Macro et microplastiques dans les eaux pluviales et dans les rejets urbains de temps de pluie de l'agglomération parisienne

Macro and microplastics in stormwater and combined sewer overflows in Paris megacity

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RÉSUMÉ

Les eaux pluviales et les rejets urbains de temps de pluie pourraient constituer une source importante de macro et microplastiques (déchets plastiques de moins de 5 mm) dans l'environnement. Les flux de déchets plastiques sont cependant très peu étudiés dans les eaux urbaines. Dans le but de compléter ces données, les concentrations en macro et microplastiques ont été estimées (i) dans les refus de dégrillage et en entrée d'un bassin de rétention d'eau pluviale situé à l'aval du bassin versant de Sucy-en-Brie (94370) ainsi que (ii) dans les rejets urbains de temps de pluie du déversoir d'orage de Clichy (92110). Les macroplastiques sont triés, pesés et répertoriés tandis que les microplastiques sont extraits par une méthode de séparation densimétrique au NaI suivie d'une digestion chimique. Les microplastiques sont ensuite comptés à l'aide d'un microscope et identifiés par spectroscopie infrarouge. Les premiers résultats concernent uniquement les eaux pluviales de Sucy-en-Brie. Ceux-ci révèlent des pourcentages massiques en macroplastiques variant entre 1,5 et 37,5 %. De plus, 8 principaux types de déchets constituent près de 95 % des macroplastiques retrouvés. Pour les microplastiques, deux évènements pluviaux ont été à ce jour échantillonnés au bassin de Sucy-en-Brie. Seuls les microplastiques compris entre 1 et 5 mm du premier évènement pluvial ont été analysés. Pour cette gamme de taille, nous retrouvons des concentrations en microplastiques variant entre $4,6*10^{-2}$ et $9,3*10^{-3}$ fragments/L, avec une présence marquée de polyamide et de polyéthylène.

ABSTRACT

Stormwater and combined sewer overflows (CSO) could represent an important source of macro and microplastics (plastic waste smaller than 5 mm) in environment. However, plastic waste fluxes are under studied in urban waters. To add more data on this topic, macro and microplastic concentrations are estimated (i) in the grid refusals and in the inlet canal waters from a stormwater reservoir of a separate sewer system, situated in Sucy-en-Brie (94370) and (ii) in CSO discharges at the Clichy outfall (92110). Macroplastics are sorted, weighted and classified whereas microplastics are extracted using a NaI density separation followed by a chemical digestion. Micoplastics are then identified using a microscope and infrared spectroscopy. First results only concerned stormwater reservoir of Sucy-en-Brie. Those data show macroplastic mass percentages varying between 1.5 to 37.5 %. Moreover, 8 main plastic types correspond to 95% of all the macroplastics observed. Concerning microplastic concentrations, two rain events has been sampled at Sucy-en-Brie. Only 1 to 5 mm microplastics size range of the first rain event has been analyzed. For this size range, we found microplastic concentrations varying between $4.6*10^{-2}$ and $9.3*10^{-3}$ fragments/L, predominance of polyamide and polyethylene is observed.

MOTS CLÉS

Macroplastic, Microplastic, Stormwater, Urban effluents, Combined sewer overflow

1 INTRODUCTION

Plastic waste management is currently an important environmental issue. Due to their noteworthy mechanical and chemical properties (lightness, low reactivity, etc.), plastic production has known an exponential increase, from 1.5 million of tons in 1950 to 335 million of tons in 2016 (PlasticsEurope, 2017). Each year, the plastic waste flux from rivers to ocean is estimated between 1 to 2.5 million of tons (Lebreton et al., 2017). However, most of the plastics being non-biodegradable, those materials are accumulating to such an extent that plastic waste is now ubiquitous in all environmental compartments. This accumulation may disturb the ecosystems in different scales and in different ways. In 2004 a distinction was made between macroplastics, plastic waste bigger than 5 mm, and microplastics, smaller than 5 mm (Thompson et al., 2004). It has been demonstrated that plastic waste discharges in freshwaters are generally linked to two factors : (i) population density and (ii) the efficiency of waste management (Jambeck et al., 2015). In the case of Paris megacity, a metropolis of more than 10 million inhabitants, the urban metabolism of plastic waste is not precisely understood. Preliminary results were provided for microplastics in runoff and CSO but only a few number of rain events were studied, and volumes sampled were relatively low leading to high uncertainties (Dris et al., 2018). For macroplastics, our objective is to obtain mass concentrations and then annual fluxes in CSOs and stormwater runoff. Whereas for microplastics, we focus on concentrations during several rain events in those urban water compartments.

