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Microplastic Pollution in Stormwater: Preliminary Findings from the Oregon Coast

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by

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Abstract
Microplastics have become ubiquitous in marine environments and pose a risk to ecosystem, organismal, and human health. Stormwater runoff has been suggested to be a major contributor to marine microplastic pollution. This project aims to quantify the average concentration of microplastics in stormwater in a community on the Oregon Coast. To accomplish this, stormwater samples were collected from five sites in Cannon Beach, Oregon, and one sample was analyzed using a dissection microscope. Using this technique, the number, size, and composition of the microplastic particles were determined. The calculated concentration of microplastics in the stormwater sample was 12.21 MPs/L, and the dominant microplastic type was tire wear. Establishing a baseline of microplastic pollution originating from stormwater systems along coastal regions is the first step in developing effective mitigation strategies. The work produced in this study will contribute to the baseline data for an ongoing research project aimed at testing the efficacy of various microplastic mitigation strategies, including stormwater control measures.

Keywords: Microplastics, Stormwater, Urban Runoff, Plastic Pollution, Coastal Regions, Tire Wear Particles

Introduction

Microplastics (MPs hereafter) are defined as pieces of plastic that are less than five millimeters in length (Arthur et al., 2009). The two broad categories of MPs are primary and secondary. Primary MPs are plastic particles that were designed for commercial or industrial use, which includes microbeads from facial exfoliants and pre-production plastic pellets. Secondary MPs are created from the breakdown of larger plastic pieces through weathering or UV exposure (Arthur et al., 2009; Gewert et al., 2015). Variations in MP morphologies include: fibers, fiber bundles, films, foams, fragments, and spheres (Rochman et al., 2019). Global plastic use in 2019 was 460 million tonnes and is projected to triple by the year 2060 (OECD, 2022a). On a global scale, only 9% of plastics are properly recycled, and 22% are mismanaged or left as uncollected litter (OECD, 2022b).

MP pollution is becoming increasingly prevalent in marine ecosystems and is posing a threat to ecosystem health and function. The presence and toxic effect of MPs on organisms in the marine environment have been documented in numerous studies (Baechler, Granek, et al., 2020; Baechler, Stienbarger, et al., 2020; Botterell et al., 2019; Tanaka & Takada, 2016; Vo & Pham, 2021). Some major effects of MPs to marine organisms include inflammation, altered gene expression, digestive system blockages, and reduced growth rate (Gola et al., 2021). More recent studies have investigated the sorption and leaching of toxic chemicals by MPs. Harmful organic pollutants that are sorbed by MPs can be leached and bioaccumulate in the biological tissue of organisms that consume them, adding to the complexity of the relationship between MPs and marine organisms (Koelmans, 2015). Tropic transfer of MPs has been documented and is of concern for marine organism health as well as human health (Baechler, Stienbarger, et al., 2020; Farrell & Nelson, 2013; Setälä et al., 2014).

The marine environment has been identified as a major sink for MPs (Petersen & Hubbart, 2021). Sources of MPs in the marine environment can be traced back to anthropogenic activities related to tourism, wastewater treatment, and urbanization (Gola et al., 2021; Werbowski et al., 2021). In regions near large bodies of water, MPs concentrations have been shown to be correlated with proximity to human populations (Grbić et al., 2020; Pedrotti et al., 2016). This relationship has been exhibited in urbanized areas through the sampling of different environmental compartments including surface water, fish, sediment, stormwater runoff, and treated wastewater (Zhu et al., 2021).

Stormwater runoff is suggested to be a major contributor to marine MP pollution (Piñon-Colin et al., 2020; Stang et al., 2022; Werbowski et al., 2021). In urban environments, major sources of MPs that are transported through stormwater runoff include tire wear particles, road dust, and litter (Monira et al., 2021; Werbowski et al., 2021). These particles accumulate on road surfaces and get flushed into stormwater systems during precipitation events and are transported to open waterbodies (e.g., the ocean in coastal communities) (Monira et al., 2021). Studies conducted in Toronto, Denmark, and San Francisco have quantified MP concentrations and found stormwater runoff to contain higher concentrations of MPs compared to the bodies of water it is deposited into (Grbić et al., 2020; Olesen et al., 2019; Werbowski et al., 2021; Zhu et al., 2021).

