Figure 4. Natural organic debris (plant debris and putrescible waste) was not categorised in detail and only weighed (*c.f.* §2.).

For S_{6cm} and S_{1cm}, the plastic category was the most numerous with mean values of 71±9% and 62±10% (N = 11 with triplicates), respectively, excluding the first four campaigns. For S_{6cm}, medical and sanitary waste had the second-largest percentage (16±9%) and consisted mainly of bandages. For S_{1cm}, cigarette butts had the second-largest percentage (24±13%). Other material types (paper/cardboard, metal, etc.) accounted for the smallest percentage (<7%). For S_{6cm} and S_{1cm}, both triplicates showed a relatively low variability for the plastic category (variation between the minimum and maximum values was <8% and <34% for S_{6cm} and S_{1cm}, respectively).

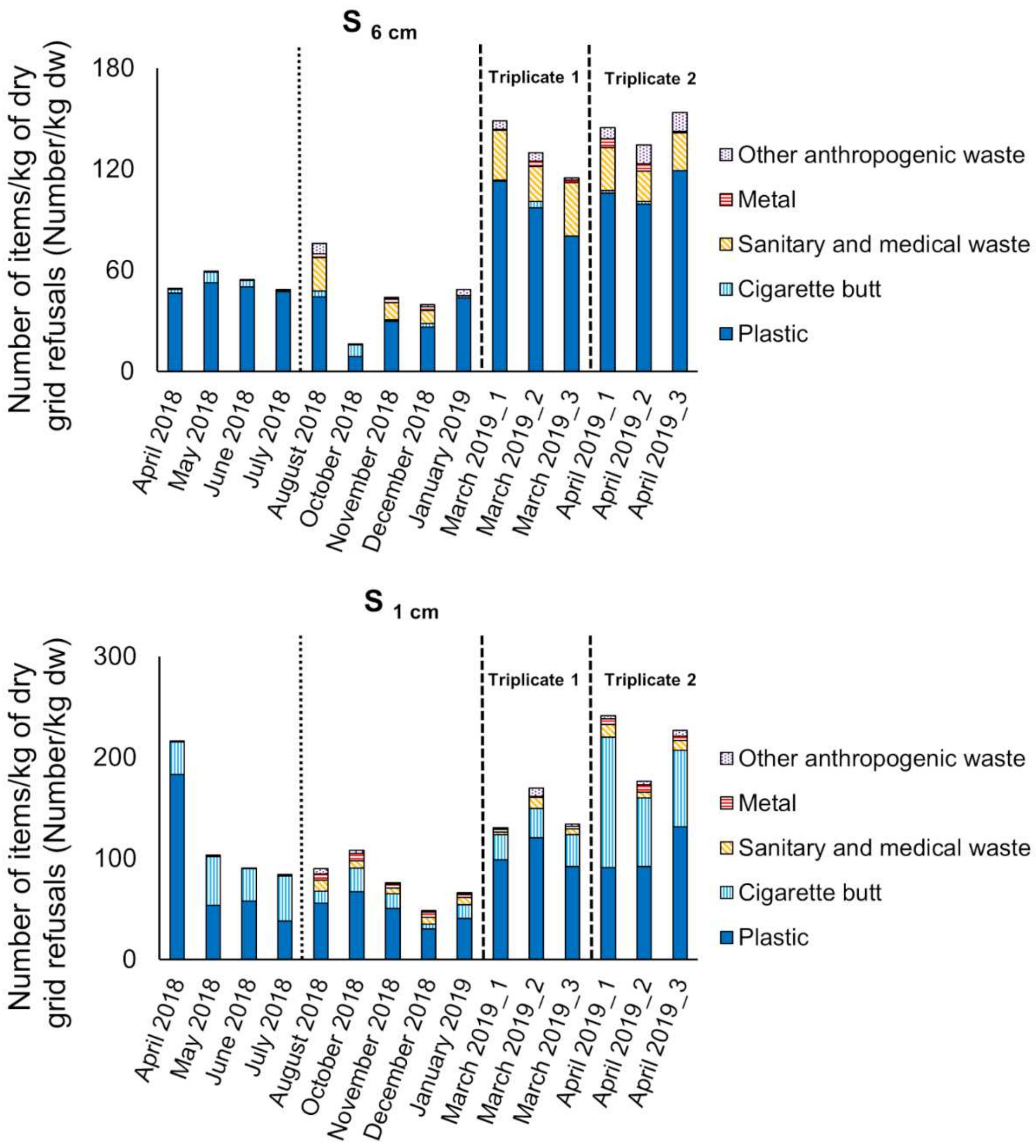


Figure 4: Anthropogenic macrolitter composition for each screen. The first four campaigns (April - July 2018 are separated by a dotted line) only focused on plastics and cigarette butts. The y-axis is different for each graph. Triplicates 1 and 2 are separated by dashed lines.

