

Urban roadside pollution: microplastic contamination and its correlations with litter, tire wear, and heavy metals

Pollution routière urbaine : Contamination en microplastiques et ses corrélations avec les déchets, les particules de pneus et les métaux lourds

Kelsey Smyth^a, Clément Vadaine^a, Tiago De Oliveira^b, Romain Tramoy^a, Antoine Tourret^a, Johnny Gasperi^b, Noureddine Bousserhine^a, Laure Garrigue-Antar^a, Julien Le Roux^a, Rachid Dris^a

kelsey.smyth@enpc.fr, clement.vadaine@u-pec.fr, tiago.de-oliveira@univ-eiffel.fr, romain.tramoy@u-pec.fr, antoine.tourret@u-pec.fr, johnny.gasperi@univ-eiffel.fr, bousserhine@u-pec.fr, laure.garrigue-antar@u-pec.fr, julien.le-roux@u-pec.fr, rachid.dris@u-pec.fr.

^aLaboratoire Eau, Environnement et Systèmes Urbains (LEESU), École nationale des ponts et chaussées, Institut Polytechnique de Paris, Université Paris-Est Créteil.

^bLaboratoire Eau et Environnement, Université Gustave Eiffel

RÉSUMÉ

Les microplastiques sont peu étudiés dans les eaux de ruissellement et les sols urbains récepteurs. Les études existantes des microplastiques dans les sols urbains n'incluent généralement pas d'autres polluants urbains qui pourraient être liés. Cette étude fournit un aperçu complet de la pollution des sols urbains récepteurs des eaux de ruissellement routières. Elle s'appuie sur une étude précédente de bassin de rétention d'autoroute qui traité des particules d'usure des pneus et qui a montré un lien entre les déchets plastiques et les microplastiques (25 à 500 µm). Dans cette étude, les sites comprennent trois bords de route avec des niveaux de trafic entre 3000 à 17000 vh/jr et un parking équipé de cellules de biorétention, situés en Île-de-France, au nord-est de Paris. À chaque site, des échantillons de sol composites ont été prélevés à des endroits recevant des eaux de ruissellement et analysés pour la présence de déchets plastiques, de microplastiques, de particules d'usure des pneus et des routes, et de métaux lourds. En outre, une analyse chimique des composés associés à l'usure des pneus et des études d'écotoxicité du sol et de ses lixiviats compléteront ces données. Les résultats préliminaires montrent que les concentrations de tous les polluants diminuent à mesure que la distance à la route augmente. On soupçonne que les particules provenant de l'usure des pneus et des routes sont corrélées aux métaux. De plus, les résultats suggèrent que les microplastiques, dans la gamme de taille analysée, proviennent plutôt de l'atmosphère et de l'usure des pneus et la chaussée que de la fragmentation des macroplastiques.

ABSTRACT

Microplastics are not frequently studied in stormwater runoff and receiving urban soil. Existing urban soil studies focusing on microplastics generally do not include other urban pollutants which may be related. This study provides a comprehensive overview of pollution in urban soils receiving road runoff. It builds on a previous study of a highway bioswale which analyzed tire wear particles and found a link between plastic litter and microplastics. In this study, sites include three roadsides with levels of traffic ranging from 3000 to 17000 vh/d and one parking lot outfitted with bioretention cells, located in the Île-de-France region to the North East of Paris. At each site, composite soil samples were collected at locations receiving stormwater runoff and analyzed for plastic litter, microplastics, tire and road wear particles, and heavy metals. In addition, chemical analysis for tire wear associated compounds and ecotoxicity studies of soil and its leachate will complement this data. Preliminary results show that concentrations for all pollutants decrease as the distance increases from the road. It is suspected that tire and road wear particles are correlated with metals. Further, the results suggest that microplastics, in the analysed size range, also more likely derived from atmospheric deposition than fragmentation of plastic litter.

