Microplastics pathways in the urban environment: Urban roadside snowbanks

Cheminement des microplastiques dans l'environnement urbain : les bancs de neige de bord de route

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RÉSUMÉ

La connaissance relative aux microplastiques (MP) dans l'environnement croît rapidement dans le but de combler certaines lacunes. Une de ces lacunes est l'occurrence de MP dans les bancs de neige en bordures de route en milieu urbain. Des bancs de neige ont été examinés sur 16 sites dans les villes de Luleå et Umeå au nord de la Suède dans le but d'estimer les quantités de MP présentes ainsi que d'évaluer l'influence des caractéristiques de sites sur ces estimations. Les MP extraits des échantillons de neige fondus ont été classifiés selon trois catégories (concentration moyenne indiquée entre parenthèses) : 1. Usure des pneumatiques et de la chaussée (19300 particules/L), 2. Peinture de marquage de la chaussée (430 particules/L), 3. Plastiques (33 particules/L). Aucune corrélation entre les concentrations de MP et les caractéristiques de sites n'a pu être mise en évidence. Cette étude apporte la preuve que la neige urbaine accumule des MP qui peuvent atteindre les eaux réceptrices soit par déversement direct lors du déneigement soit par le réseau de drainage lors de la fonte.

ABSTRACT

The knowledge base concerning microplastics (MPs) in the environment is rapidly developing with the goal of closing the existing knowledge gaps. One of such gaps, the occurrence of MPs in roadside snowbanks in urban areas, was surveyed at 16 sites in two northern Swedish cities, Luleå and Umeå, with the objective of estimating the quantities of MPs in snowbanks and evaluating the influence of site characteristics on such estimates. The MPs extracted from the melted snow samples were classified into three categories (the mean particle concentrations are shown in the brackets): 1. Tire and pavement wear particles (19,300 particles/L), 2. Road marking paint particles (430 particles/L), and 3. Plastics particles (33 particles/L), No correlations were found between the MP concentrations and site characteristics. The study provided the evidence that urban snow stores MPs, which may reach the receiving waters either with direct snow disposal or snowmelt discharge via storm sewers.

KEYWORDS

Microplastics (MPs), road paint, tire wear, urban snow

1. INTRODUCTION

Microplastics (MPs), generally defined as plastics particles with all dimensions smaller than 5 mm, are emerging pollutants of concern adversely impacting on aquatic life (Carlos de Sá et al., 2018). They are ubiquitous in many waters, and particularly in those strongly affected by anthropogenic activities, as shown, for example, for urban hydrosystems (Dris, 2016). The research on sources, pathways and fate of MPs is rapidly advancing, but there are still knowledge gaps, including the occurrence of MPs in urban roadside snowbanks in cool temperate climate and possible MP entry into the receiving waters with snow disposal into open waters, or snowmelt runoff conveyed by storm sewers. While stormwater runoff may convey relatively low concentrations of MPs, reported e.g. by Jönsson (2016) as 5.4-10 plastics particles/L and 220-4,267 road wear particles/L, one would expect higher concentrations in urban snow and its melt, because of higher production of MPs from winter traffic and road maintenance, and MPs accumulation in seasonal urban snowbanks over periods of 3-4 months.

MPs are released to the urban environment from various sources, but with respect to urban runoff and snowmelt, the main sources are abrasion of asphalt pavements, tire wear, road paint particles and atmospheric deposition. Abrasion of asphalt pavements, which generally contain polymer modified bitumen, was reported in Sweden at a rate of 110,000 tons/year (Gustafsson, 2001). Major contributors to this high rate are the studded tires used during winter months, and attrition by winter road maintenance operations including snow ploughing and grit applications (Vogelsang et al., 2018). Operational wear of tires, whose 60% of the outer parts consist of synthetic polymers like styrene butadiene and polybutadiene rubbers, represents another strong source of MPs (Kole et al., 2017), estimated for Sweden at about 12,000 tons of MPs per year (Magnusson et al., 2016). Road paints contain thermoplastic elastomers, which contribute to export of MPs from roads (Magnusson et al., 2016; Vogelsang et al., 2018). Finally, atmospheric deposition of MPs, which depends on local sources of MPs, also contributes to MP loads in urban catchments. For the City of Paris, Dris et al. (2016) reported the daily rates of MPs in atmospheric deposition, on average, as 110 ± 96 particles/m^2/day, of which 17% were purely synthetic and 12% were mixtures of synthetic and natural fibres (the rest were either natural or transformed natural fibres). The possible sources of these particles were identified as synthetic fibres from clothes, houses, and degradation of macro-plastics.

