Landscape features impact microplastic and nutrient patterns during wet deposition events via stormwater runoff

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Introduction

- Microplastic (MPs; plastic particles < 5 mm) pollution is ubiquitous in our modern world and has implications for ecosystem and human health alike[1]. Microplastic pollutants enter the environment from anthropogenic sources through several pathways, including wastewater effluent (household, industrial, agricultural, *etc.*) plastic littering, and atmospheric deposition[1, 2].
- During rain events, MP and nutrient pollution can directly enter aquatic ecosystems, such as streams, lakes, and oceans, through a variety of pathways:[3]

  1) Wet deposition: pollutants suspended in the atmosphere are transported to land through rainwater[2].
  2) Stormwater runoff: rainwater travels across the landscape and collects debris and pollutants from landscape features such as rooftops and agriculture fields [4].

- Research on the pathways of MPs into waterways is lacking studies on the connections between landscape features (*e.g.,* buildings, trees, parking lots) and MP and chemical deposition patterns in stormwater runoff and wet deposition.

Objectives and Hypotheses

Objective:
To study 1) microplastic abundance and particle characteristics and 2) nutrient concentration in building stormwater runoff.

Predictions:
Anthropogenic microparticles (AP) patterns in building stormwater will:

P_1: Be similar across building sites since sites are geographically close to one another. With similar patterns for nutrient concentrations.

P_2: Represent a diverse range of color, sizes, and morphologies, with plastic microfibers the most common particle type.

Methods

Sites:
Samples were collected opportunistically from stormwater drainpipes from three different buildings on the CSU Bakersfield (CSUB) campus on March 10th and 23rd, 2023 during rain events.

Microplastic Sample Collection and Processing:

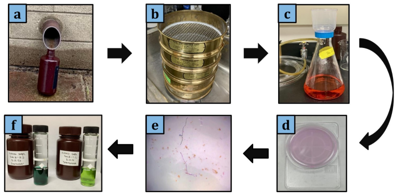
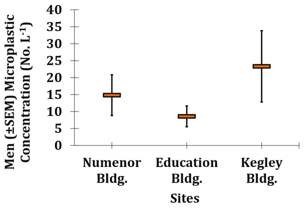


Figure 1. Water samples were (a) collected during rain events and brought to the lab and were (b) fractionated by size class, (c) vacuum filtered onto polycarbonate filters, and (d) stained with Rose Bengal dye, which stains organic particles (e.g., cotton microfibers). Light microscopy was used to identify, count, and characterize microparticles (e). Nutrient analysis was performed using colorimetric methods (f).

Results

Anthropogenic Microparticle Concentration and Characteristics



- Fibers made up 96% of anthropogenic microparticles (AP) found in stormwater runoff.

Figure 2. Mean microplastic concentration (No. L^{-1}) at the three buildings on the CSUB campus (n = 3 samples site^{-1}). Error bars represent the standard error of the mean (SEM).

- Anthropogenic microparticle concentration differed across sites ($F_{2,33}$=25.09, P<0.05), with the Kegley site ~ 2× more AP compared to the Education building (Fig. 2)

Nutrient Concentration

Table 1. Descriptive statistics of nutrient concentrations in mixed stormwater and wet deposition samples (n = 3 replicates per site). s = standard deviation, SEM = standard of the mean, Min. = minimum, Max. = maximum). Lowercase letters indicate significant differences between sites for each nutrient parameter at P < 0.05.

Nutrient	Site	Mean (ppm)	s	SEM	Min.	Max.
Nitrite NO_2^-	Num. ^{a}	0.070	0.075	0.043	0.022	0.156
	Edu. ^{a}	0.028	0.004	0.002	0.023	0.300
	Keg. ^{a}	0.013	0.008	0.005	0.008	0.022
Nitrate NO_3^-	Num. ^{a}	3.267	0.351	0.203	2.90	3.60
	Edu. ^{a}	1.867	0.153	0.088	1.70	2.00
	Keg. ^{a}	1.333	0.777	0.448	0.70	2.20
Ammonia NH_3	Num. ^{a}	2.713	1.547	0.893	1.80	4.50
	Edu. ^{b}	0.587	0.163	0.094	0.41	0.73
	Keg. ^{b}	0.280	0.053	0.031	0.22	0.32
Orthophosphate $-PO_4^{-3}$	Num. ^{a}	0.690	0.092	0.053	0.61	0.79
	Edu. ^{b}	0.853	0.090	0.052	0.75	0.91
	Keg. ^{c}	0.253	0.051	0.030	0.21	0.31