To characterise the plastic pollution in the stormwater, the most common items found in S_{6cm} and S_{1cm} (Figure 5) were identified.

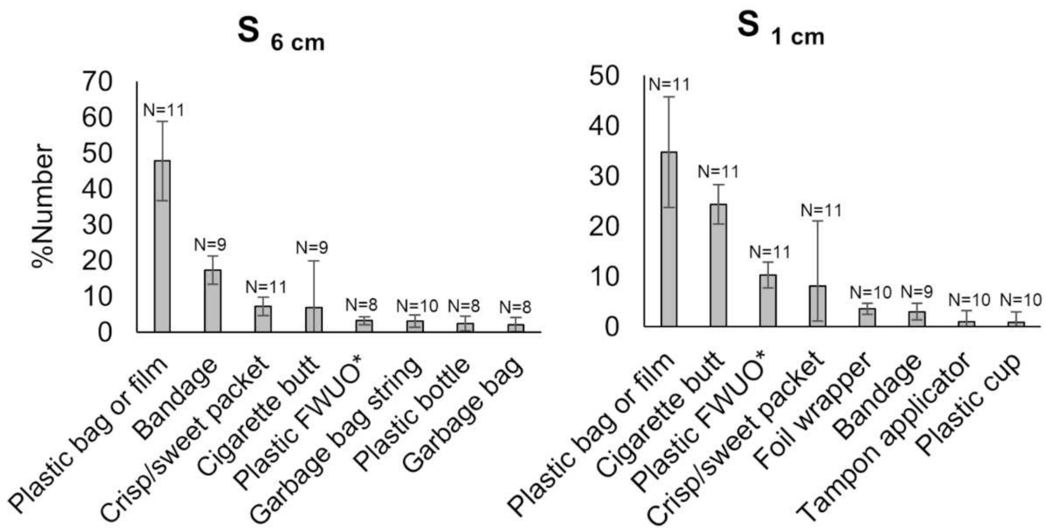


Figure 5: Mean percentages of the eight most common items found in the screened materials. The error bars illustrate the standard deviations and N denotes the number of samples where the item was present. For a more accurate comparison, the first four campaigns were not included. *Plastic FWUO = plastic fragment with unknown origin

Plastic bags and films, cigarette butts and bandages were the most numerous items found in the screened materials samples (Figure 5). Plastic bags and films were the predominant items found in S_{6cm} and S_{1cm} of all the other items. The most common items found in S_{6cm} and S_{1cm} are similar; however, they do not account for the same proportions.

3.2. Macrolitter mass percentages in screened materials and concentrations in urban runoff

Percentages by dry weight (dw%) of each waste category for each screen are presented in Figure 6. The highest average percentages for S_{6cm} and S_{1cm} corresponded to natural organic debris (76±13 and 94±3 dw%, respectively), plastics (12±6 and 3±2 dw%, respectively), and sanitary and medical waste (8±5 and 2±1 dw%, respectively) with N = 11 (with triplicates) and the first four campaigns were not included in the mean values. Other anthropogenic waste (2±5 and <1 dw% for S_{6cm} and S_{1cm}, respectively) and metals (2±2 and <1 dw%, respectively) accounted for minor percentages, except for one sample (March 2019_3).