2 METHODS

2.1 Sampling sites

Two sampling sites has been selected. For stormwater, Sucy-en-Brie catchment (situated in the south east of Paris metropolis) was selected in collaboration with the Direction of the Sanitation and Environmental Services of Val-de-Marne (DSEA 94). It has been chosen because this area is particularly well documented and well-instrumented to study rain events. This catchment is approximately 228 hectares, including a part of the Sucy-en-Brie city. This city is occupied by 25,000 inhabitants. It is mainly a residential region, commercial activities are limited. A stormwater reservoir is located at the catchment outflow. This reservoir is equipped of a basin and a lamellar clarifier which is used to remove particulates from liquids. A 60 mm grid (written GR1, for Grid Refusal 1), is situated at the stormwater reservoir entrance to prevent the arrival of debris in the basin. The stormwater of the basin is pumped to the lamellar clarifier for decantation. A 10 mm grid (GR2), located just before the lamellar clarifier, is devoted to protecting it from debris bigger than 10 mm. The accumulated debris on the two grids are used to study the macroplastic concentrations.

On the other hand, the CSO Clichy outfall (in the north east of Paris), which is the most important outfall in Paris megacity managed by the Paris Public Sanitation Service (SIAAP), was selected. Concentrations of plastic waste in the CSO of Clichy will be studied in the outlet channel.

2.2. Sampling methods

For the stormwater of Sucy-en-Brie, debris are collected from the two grid refusals (between 30 and 60 kg per grid). They are weighted and pretreated. The grid refusal debris will be collected once per month for one year (from February 2018 to March 2019) to follow the concentration variations of plastic waste. Whereas microplastics are studied by collecting samples of 80 to 100 L of water from the inlet canal (upstream of the grid refusals) during rain events. This water is then filtered with an 80 µm net. To date, two rain events were sampled. For a given event, between 3 and 5 samples were collected.

Concerning the Clichy outfall, debris are collected using a net with a mesh size larger than 5 mm with exposure time of 10 minutes during an overflow discharge. Microplastics are collected from the outfall canal during a rain event using two different nets: a 300 µm net with a 5 minutes exposure time and an 80 µm net using a 1-minute exposure time to prevent clogging.

2.2 Analytical procedure

For the macroplastic study, a subsample of the debris collected at the different sampling sites (from 3 to 6 kg) is randomly selected, weighted and dried in an oven at 40°C during at least 10 days. They are weighted again, to get the dry masses, and visually sorted. Plastics and anthropogenic debris (such as aluminum cans, health-care waste, etc.) bigger than 5 mm are classified.

Concerning microplastics, their extraction from water samples is performed in 3 main steps: (i) the samples are sieved using a 5 mm and a 1 mm sieve, (ii) then separated with a NaI density separation (d=1600 kg/m^3), (iii) and finally digested with a H_2O_2 30 % solution to remove the organic matter. The samples were then filtered and microplastics were counted with a stereomicroscope coupled with an image analysis software. The fragments and a part of the fibers (between 10 and 30% of the total fibers) will be analyzed with FTIR spectroscopy.

3 RESULTS AND DISCUSSION

3.1 Macroplastics in grid refusals of Sucy-en-Brie

We will only present the results about the Sucy-en-Brie sampling site. The different characteristics of the collected macroplastic samples are summarized in table 2 for GR1 (60 mm) and GR2 (10 mm).

Table 1 : Characteristics of the grid refusal samples and plastic waste mass percentages

Sample	Date	Wet mass (kg)	Dry mass (kg)	Water mass percentage (%)	Number of plastic debris found	Plastic mass (kg)	Plastic mass percentage (%)
GR1	04/12/2018	5.74	1.44	74.9	71	0.20	13.9
	05/22/2018	3.46	1.28	63.0	81	0.48	37.5
GR2	03/02/2018	16.89	4.20	75.2	405	0.19	4.5
	04/12/2018	7.17	1.44	79.9	312	0.12	8.0
	05/22/2018	5.00	1.34	73.2	140	0.02	1.5

Those samples are characterized by a high water proportion (a mean value of 70.3 %). The dry masses are all approximately the same (except for 03/02/2018 sample). On average, we observe 76 objects for GR1 and 286 objects for GR2 accumulated for the same time intervals. Plastic mass fraction is more important for GR1 than GR2. This plastic mass fraction can reach high values (37.5 %). GR2 presents variable values that ranges from 1.5 to 8 %. As illustrated in figure 1, eight different types of macroplastics are found in the grid refusals: fragments of plastic bags and/or films, packaging food (candies, biscuits, etc.), bottles, solid fragments with unknown origin (written FWUO), cigarette filters, garbage bags, polystyrene fragments, and plastic cups.