Along the Oregon Coast, stormwater runoff and the sediment it carries gets expelled into the ocean, but the significance of this pathway as a source of MP pollution has not yet been quantified. Other studies conducted in Oregon have found MPs in commercial bivalve species, stormwater runoff, and rivers (Baechler, Granek, et al., 2020; Valine et al., 2020; Wolfand et al., 2023). The presence of MPs in nearshore and estuarine locations along the Oregon Coast can be shown through a study which detected MPs in bivalve samples from all 15 sampling sites (Baechler, Granek, et al., 2020). MP pollution in stormwater runoff from Portland, Oregon has been evaluated and was reported at a range of 1.1-9.7 MPs/L (Wolfand et al., 2023). A study sampling four major rivers in Oregon for MPs found particles in all samples, which speaks to the ubiquity of MPs in surface waters (Valine et al., 2020).

This project is aimed at identifying and quantifying MPs in stormwater collected on the Oregon Coast. With a lack of state or federal legislation to address MP pollution, establishing a baseline of microplastic pollution originating from stormwater systems along coastal regions is the first step in developing effective mitigation strategies. Due to the known prevalence of MPs in the environment, it is hypothesized that the concentration of MPs in stormwater will be greater than zero. Due to the proximity of the sample sites to roadways, it is also expected that tire wear particles will be the dominant particle type. The work produced from this study will contribute to ongoing research to test the efficacy of MP reduction strategies.

Methods

Study location

Located at approximately 43.73° N to 45.59° N Latitude, Oregon's 363-mile coastline is known for its impressive kelp forests and diverse intertidal ecosystems. There are five marine reserves along the coast that are managed by the Oregon Department of Fish and Wildlife. Commercial fishing on the Oregon Coast includes albacore, groundfish, squid, salmon, Dungeness crab, Pink shrimp, and Bay clams (ODFW, 2024). The Oregon Coast is characterized by a temperate climate with wet winters and dry summers. Annual precipitation is normally within the range of 65 to 90 inches. Precipitation peaks during the months of November, December, and January (Taylor & Bartlett, 1993).

This study was conducted in Cannon Beach, Oregon, located in the northern region of the Oregon Coast. Stormwater samples were collected on March 11, 2024, which had a reported 1.33 inches of rainfall (Cannon Beach Oregon, 2024). Cannon Beach is a popular tourist destination, having 1.5 million annual visitors despite having a population of only 1,500 residents (*Welcome to Our City! | Cannon Beach Oregon*, n.d.).

Sample collection

Stormwater samples were collected from three outfall pipes and two storm drains in Cannon Beach, Oregon (Figure 1). Stormwater was pumped over a 63µm sieve using an ISCO 6712 autosampler that was propped on two orange five gallon buckets. Between each sample, the sieve was triple rinsed with deionized (DI) water that had been filtered with a 20 µm sieve. Prior to sample collection at each site, the autosampler was primed by pumping stormwater through the tubing for two minutes. When priming, the sampler was positioned to ensure that the water would not reenter the storm drain. After weighing the empty bucket with a hanging scale, the sieve was positioned over an orange five-gallon bucket using a custom metal sieve holder (Figure 1). For each sample, approximately six liters of water was pumped through the sieve into the bucket then the bucket was re-weighed with a hanging scale. At one outfall site, the stormwater sample was collected in a tripled rinsed, 1-liter DI water bottle because the autosampler was unable to be set up at the location. Instead, six liters of water were collected and poured over the sieve by hand. The sample caught within the sieves were triple rinsed with a wash bottle filled with filtered DI water into triple rinsed glass mason jars with aluminum foil covering the opening. Triplicate samples were collected from storm drain 1. Field blank samples were collected by exposing to the air a second sieve and bucket set-up while the water samples were collected to account for atmospheric deposition of MPs. One field blank was used at the site where triplicate samples were collected. Orange MP fibers are not commonly found in the environment, so sample collectors wore orange ponchos to later identify instances of contamination.

Figure 1. Left: Location of the five sample location sites in Cannon Beach, Oregon. Right: Sample collection set-up using an ISCO 6712 autosampler, orange five gallon buckets, sieves, custom sieve holders, and orange ponchos for sample collectors.

Sample processing

Water samples were transported and stored in 16-ounce mason jars. They were refrigerated in the lab until being transferred onto filters to be analyzed. The samples analyzed in this report did not contain much organic matter, so a KOH digestion or density separation was not necessary. Using a flask above a vacuum filtration system, the samples were transferred onto

10µm polycarbonate membrane filters (Figure 2). After pouring the sample into the flask, the mason jar, aluminum foil, and the filtration funnel was triple rinsed with DI water. Once filtration was completed, the filter was placed in a petri dish that was triple rinsed and properly labeled prior to use. The filtration process took place under a laminar flow hood, and a HEPA filter was running while working in the laboratory. Orange jumpsuits made of 100% cotton were worn to identify instances of contamination. An air fall filter in a petri dish was set up under the laminar flow hood and was opened while each sample was filtered.