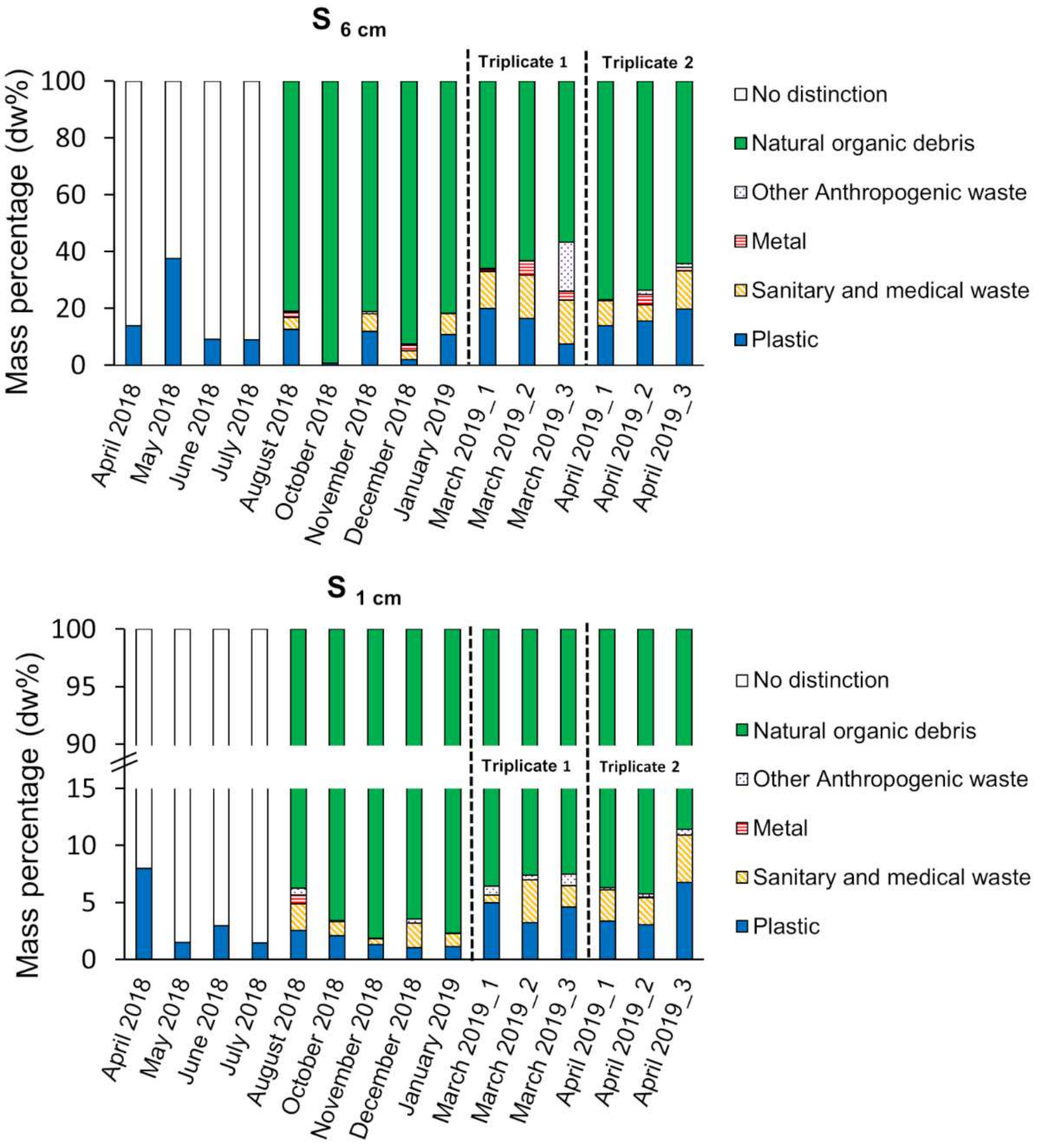


Figure 6: Percentages by dry weight (dw%) of each waste category for each screen. Only plastics and cigarette butts were included in the first four samples.

For triplicates 1 and 2 at S_{6cm}, plastic mass percentage ranges were 7-20 and 14-20 dw%, respectively, whereas for triplicates 1 and 2 at S_{1cm}, the ranges were 3-5 and 3-7 dw%, respectively. When all the anthropogenic waste was compared for triplicates 1 and 2 at S_{6cm} (plastics, metals, sanitary and medical waste, and other anthropogenic waste) the mass percentage ranges were 34-43 and 23-35 dw%, respectively, and for triplicates 1 and 2 at S_{1cm}, these ranges were 6–7 and 6–11 dw%.

3.3. Plastic debris flux

The macrolitter concentration of stormwater (mg/m^3, Figure 7) was calculated based on the collected data.