While general estimates of MP loads can be obtained using material flow analysis, determination of the load fractions reaching the receiving waters is a major challenge. MPs (and other pollutants) stored in urban snow can reach the receiving waters either with snowmelt conveyed by sewers, or with snow disposed directly in open waters. In the former case, only some portion of MPs in snow deposits is entrained by surface runoff and enters sewers, the rest may infiltrate into ground, particularly in the catchments featuring infiltration facilities. Direct disposal of urban snow into open waters is generally not permitted in Sweden, but about ten cities with space limitations for on-land snow disposal may apply for and receive special permits for the direct disposal (Magnusson et al., 2016).

The objectives of this study were twofold: (1) Estimate the quantities of MPs in urban roadside snowbanks, and (2) Examine the relation of such quantities to the sampling site characteristics.

2. MATERIALS AND METHOD

2.1 Study area and sampling

Snow samples were collected in the cities of Luleå (75,000 inhabitants; 65°35'5.35''N, 22°9'24.13''E) and Umeå (85,000 inhabitants; 63°49'33.05''N, 20°15'46.93''E), at eight sampling sites in each, during the winter of 2016/17. In each city, four sites were chosen along higher traffic intensity roads (17,900-23,000 vehicles/day) and four along low traffic intensity roads (<6,000 vehicles/day). These four sites were arranged (in both cities) in pairs, one pair just before the intersection, with one sampling point 0.5 m and the second one 2.5 m from the road, and the second pair was arranged in the same way, but 250 m from the intersection. Snow samples were extracted by a titanium ice drill, 1 m long and 12 cm in diameter. Snow from individual holes was collected in separate plastic bags, transported in coolers to the laboratory, and stored in climate rooms at -10 °C.

2.2 Laboratory analysis

The snow samples were melted at room temperature, sequentially filtered by filters with decreasing mesh sizes of 300, 100 and 50 µm, and the filter residues were analyzed for microplastics, using a Leica M205 C stereo microscope (100x magnification). Particles in individual samples were divided into three main categories: plastics particles, road particles and "white" particles, which were assumed to be road paint. The plastics particles were counted and divided into four categories: fibres, fragments, flakes and films. The rubber and bitumen particles were counted as one category called "road particles". All particles were analyzed optically and the particles suspected, but without full certainty, to be composed of plastics were further checked by a melting test. The particles that melted when exposed to heat were considered to be plastics. The identity of rubber and bitumen particles was verified by physically compressing them with tweezers.

3. RESULTS AND DISCUSSION

3.1 Quantities of microplastics in urban snow

MPs were found, in varying quantities, in all the samples collected and their examples are shown in Figure 1, displaying optical images of road wear, tire wear, and road paint particles; and, plastics fibres.

Figure 1. Microscopic images of selected MPs: (a) Road wear particle, (b) Tire wear particles, (c) Road paint particles, and (d) Plastics.

Total concentrations of MP particles in individual samples, expressed as particle count/L and unit area loads (particle count/m^2), are listed in Table 1. The most common type of MP particles were road particles (with an average of 19,300 particles//L), followed by road paint particles (with an average concentration of 430 particles/L), and plastics particles (with an average of 33 particles/L). There was a strong correlation (Pearson coefficient = 0.7 and Spearman coefficient =1) between the road wear particles and road paint particles.

Table 1: Measured MP concentrations (particles/L) and calculated unit area loads (particles/m^2) at 16 sampling locations

Sample	Plastics particles		Road wear particles		Road paint particles	
No.	Particles/L	Particles/m^2	Particles/L	Particles/m^2	Particles/L	Particles/m^2
1	72	4,780	39,000	2,590,000	989	65,600
2	36	1,920	7,450	403,000	133	7,220
3	24	914	6,270	239,000	674	25,700
4	40	1,640	2,660	108,000	139	5,640
5	11	1,410	17,500	2,310,000	62	8,170
6	24	1,370	193,000	11,300,000	4,020	235,000
7	32	1,750	12,800	691,000	428	23,200
8	27	1,610	7,080	417,000	277	16,300
9	11	712	670	42,000	14	876
10	21	4,880	2,780	642,000	45	10,300
11	12	1,650	2,710	360,000	36	4,800
12	13	3,480	1,640	427,000	52	13,600
13	148	11,900	11,600	938,000	0	0
14	14	3,030	963	205,500	0	0
15	29	1,660	2,640	153,000	9	512
16	8	988	144	17,800	2	247
Mean	33	2,730	19300	1,300,000	430	26,100
SD	34	2,760	47400	2,770,000	998	58,000

The plastics particles in snowbanks consisted of plastics fibres (43.8%±17.1 %), fragments (39.9%± 15%), flakes (12.7%±13.5%) and films (3.6%±11.2%). No comparable data were found in the literature for urban snow.