Figure 2. Water sample filtration system.

Microscope analysis

One water sample and the corresponding field blank were analyzed using a Leica dissection microscope. A snorkel fume hood was positioned over the microscope and an orange jumpsuit was worn while analyzing each sample. At 80x magnification, the sample slide was scanned in a left to right sweeping pattern to cover the entire slide. Potential MP particles were prodded with a metal dental scaler. Malleability and indentations in the particles indicated that they are synthetic, while brittleness and breaking indicated organic material. Suspected tire wear particles resembled rubber when prodded. While deviations from average MP appearance were encountered, MP particles typically exhibited even thickness and consistent coloring throughout (Hidalgo-Ruz et al., 2012; MERI, n.d).

Images of each particle were taken and measured using the Leica LAS program. Images were taken between 25-100x magnification depending on the size of the MP. The type, color, end-to-end length, width, and location of each MP was recorded.

The petri slide for each sample was only open when potential MPs were being prodded, and an air fall slide positioned on the microscope was open at the same time. The amount of time that the air fall was open was recorded. The same air fall was used for both samples but was analyzed after each one was completed. The type and color were recorded for each MP that was on the control slide.

Data analysis

For both the water sample and the field blank, orange fibers were subtracted from the total fiber count due to the assumption that they originated from the sample collectors and are a form of contamination. The same field blank was used to collect three water samples, meaning that it was exposed to the atmosphere three times longer than the water sample. To compensate for this, the total number of particles found in the field blank was divided by three.

Airfall control slides were exposed to the air while the water samples were being filtered and analyzed under the microscope. The number of fibers found in the air fall samples was subtracted from the total fiber count in both the water sample and the field blank.

To calculate the number of particles in the stormwater sample, the number of MPs in the field blank was subtracted from the total number of MPs in the water sample. The concentration of MPs per liter was calculated using the following equation:

MPs in stormwater sample/mass of water sample (kg) = MPs/kg = MPs/L

Preliminary Results

MPs found

In the water sample, field blank, and air fall filters, the following MP types were found: fibers, tire wear, foams, films, and fragments (Figure 3). The total number of particles found on each filter is reported below in Table 1.