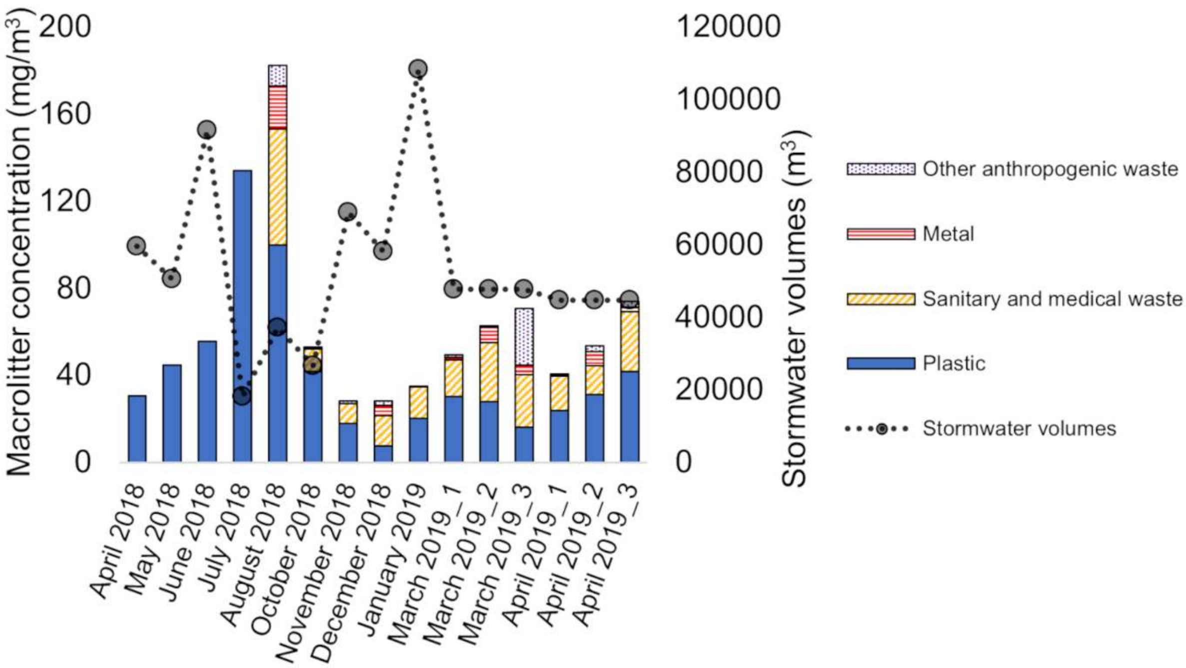


Figure 7: Macrolitter concentrations (mg/m^3) and stormwater volumes filtered through the screens for the studied periods (both screens S_{6cm} and S_{1cm} are cumulated)

The concentrations of all the anthropogenic waste ranged from 28 to 182 mg/m^3 and the mean and median concentrations of each waste category are presented in Table 1. Mean values are always higher than median values owing to heavy items that impact the mean values.

Table 1: Mean and median concentrations for each waste category (N = 15 for plastics and 11 for other categories)

	Mean concentration ± standard deviation (mg/m^3)	Median concentration (mg/m^3)
Plastic	41±33	31
Sanitary and medical waste	21±13	16
Metal	4±6	2
Other anthropogenic waste	4±8	1
Natural organic debris	811±1445	247

The natural organic debris concentrations are not presented in Figure 7 because their concentrations are significantly higher than the other waste categories. The plastic debris concentrations ranged between 7 and 134 mg/m^3 (minimum and maximum values, respectively).

Utilizing the method$_{Concentration}$, the mean and median mass of the plastic debris accumulated on the screens in one year were 27±22 and 21 kg, respectively.

For the method$_{Annual\ Mass}$, major fractions found in the screened materials and the percentage by weight (w%) of plastics accumulated on both screens (estimated from mass percentages previously presented) are summarised in Table 2.