KEYWORDS

Urban pollution, soils, road runoff, microplastics, bioretention

Pollution urbaine, sols, ruissèlement de chaussées, microplastiques, ouvrages de biorétention

INTRODUCTION

The marine environment is the most studied environmental matrix for microplastics, while other matrices remain less defined (de Souza Machado et al., 2018). In the terrestrial environment, urban soil is less well studied for microplastics (Surendran et al., 2023). Urban soil and stormwater runoff are interrelated as stormwater can carry and transport various pollutants to roadside soil (Sewwandi et al., 2024). In this way, roadside soil acts as both a stormwater filter and a source of stormwater pollution in the event of pollutant resuspension from the soil. Despite less attention to date, urban soils are also very exposed to plastic pollution from diverse sources, such as from transportation, industrial processes, rapid urbanisation, littering, and atmospheric deposition (Praveena et al., 2024). Microplastics from these sources can be transported via stormwater runoff to receiving urban soils including those running along roadways, parking lots, and in low impact development (LID) systems, likewise, receiving runoff. Microplastics are of interest to characterize in urban soils, as well as other urban pollutants, as they negatively impact soil-residing fauna such as earthworms and microorganisms' activities, soil properties (e.g., soil structure, physico-chemical properties, nutrient mobility, etc.) and therefore, vegetation growth (Sajjad et al., 2022). These impacts are relevant to vegetated urban spaces such as to parks, green boulevards, LID, etc.

Several studies have investigated soils for microplastics concentrations in urban areas, though not only located directly next to roads, such as urban locations throughout cities in Portugal, Pakistan, China, and Korea (Leitão et al. 2023; Rafique et al., 2020; Qiu et al., 2023; Choi et al., 2021). One recent French study was located in the same Île-de-France region as this study and it is one of very few studies to study plastic litter and tire-and-road wear particles in combination with microplastics in the same study, in urban roadside soil in a bioswale (Beaurepaire et al., 2025). These pollutants are less frequently evaluated together in the same studies as they require different analytical methods and the analysis of tire and road wear particles is difficult due to their complex chemical composition and black opaque colour (Järlskog et al., 2022). The present study builds off of Beaurepaire et al., (2025), as it aims to evaluate roadside soil receiving stormwater runoff from departmental roads and a parking lot with varying traffic levels for many urban pollutants. Evaluated sites include soil receiving stormwater runoff from three roadsides and one parking lot in which two bioretention cells are situated. Soil gradients at increasing distances from roads were evaluated for each of the three road sites. Specifically, this study evaluates plastic litter, microplastics, tire and road wear particles, and heavy metals at each of these sites. In addition, soil leachate was analysed for tire and road wear associated compounds (e.g., 6PPD-q, DPG, etc.) (Sandré et al., 2022) and for ecotoxicity studies on daphnia. Ecotoxicity of total soil on earthworms was also evaluated. This study aims to examine possible correlations between the studied urban pollutants and the influence of traffic on pollutant concentrations in urban soil.

1 METHODS

1.1 Site description

Roadside soil samples were collected from four different locations receiving road runoff in the Île-de-France region of France, within 40 km North East of the city limits of Paris. These sites include three departmental road sides in the towns of Compans, Montbarbin, and Vaires-sur-Marne with traffic varying between 3,000 to 17,000 vehicles/day. At each roadside site, two composite soil samples were collected: one directly beside the edge of the road (i.e., 0 – 1.5 m) and one further away (i.e., 1.5 – 3 m). Each sample zone consisted of an area of 5 m long x 1.5 m wide. The fourth site was a parking lot located in Sausset park where soil samples were collected from two bioretention cells (i.e., Sausset Basin A and B), and along a stormwater flow path starting at the pedestrian entrance in the parking lot (SAUS-Ent) as well as at the bottom of this flow path within a small forested area (SAUS-For). The four samples in the Sausset parking lot also consisted of 5 m by 1.5 m rectangular areas.