- **Nitrite** concentrations did not differ between sites ($F_{2,6}$=1.38, P > 0.05).
- **Nitrate** and **ammonia** differed between sites ($F_{2,6}$ =11.96, P < 0.05; $F_{2,6}$ = 6.52, P < 0.05), with Numenor nitrate ammonia concentrations ~5.5× and ~9.7× greater than the Kegley site.
- **Orthophosphate** concentrations differed across all sites ($F_{2,6}$ = 6.52, P < 0.05), with the Education building site up to ~ 1.2×and ~ 3.4× more orthophosphate than the Numenor and Kegley sites, respectively.
- Overall, the Num. site had the highest nutrient concentration, except for orthophosphate, and the Keg. site had the lowest nutrient concentrations for every measurement (Table 1).

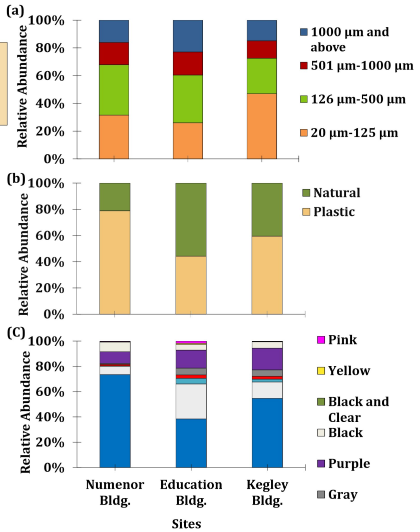


Figure 3. Relative abundance (%) of anthropogenic microparticles across size classes (a), material types (b), and color (c). Purple colored fibers represent clear cellulosic fibers stained with Rose Bengal (*i.e.,* anthropogenic, natural-based microfibers).

- Anthropogenic microparticle sizes were not distinct across sites (Size: $\chi^2_{[2]}$ = 19.33, P > 0.05). Approx. 60 – 70% of all AP were found in the 500 – 20 µm size classes (Fig. 3a).
- Anthropogenic microparticle material and color composition patterns were unique across sites (Material: $\chi^2_{[2]}$ = 32.38, P < 0.0001; Color: $\chi^2_{[2]}$ = 81.27, , P < 0.0001). Plastic microfibers and blue particles dominated the AP composition of the Numenor site, while natural fibers and blue and black microparticles were more abundant at the other sites (Fig. 3b).

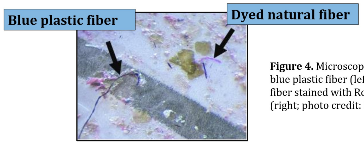


Figure 4. Microscope photo of blue plastic fiber (left) and natural fiber stained with Rose Bengal die (right; photo credit: RE McNeish).

Conclusions

Summary:

- Anthropogenic microparticle concentration differed between sites, refuting P_1 (Fig. 2). There were a variety of particle sizes, colors, and morphologies, with plastic microfibers were the most common morphology of AP across all sites, supporting P_2. Nutrient concentrations differed between sites for all parameters except for nitrite, partially supporting P_1.
- Differences in AP characteristics across sites may be due to some sites sampled during a different rain event. In addition, the Numenor site had tree canopies overarching the building, possibly contributing to nutrient differences compared to other sites.

Implications:
This study found that stormwater and wet deposition serve as pathways for pollutant movement through the environment, emphasizing the important role of stormwater in the mobilization of MP and chemicals. MPs can be transported through atmospheric deposition, cycling from anthropogenic sources to sinks, like aquatic habitats, or organisms in the "microplastic cycle."[5]

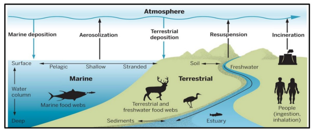


Figure 5. Atmospheric deposition can facilitate the cycling of pollutants like MPs in the microplastic cycle; arrows depict fluxes of pollutants. Photo credit: Rochman and Hoellein 2020.

Research Directions:

- Future studies should incorporate wet deposition data in order to investigate the AP and nutrient contributions of wet deposition versus stormwater runoff.
- More urban landscape features, with differing land uses, should be included in future research, along with more time points to study the temporal variation in AP and nutrient composition.

References

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