Table 2: Mean composition of screened materials and estimation of mean plastic mass accumulated in one year on the screens (mean value ± standard deviation)

	S_{6cm} and S_{1cm} combined
Water content (w%)	74±4
Organic waste mass (w%)	22±4
Plastic and non-plastic anthropogenic waste mass (w%)	4±2
Plastic waste mass (w%)	2±1
Total mass of screened materials per year (mean value from 2015 to 2019, kg)	5,359±667
Estimation of plastic mass per year in screened materials (mean value from 2015 to 2019, kg)	107±55

Based on this data, 107±55 kg of plastic debris were accumulated in the screened materials of Sucy-en-Brie in one year.

The results of these two methods can be normalised to the impervious surface area (62 ha) and population (~5,700 inhabitants) of Sucy-en-Brie to calculate ratio$_{Area}$ and ratio$_{Cap}$, respectively, which are provided in Table 3.

Table 3: Annual plastic debris flux normalized to impervious surface area and population of Sucy-en-Brie for method$_{Concentration}$ and method$_{Annual\ Mass}$

Sucy-en-Brie	**Method$_{Concentration}$**	**Method$_{Annual\ Mass}$**
Annual plastic flux in stormwater of Sucy-en-Brie (kg.yr^{-1})	27.4±22	107.2±55.2
Ratio$_{Area}$: plastic flux per impervious surface area (kg.yr^{-1}.ha^{-1})	0.4±0.3	1.7±0.9
Ratio$_{Cap}$: plastic flux per capita (g.yr^{-1}.cap^{-1})	4.8±3.9	18.8±9.7

4. Discussion

4.1. Macrolitter composition in screened materials

Because they are in series, differences in the waste composition of the S_{6cm} and S_{1cm} screened materials can be observed (Figure 3 and 5), which is attributed to the mesh size difference. The most important difference in waste composition is the abundance of cigarette butts in the S_{1cm} material. Generally, cigarette butts pass through S_{6cm} but not through S_{1cm}. The S_{1cm} mesh size is not small enough to retain all the cigarette butts in the stormwater, as evidenced by the presence of cigarette butts in the lamellar settling tank (personal observation); however, the fraction that is not retained is difficult to estimate. Based on their distinctive shape, some plastic films were determined to be discarded cigarette box packaging.

This study found 52 and 60 different item categories and 1,613 and 3,126 items for S_{6cm} (Table S1) and S_{1cm} (Table S2), respectively. Plastic debris represented 71% and 62% of the S_{6cm} and S_{1cm} items, respectively, which reflects the relatively low diversity of the composition of the screened materials and the predominance of plastic waste. Plastic bags and films were the most common items found in the screened materials. Bandages were also common, which could be related to the proximity of health facilities to the catchment, mismanagement of health and sanitary waste, and illicit disposal; this is because this type of waste requires costly disposal procedures. Because condoms and sanitary napkins were observed in the waste, misconnections between the stormwater and wastewater systems most likely exist in this catchment. These misconnections are easily identified in separate sewer systems (Ellis and Butler, 2015). The most recent estimate is that 10% of all connections are misconnections between stormwater and wastewater sewers (data provided by the DSEA), which explains the presence of these types of unexpected waste.

Considering the relatively low variability between waste categories and the eight most common items found, the waste composition must be linked to several parameters such as: (i) the habits of the citizens, (ii) the layout of the sewer network (e.g. illicit connections, layout of gully pots) and (iii) the cleaning service of Sucy-en-Brie (e.g. garbage bin availability, urban cleaning). The distribution of the screened materials may reflect the type of items that are socially acceptable to discard in the street, easily lost, or difficult to clean, except for waste caused by errors linked to misconnections (e.g. tampon applicators), illicit disposal to avoid disposal costs (e.g. bandages), and animal behaviour (e.g. birds) that could potentially spread macrolitter. However, additional studies on these topics are necessary to confirm these trends.

4.2. Macrolitter and plastic debris mass percentages in screened materials and concentrations in urban runoff

When the S_{6cm} and S_{1cm} waste from the same campaigns are combined, the mass of the screened materials is primarily composed of water (>70 w%) and natural organic debris (~22 w%) (Table 2). Non-plastic anthropogenic waste and plastic debris account for 4±2 and 2±1 w%, respectively. The plastic debris percentage in the screened materials was low as compared to that of natural organic debris; however, the mass of the plastic debris corresponds to a mean percentage of 53±16 w% of all the anthropogenic waste mass, showing the abundance of plastic debris. Although some waste categories are abundant in number (i.e. cigarette butts), they represent minor mass fractions (Figure 4 and 6).