1.2 Sampling

Soil samples were collected in February 2025 using a band sampling strategy. Vegetation was first cut down to the ground, while retaining the roots. Using a manual auger, 20 subsamples were collected at the surface (upper 5 cm) of each of the 10 sample locations. These were used to form approximately 2-kg composite samples, which were homogenized in metal basins. Soil was subsequently separated into separate glass containers for each analysis type (i.e., microplastics, tire and road wear particles, metals, soil characterization, and ecotoxicological, microbial, and chemical analyses). Further, all litter greater than 5 mm in size was collected at each soil sampling site. Sampling sites were divided into two to three adjacent rectangular zones in series, each with an area of 5 m x 1.5 m. The collected litter was then categorized and weighed per category as follows: plastic, rubber,

paper/cardboard, metal, glass, and textile. Items were characterized following the OSPAR/TG ML classifications and using the J-list to classify by use and the associated economic sector.

1.3 Lab analysis

1.3.1 Microplastics and heavy metals

Composite soil subsamples of 10 g each were subjected to an organic digestion using a 30% hydrogen peroxide solution, followed by a 24-hour density separation using 1.8 g/cm³ sodium iodide solution. The recovered density separation supernatant was rinsed with filtered MilliQ water and filtered onto aluminum oxide filter papers (25 mm diameter, 0.2 µm pore size). Microplastics (25 – 5,000 µm) were analyzed in transmission mode by micro-FTIR with a Nicolet iN10 (Thermo Scientific, USA) FTIR with OMNIC Picta software. Each filter was imaged in mapping mode with a pixel resolution of 25 µm and data was extracted using siMPle software with the provided spectra library (Liu et al., 2019). In addition, total trace metals and major cations were analyzed using a portable X-ray fluorescence (XRF) instrument (Bruker, model S1 TITAN). The resulting soil was analyzed in duplicate.

1.3.2 Tire and road wear particles

Likewise, 10 g composite soil subsamples underwent a few processing steps to prepare for tire and road wear particle analysis. This included drying at 105°C for 24 h, dry sieving to include particles between 1 µm to 1 mm in size, and ball milling at 400 rpm for 3 minutes using tungsten balls. Then, 50 mg of each milled-sample were digested with 10% KOH solution at 60°C, over 24 hours. Digested sample was filtered on a 1 µm PTFE filter and then around 3 mg of the sample was collected in the pyrolysis cup for analysis. Analyses were performed using a multi-shot pyrolyzer EGA/PY- 3030D equipped with an auto-shot sampler (AS-1020E), manufactured by FrontierLab (Fukushima, Japan), at a pyrolysis temperature of 600 °C. The gas chromatography column used for the compound elution was the Ultra ALLOY+-5 from FrontierLab (Fukushima, Japan), with a temperature program as follows: hold of 5 min at 50 °C, then 50 °C to 300 °C at a rate of 25 °C/min and a final hold of 10 min at 300 °C. Two specific pyrolysis products were selected for the detection and quantification of SBR and NR in samples including 4-phenylcyclohexene (4-PCH) and dipentene (DP), respectively.

2 RESULTS

Microplastics at the urban soil sites ranged in concentration from 8.6×10^3 – 1.6×10^5 MPs/kg of soil with an average concentration of 6.6×10^4 MPs/kg (Fig. 1). This falls within a similar concentration range to a previous French study of a bioswale receiving highway runoff water in the same Île-de-France region (Beaurepaire et al., 2025) and to urban topsoil in Coimbra, Portugal (Leitão et al. 2023). However, in comparison to agricultural soil which is more frequently studied, urban soil is significantly more concentrated in microplastics. One agricultural soil study, located 70 km East of Paris using the same analysis as this study, found microplastics concentrations 21 times less concentrated than these urban soils (Smyth et al., 2025). These roadside soil concentrations were 15 to 125 times more concentrated than other urban soils studied in Pakistan, China and Korea, which examined slighter larger sized microplastics in various ranges between 50 – 5000 µm (Rafique et al., 2020; Qiu et al., 2023; Choi et al., 2021). At each of the roadside sites (i.e., Compans, Montbarbin and Vaires), a decreasing trend in microplastics concentration was observed from the roadside to a distance of 1.5 – 3 m from the road (Fig. 1). Similarly, Sausset Basin A was more concentrated in microplastics than Sausset Basin B which received less parking lot runoff water. Finally, a higher concentration of microplastics were found at the parking lot edge near the park's pedestrian entrance than within a forested part of the park receiving runoff water from the same pedestrian entrance of the parking lot.