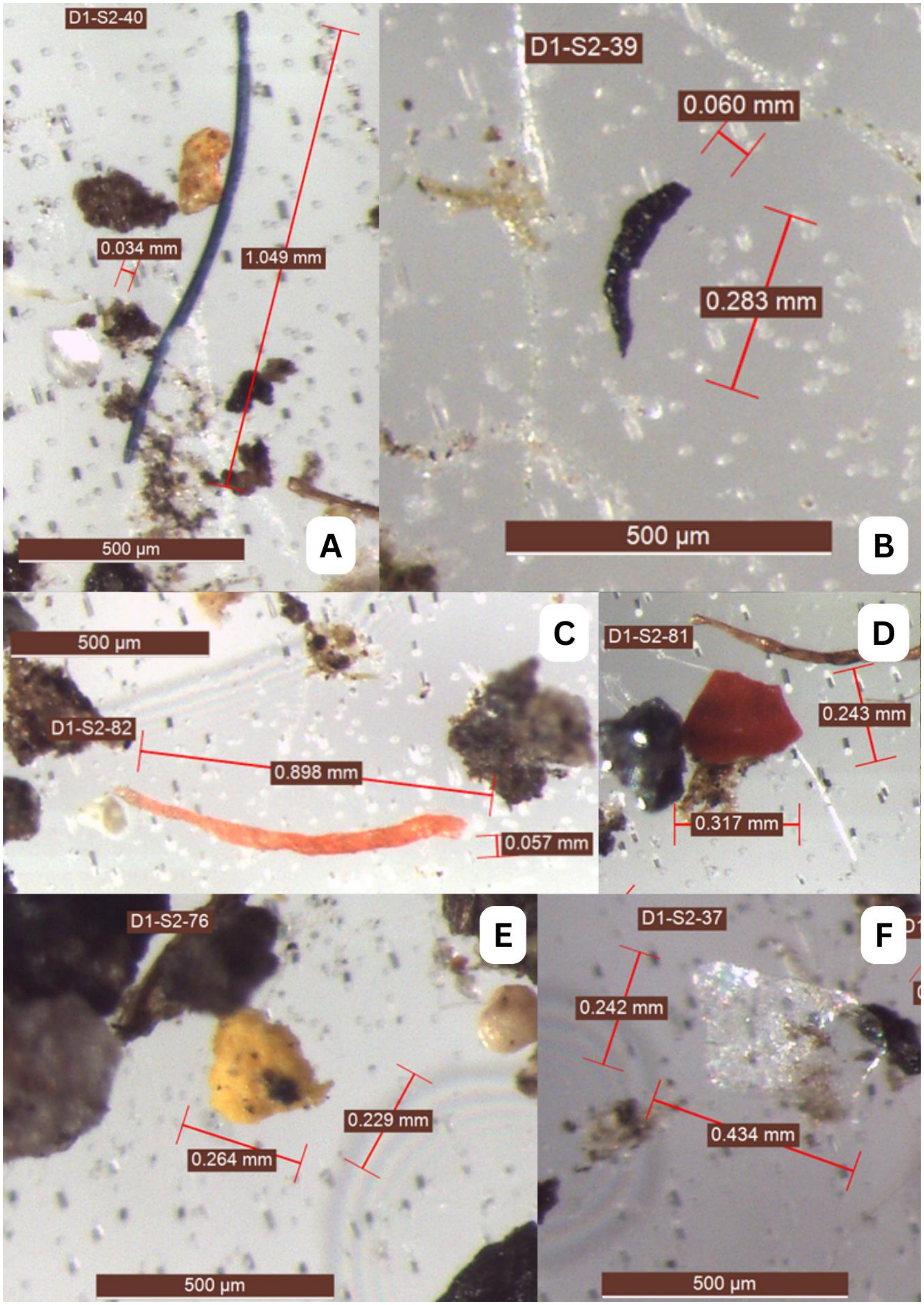

Figure 3. Examples of each MP type that was found in the water sample. (A) Fiber. (B) Tire wear. (C) Orange fiber. (D) Fragment. (E) Foam. (F) Film.

Table 1. Number of MPs in each filter.

Filter	Count
Water Sample	102
Field Blank	27
Air Fall (Processing)	1
Air Fall (Analysis)	7

Abundance by MP type

After adjusting for orange fibers and air fall samples, there were 91 MPs in the water sample and 8 MPs in the field blank (Table 2). Tire wear particles were the most abundant particle type in the water sample, followed by fibers, foams, fragments, and films (Table 2). On average, the fibers in the water sample were longer than the fibers found in the field blank (Table 2).

Table 2. The count and average measurements for each particle type found in the water sample and field blank after adjusting for orange fibers, air falls, and exposure time.

	Water Sample			**Field Blank**		
Particle Type	Count	Average Length (mm)	Average Width (mm)	Count	Average Length (mm)	Average Width (mm)
Fiber	25	1.856 (±1.376)	0.039 (±0.016)	7.333	1.568 (±1.568)	0.032 (±0.009)
Tire Wear	61	0.354 (±0.183)	0.109 (±0.070)	0.333	0.186	0.186
Foam	3	0.602 (±0.542)	0.385 (±0.287)			
Fragment	1	0.317	0.243			
film	1	0.434	0.242			
Total	91			7.667		

Tire wear made up 67% of the total MPs found in the water sample (Figure 4). After adjusting for atmospheric deposition, 72% of the water sample was made up of tire wear particles.