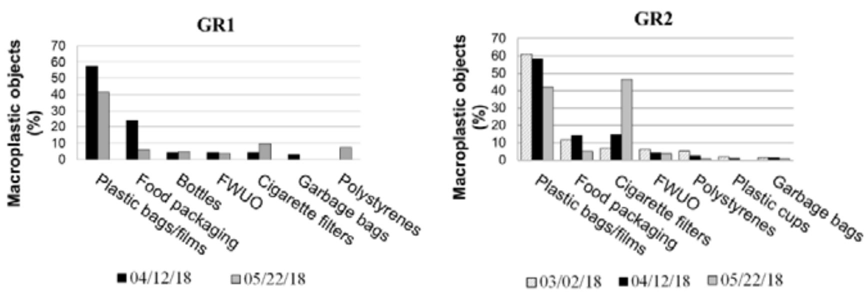

Figure 1: Proportions of the main macroplastic objects found for GR1 and GR2

For all the samples, films, plastic bags and food packaging represents the majority of the macroplastic debris, excepted for 05/22/18 GR2 for which the cigarette filters are found in high proportion (46.4%). Plastic bottles are exclusively found in GR1, due to the mesh size (60 mm). It must be noted that the waste collected at GR1 comes directly from the stormwater (that directly comes from precipitation) whereas GR2 debris comes from stormwater which is pumped in the reservoir, then brought to the lamellar clarifier. This pumping could have an influence on the macroplastic repartition. For both GR1 and GR2 we observe the presence of fragments with unknown origin (FWUO) which originate from bigger debris fragmentation. A first rough assessment of the macroplastic mass concentration in stormwater can be proposed. Considering the characteristics of the Sucy-en-Brie catchment and the mean rainfall depth during the sampling period of March/April 2018 (45.7 mm, mean precipitation data from DSEA 94), the runoff volume at the outflow of this catchment is approximately 22,000 m^3. For the GR1 and GR2 subsamples, 0.32 kg of macroplastics has been collected for this period. If we extrapolate this value to the entire debris accumulated in the grid refusals, the macroplastic mass concentration is approximately: $8.3 * 10^{-5}$ kg/m^3. For the sampling period of April/May we observed almost the same precipitations (47.5 mm, mean precipitation data from DSEA 94). Extrapolated to the whole accumulated grid refusal debris, we find a macroplastic mass concentration for the April/May sampling period quite similar to the March/April period: $8.6 * 10^{-5}$ kg/m^3. Those calculations must be considered with caution because the macroplastic mass percentage could be more variable with further samples. Due to that, those results must be confirmed with the incoming data.

3.2 Microplastics in stormwater of Sucy-en-Brie

Concerning microplastics, first results on the 06/11/18 rain event are illustrated in Figure 2, presenting the microplastic concentrations of 1-5 mm microplastic fragments in fragments/L in relation to the water flowrate of the inlet canal of Sucy-en-Brie.

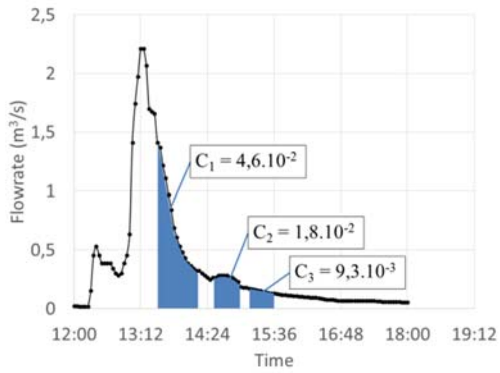

Figure 2 : 1-5 mm microplastic concentrations (fragments/L) depending on time and on the water flowrate in the inlet canal of Sucy-en-Brie catchment for the rain event of 06/11/18 (data from DSEA 94). Sampling period is displayed in blue.

For the results we have, higher concentrations are situated just after the flowrate peak. Then the concentration decreases with time. Those observations must be considered with caution. Indeed previous works found microplastic concentrations between 2 and 29 fragments/L (Dris et al., 2018) for the same catchment. Lower values could be explained by the fact that we did not analyze the smaller microplastics (1 µm to 1 mm). Infrared spectroscopy confirmed the presence of polyamide and polyethylene. 6 fragments found during this rain event could not be analyzed due to their high degradation. An infrared microspectroscope will be used to analyze smaller fraction. Analyses on the other rain event samples are in progress.

CONCLUSION

We only presented the first results for the stormwater of Sucy-en-Brie. Samples from CSO of Clichy will be collected in the coming months. Macro and microplastics study in stormwater and in CSO can be a hard task, particularly during rain events, but it could help for a better estimation of plastic waste fluxes in the Paris megacity using different analysis protocols. Those protocols and study could contribute to the establishment of monitoring system of plastic waste repartition and could be applied to other agglomerations to better understand the plastic waste sources. On the other hand, these studies could serve to prioritize actions for the reduction of plastic inputs in environment.

BIBLIOGRAPHIE

Dris, R., Gasperi, J., Tassin, B., 2018. Sources and Fate of Microplastics in Urban Areas: A Focus on Paris Megacity. Freshw. Microplastics 69–83. https://doi.org/10.1007/978-3-319-61615-5_4

Jambeck, J.R., Geyer, R., Wilcox, C., Siegler, T.R., Perryman, M., Andrady, A., Narayan, R., Law, K.L., 2015. Plastic waste inputs from land into the ocean. Science 347, 768–771. https://doi.org/10.1126/science.1260352

Lebreton, L.C.M., Zwet, J. van der, Damsteeg, J.-W., Slat, B., Andrady, A., Reisser, J., 2017. River plastic emissions to the world's oceans. Nat. Commun. 8, ncomms15611. https://doi.org/10.1038/ncomms15611

PlasticsEurope, 2017. Plastics - the facts 2015/2016.

Thompson, R.C., Olsen, Y., Mitchell, R.P., Davis, A., Rowland, S.J., John, A.W., McGonigle, D., Russell, A.E., 2004. Lost at sea: where is all the plastic? Science 304, 838–838.