Additionally, litter was collected at the same sites over two field campaigns: once in February at the same time as soil sampling and once in September. The same trend as microplastics was observed in that plastic litter by mass was highest at the roadside and decreased in mass with increasing distance from the roadside at all three road locations (Fig. 2). Further, plastic litter mass appears to be correlated with microplastic concentrations for the roadside sites, but no correlation exists between plastic litter and microplastics at the four sites within the parking lot. Similarly, tire and road wear concentrations and some metals followed the same trend as plastic litter and microplastics with regards to highest concentrations at the roadside and decreasing with distance from the road (Fig. 1). However, the highest concentrations of tire wear out of all samples, in the form of styrene butadiene rubber, were found in the parking lot, despite much lower traffic loading than the studied roads (Fig. 1). This might be related to strong tire abrasion occurring during parking maneuvers compared to driving on a straight road.

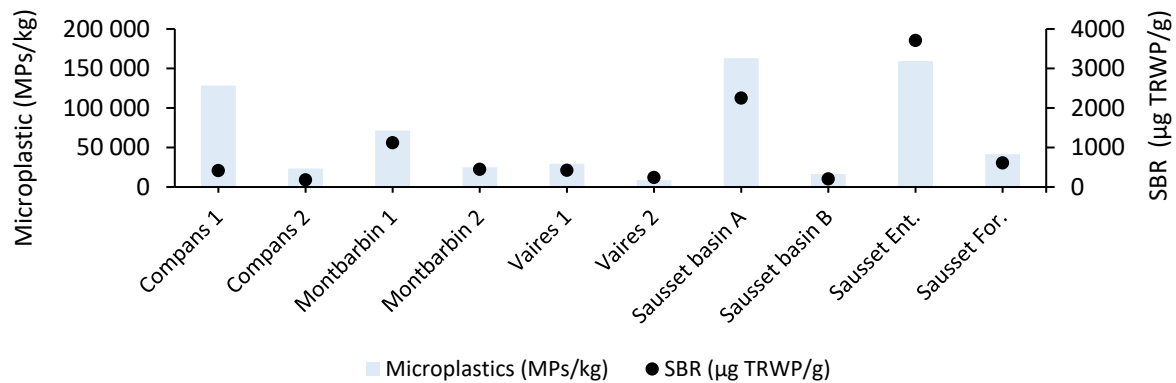


Fig. 1 Microplastic and styrene butadiene rubber (SBR) concentrations by site

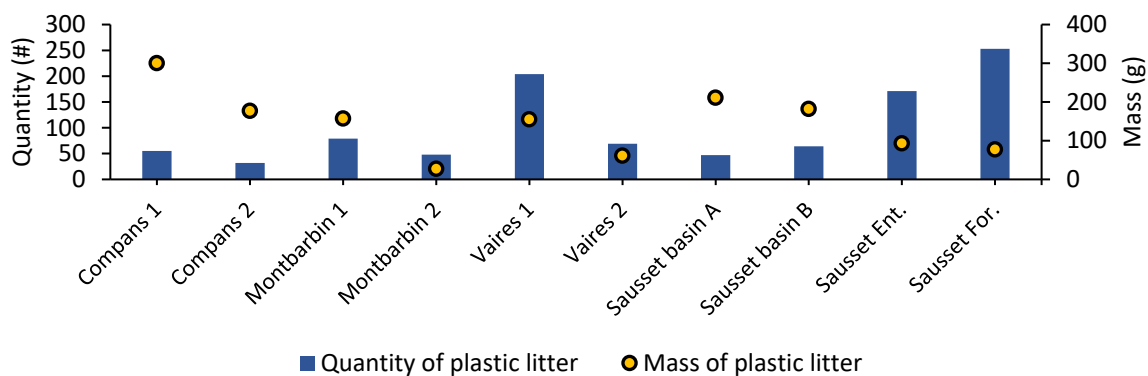


Fig. 2. Plastic litter by site

LIST OF REFERENCES

- Beaurepaire, M., de Oliveira, T., Gasperi, J., Tramoy, R., Saad, M., Tassin, B., & Dris, R. (2025). Stock and vertical distribution of microplastics and tire and road wear particles into the soils of a high-traffic roadside biofiltration swale. *Environmental Pollution*, 373.
- Choi, Y. R., Kim, Y.-N., Yoon, J.-H., Dickinson, N., & Kim, K.-H. (2021). Plastic contamination of forest, urban, and agricultural soils: a case study of Yeosu City in the Republic of Korea. *Journal of Soils and Sediments*, 21(5), 1962–1973.
- de Souza Machado, A. A., Kloas, W., Zarfl, C., Hempel, S., & Rillig, M. C. (2018). Microplastics as an emerging threat to terrestrial ecosystems. In *Global Change Biology* (Vol. 24, Issue 4, pp. 1405–1416). Blackwell Publishing Ltd.
- Leitão, I. A., van Schaik, L., Ferreira, A. J. D., Alexandre, N., & Geissen, V. (2023). The spatial distribution of microplastics in topsoils of an urban environment - Coimbra city case-study. *Environmental Research*, 218.