The natural organic debris concentrations showed the highest variability with a standard deviation of 1,145 mg/m^3 and a high variation between the minimum (176 mg/m^3 in March) and maximum values (4,975 mg/m^3 in October) (Figure 7 and Table 1). This is assumed to be caused by seasonal variability, most likely leaves dropping in autumn that are subsequently transported by the increased precipitation amounts in autumn (Figure 2).

Higher anthropogenic waste concentrations, particularly plastic debris concentrations, were observed during the summer period from July to August (Figure 7). Compared to natural organic debris, non-plastic anthropogenic waste and plastic debris presented a different seasonal pattern. Initially, it appears that the plastic debris concentrations correspond to smaller stormwater volumes; however, when plotted against stormwater volume, plastic debris concentration decreases when stormwater volume increases (Figure S3). However, no obvious correlation was found ($R^2 = 0.21$ and p-value = 0.08 utilizing the Spearman-Rs test, Figure S3), which indicates that other parameters influence plastic debris accumulation in the screened materials.

Precipitation fluctuations may have a significant influence on plastic debris accumulation. In July and August 2018, only 4 and 5 rain events were recorded, respectively, versus 12–20 per month in the winter. The summer and winter periods were compared using the mean stormwater flow rates at the outlet of the catchment for each rain event (Table S4). The July-August rain events presented significantly higher mean flow rates compared to those in the winter period ($p = 0.01$ with a Mann-Whitney-Wilcoxon test, $N = 9$ for the July–August period and $N = 44$ for the winter period). The summer period is characterised by infrequent, intense storm events. High-intensity rain events may carry more waste than less intense rain events; however, the holidays that occur in July and August may cause greater waste discharge due to recreational activities. Both parameters, storm events and holidays, may explain the higher values observed in the July-August period compared to the other periods.

4.3. Plastic debris flux

As shown in Table 3, the method$_{\text{Annual Mass}}$ yields higher mass accumulation values than the method $_{\text{Concentration}}$. Based on the standard deviation of the method $_{\text{S Annual Mass}}$ (Table 2), the mass accumulation values are more widespread than those of the method $_{\text{Concentration}}$, which may be because the $\text{method}_{\text{Annual Mass}}$ uses annual mean values. The application of both methods enables a better assessment of the plastic accumulation in the screened materials.

The Sucy-en-Brie ratios can be extrapolated for the Greater Paris area, which is defined as a catchment encompassing Paris and 284 neighbouring cities, spanning 183,000 ha, and with a population of approximately 8.9 million (Risch et al., 2018). Sucy-en-Brie's $\text{ratio}_{\text{Area}}$ and $\text{ratio}_{\text{Cap}}$ were multiplied by the impervious area of Greater Paris (50,900 ha estimated by Risch et al., 2018) and the Greater Paris population (Table 4). These values correspond to a maximum plastic litter discharge in the stormwater assuming the habits of the Sucy-en-Brie citizens, the urban cleaning methods and the layout of the sewer network are representative of the Greater Paris area. Moreover, these values consider all stormwater, without distinction of sewer systems (combined or separate). Only a part of this stormwater remains untreated. To ensure a better comparison between Sucy-en-Brie and Greater Paris, we estimated the untreated stormwater from separate sewer systems. For this reason, $\text{ratio}_{\text{Area}}$ was multiplied by the impervious surface area drained by separate sewer systems (19,000 ha, Table 4).

Table 4: Extrapolation of Sucy-en-Brie ratios to the Greater Paris area utilizing $\text{Method}_{\text{Concentration}}$ and $\text{Method}_{\text{Annual Mass}}$

Greater Paris	**$\text{Method}_{\text{Concentration}}$**	**$\text{Method}_{\text{Annual Mass}}$**
$\text{Ratio}_{\text{Area}}$ * impervious surface area of Greater Paris (tons.yr^{-1})	22.4±17.8	88.1±45.3
$\text{Ratio}_{\text{Cap}}$ * population of Greater Paris (tons.yr^{-1})	42.8±34.6	167.4±86
$\text{Ratio}_{\text{Area}}$ * impervious surface area connected to separate sewer systems (for untreated stormwater)	8.4±6.6	32.9±12.5

Using the $\text{method}_{\text{Concentration}}$ and $\text{method}_{\text{Annual Mass}}$ and extrapolating the Sucy-en-Brie ratios to the Greater Paris area, a resultant annual flux of 22–167 metric tons.yr^{-1} of plastic debris was calculated. Assuming stormwater of separate sewer systems remains mainly untreated, the plastic debris flux from Greater Paris to the environment through untreated stormwater of separate sewer systems ranges between 8–33 tons.yr^{-1}.