The presence of MPs in urban stormwater, snow and snowmelt is of growing interest for developing material flow models of MPs in urban areas. Average concentrations of MPs in the roadside urban snowbanks collected in Luleå and Umeå were greater than those reported in stormwater samples by Jönsson (2016) (5.4 to 10 plastics particles/L and 220 to 4,267 particles/L of road wear particles/L) in the size range 20-300 µm, compared to 50 µm-5 mm in our study. Dris (2016) analysed MPs in stormwater during five storm events from urban catchments in Paris and reported the average concentration of fibres and fragments as 35 and 6 particles/L, respectively. Compared to plastics particles in our snow samples, the concentrations of road wear particles were three orders of magnitude greater, as a result of the use of studded tires and winter road maintenance activities, contributing to the annual abrasion of asphalt pavements in Sweden of 110,000 tons per year (Gustafsson, 2001).

3.2 Correlation of MP concentrations with sampling site characteristics

The correlation of site-specific parameters like traffic intensity, distance of the sampling point from the road pavement edge, distance from a roundabout, and distance from road intersection against concentrations of different MPs were analysed using PLS (Partial Least Square); however, no strong correlations were found. This might be explained by repeated processing of urban snow by ploughing, grit applications, handling, intermittent melting in warm weather, and collection and disposal. During ploughing, snow may be removed from the road and dumped further away and some particles can be removed by splashing. Additional loads of pavement wear particles are generated by the pavement attrition due to snow ploughing.

4. CONCLUSIONS

Quantities of MPs in urban snowbanks were estimated by sampling snowbanks in two cities in northern Sweden. The results show that MPs were abundant in snowbanks. Major vectors of MPs in urban snow are road and tire wear particles, and road paints, all containing synthetic chemicals. The plastics particles were the least common, with a mean concentration in melted snow of 33 particles/L, and consisted largely of fibres (43.8%±17.1 %). Concentrations of MPs did not correlate well with sampling site parameters, like traffic intensity or the distance from the road. Winter road maintenance practices likely affected the concentrations of MPs at different sites.

LIST OF REFERENCES

Carlos de Sá, L., Oliveira, M., Ribeiro, F., Rocha, T.L., Futter, M.N., 2018. Studies of the effects of microplastics on aquatic organisms: What do we know and where should we focus our efforts in the future? Sci. Total Environ. 645, 1029–1039. https://doi.org/10.1016/j.scitotenv.2018.07.207

Dris, R., 2016. First assessement of sources and fate of macro and micro plastics in urban hydrosystems : Case of Paris megacity - PhD Thesis. Université Paris-Est.

Dris, R., Gasperi, J., Saad, M., Mirande, C., Tassin, B., 2016. Synthetic fibers in atmospheric fallout: A source of microplastics in the environment? Mar. Pollut. Bull. 104, 290–293. https://doi.org/10.1016/j.marpolbul.2016.01.006

Gustafsson, M., 2001. Icke-avgasrelaterade partiklar i vägmiljön:Litteraturöversikt [Non-exhaust-related particles in the road environment: Literature overview] (In Swedish with English summary). Swedish National Road and Transport Research Institute VTI, Linköping.

Kole, J.P., Löhr, A.J., Van Belleghem, F.G.A.J., Ragas, A.M.J., 2017. Wear and tear of tyres: A stealthy source of microplastics in the environment. Int. J. Environ. Res. Public Health 14. https://doi.org/10.3390/ijerph14101265

Jönsson, R., 2016. Mikroplast i dagvatten och spillvatten [Microplastics in stormwater and Wastewater](In Swedish with English summary)-Masters Thesis. Uppsala University.

Magnusson, K., Eliasson, K., Fråne, A., Haikonen, K., Hultén, J., Olshammar, M., Stadmark, J., Voisin, A., 2016. Swedish sources and pathways for microplastics to the marine environment A review of existing data Table of Contents. Swedish Environmental Research Institute IVL, Stockholm.

Vogelsang, C., Lusher, A., Dadkhan, M., Sundvor, I., Umar, M., Rannekleiv, S., Eidsvoll, D., Meland, S., 2018. Microplastics in road dust - characteristics, pathways and measures. NIVA, Report 7231, Oslo, Norway.