- Järlskog, I., Jaramillo-Vogel, D., Rausch, J., Gustafsson, M., Strömvall, A. M., & Andersson-Sköld, Y. (2022). Concentrations of tire wear microplastics and other traffic-derived non-exhaust particles in the road environment. *Environment International*, 170.
- Qiu, Y., Zhou, S., Zhang, C., Qin, W., Lv, C., & Zou, M. (2023). Identification of potentially contaminated areas of soil microplastic based on machine learning: A case study in Taihu Lake region, China. *Science of the Total Environment*, 877.
- Rafique, A., Irfan, M., Mumtaz, M., & Qadir, A. (2020). Spatial distribution of microplastics in soil with context to human activities: a case study from the urban center. *Environmental Monitoring and Assessment*, 192(11).
- Praveena, S. M., Zaidi, N. M. N. M., Nafisyah, A. L., & Lingaraju, H. G. (2024). Microplastics in Urban Soils From Different Land Use Activities of Cyberjaya (Malaysia): Exploring Occurrence, Relationships, Sources and Pollution Level. *Land Degradation and Development*, 35(17), 5254–5266.
- Sajjad, M., Huang, Q., Khan, S., Khan, M. A., Liu, Y., Wang, J., Lian, F., Wang, Q., & Guo, G. (2022). Microplastics in the soil environment: A critical review. *Environmental Technology and Innovation*, 27.
- Sandré, F., Huynh, N., Gromaire, M. C., Varrault, G., Morin, C., Moilleron, R., Le Roux, J., & Garrigue-Antar, L. (2022). Road Runoff Characterization: Ecotoxicological Assessment Combined with (Non-)Target Screenings of Micropollutants for the Identification of Relevant Toxicants in the Dissolved Phase. *Water (Switzerland)*, 14(4).
- Smyth, K., Dourneau, L., Tedoldi, D., Tassin, B., Kedzierski, M., & Dris, R. (2025). Soil contamination by microplastics in a small French agricultural watershed. *Environmental Pollution*, 387, 127316.
- Surendran, U., Jayakumar, M., Raja, P., Gopinath, G., & Chellam, P. V. (2023). Microplastics in terrestrial ecosystem: Sources and migration in soil environment. *Chemosphere*, 318.
- Sewwandhi, M., Kumar, A., Pallewatta, S., & Vithanage, M. (2024). Microplastics in urban stormwater sediments and runoff: An essential component in the microplastic cycle. *TrAC - Trends in Analytical Chemistry*, 178.