The initial study by Tramoy et al. (2019) estimated that the amount of plastic debris discharged from the Seine River to the English Channel ranges between 1,100 and 5,600 tons.yr^{-1}, which correspond to 66 and 353 g .cap^{-1}.yr^{-1}, respectively. More recently, Tramoy et al. (2021, in revision) refined their estimations to 6-12 g.yr^{-1}.cap^{-1}, which approximately corresponds to the results of this study, and calculated a plastic debris discharge of approximately 100–200 tons yr^{-1} into the sea. Other sources may contribute to the plastic debris discharged into the Seine River catchment including combined sewer overflows. Additionally, the plastic discharges attributed to urban traffic may be underestimated. Plastic accumulation along the Seine River has been studied (Tramoy et al., 2019a); however, the precise estimation of plastic debris accumulation is difficult. Gasperi et al. (2014) estimated that ~27 metric tons of plastic are captured annually by floating booms placed downstream of the combined sewer overflows; however, only a portion of the floating debris is captured during storm events.

Other factors may influence the plastic debris input into the stormwater, particularly meteorological and hydrological conditions, as determined by van Emmerik et al. (2019) who observed an increase in plastic discharge up to a factor of ten for the Seine River due to meteorological and hydrological conditions. Althoff et al. (2020) estimated the plastic consumption of France to be 70 kg per inhabitant per year. The discarded plastic found in stormwater corresponds to less than 0.3 ‰ (4.8-18.8 g.yr^{-1}.cap^{-1}, Table 3) of the amount consumed per inhabitant. Thus, plastic debris fluxes in stormwater are minimal compared to plastic consumption.

However, plastic debris inputs in the Sucy-en-Brie catchment may be higher than what accumulated in the catchment outflow for several reasons. First, municipal street sweeping and sanitation services in Sucy-en-Brie may be effective in preventing most plastic debris from entering in the stormwater. Second, stormwater grates may have prevented the largest size waste from entering the sewers. Third, plastic waste may be retained in sewer systems due to installed structures and obstacles in the sewers. Additionally, the representativity of the Sucy-en-Brie catchment may be discussed, because of its size and limited industrial and commercial activities; therefore, other sites should be studied for comparison. This study, however, provides an initial estimation of the plastic debris in the stormwater of the Greater Paris area. In addition to plastic debris larger than 5 mm, microplastics in stormwater should also be studied to compare the different inputs of macro and microplastics.

The results of this study suggest that in urban areas, plastic pollution prevention techniques combining waste collection services and systems (e.g. sanitation services and waste screens to prevent waste from entering the environment) may be effective when performed soon enough. Additionally, plastic waste retention times in the urban areas of developed countries, particularly in sewer systems and on land, might be greater than what is estimated by the models (Lebreton et al., 2017; Schmidt et al., 2017). Additional studies should be performed to compare different urban catchments and confirm these trends.

5. Conclusion

This study provides the first evaluation of the abundance and composition of macrolitter and plastic debris in stormwater, particularly in screened materials. Screened materials in Sucy-en-Brie are primarily composed of water (~74 w%), natural organic debris (~22 w%), and anthropogenic waste (~4 w%). Among the anthropogenic waste, plastic was the largest in number (>60%) and mass (>50% of anthropogenic waste dry mass, on average). The plastic debris concentration in stormwater ranges from 7 to 134 mg/m^3. When extrapolated to the Greater Paris area, discharged plastic debris in stormwater ranged from 22 to 167 tons.yr^{-1}, of which an estimated 8-33 tons yr^{-1} is discharged into the environment through untreated stormwater from separate sewer systems. These estimations correspond with the recent plastic debris estimations for the Seine River. Additional studies should be performed on the plastic debris flux variability in stormwater in other urban catchments, which could help in more effectively estimating the plastic discharged into the environment.

6. Acknowledgements

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