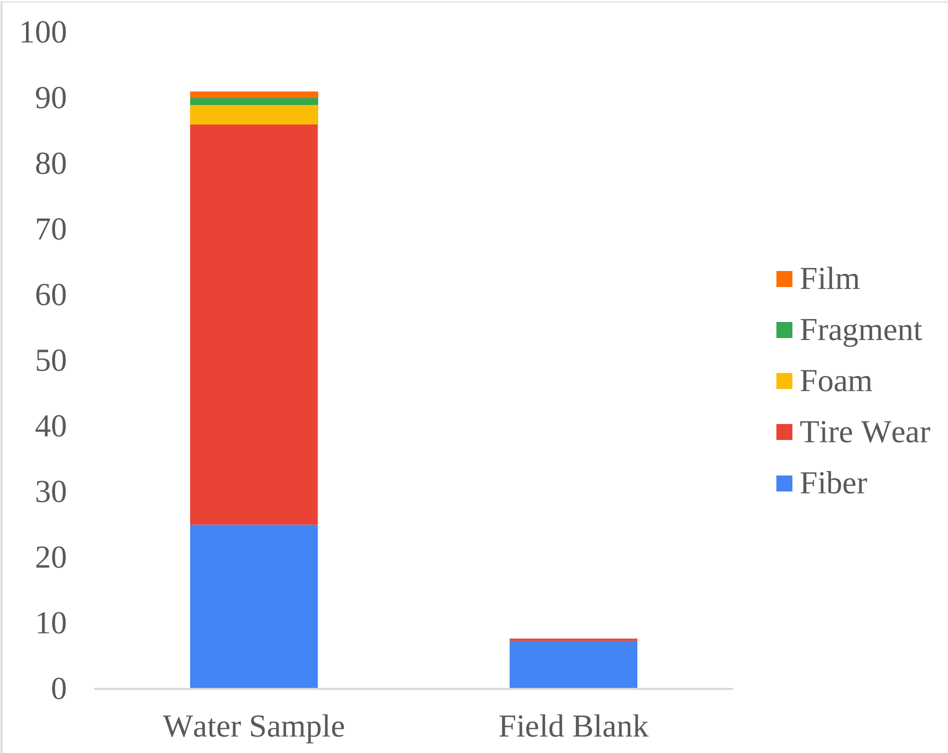

Figure 4. The abundance of MPs by morphology.

Concentration calculation

After adjusting for MP atmospheric deposition, there were 83.33 particles in the water sample. The concentration of MPs in the 6 liter water sample was calculated to be 12.21 MPs/L.

Discussion

In this study, the quantity, type, and concentration of MPs in one stormwater sample collected from Cannon Beach, Oregon was determined using light microscopy. After accounting for atmospheric deposition of MPs in the field and potential contamination in the lab, the concentration of MPs in the water sample was 12.21 MPs/L. Tire wear particles were the dominant particle type found in the water sample, making up 67% (61 total particles) of the identified MPs. The preliminary results from this study suggest that stormwater is a transport vector for MPs in the marine environment on the Oregon Coast. The information produced from this study is integral for determining the success of potential mitigation strategies.

MP types and abundance

Tire wear particles were the most abundant type of MP found in the water sample. Frequent automobile traffic near the collection site may explain the high proportion of tire wear particles that was found in the water sample. The storm drain that the water sample was collected from was located on a primary roadway near downtown Cannon Beach (Figure 5). Other studies examining the types of MPs in stormwater have also found high proportions of suspected tire wear particles (Järlskog et al., 2020; Jönsson, 2016; Werbowski et al., 2021). Werbowski et al. (2021) also found rubbery fragments (likely tire wear particles) and fibers to make up the majority of particles found (~85%) and reported individual samples to contain as much as 64% rubbery fragments.

Figure 5. Location of the storm drain (red circle) on Hemlock St in Cannon Beach, Oregon. (Google Earth, 2024).

On average, the fibers found in the water sample were 0.3mm longer than the fibers found in the field blank despite the widths being similar. Longer particles are heavier and less likely to remain suspended in the atmosphere and are more likely to be caught in the 63µm sieve. The size of the sieve (63µm) may also impact the ratio of MP types that were found. Since MP fibers are smaller than 63µm in width, the data collected is likely an underrepresentation of the actual MP fiber content in stormwater.

MP concentration

The preliminary results of this study align with the hypothesis that the concentration of MPs in stormwater is greater than zero particles per liter. The calculated concentration of 12.21 MPs/L is within the range of 1.1 to 24.6 particles/L reported in stormwater in the San Francisco Bay Area when sampling for MPs (Werbowski et al., 2021). A similar study in Sweden sampled for MPs ≥20 in stormwater from three urban catchments and found a concentration of 5.4-10 MPs/L (Jönsson, 2016).

The water sample in this study was collected on March 11, 2024. As reported by the City of Cannon Beach, there were 12.41 total inches of rain during the month of March and 1.33 inches on the day of sampling (City of Cannon Beach, 2024). The two days prior to water sampling also had a large amount of rainfall (0.94 and 1.26 inches). Järlskog et al. found inconsistencies when calculating MP concentrations due to variation in the quantity of precipitation and length of time without rainfall leading up to sampling (2020). They found that heavy rain over "several rainy days" correlated with lower MP concentrations, likely due to the dilution of the stormwater runoff (Järlskog et al., 2020). March 11th accounted for 11% of the total rainfall in Cannon Beach during the month of March 2024. While not verifiable with the available data, the rainfall leading up to and on the day of sampling may have caused a lower concentration of MPs than would be seen under different environmental conditions.

MP SOS

The data collected in this study will contribute to baseline data for 'MP SOS' (PI: Dr. Elise Granek, PSU), an ongoing research project aimed at testing the efficacy of various microplastic mitigation strategies, including stormwater control measures. The related component of this project utilizes a BACI design to test the efficacy of storm drain and laundry machine filters at reducing microplastic concentrations in stormwater and wastewater in four coastal communities. Control sampling has been completed or is scheduled to occur during storm events in April, October, and December 2024. Stormwater filter inserts will be installed in two of the coastal communities in December 2024. The efficacy of the filters will be determined by collecting water samples up and down stream of the filters during three storm events in 2025. The baseline data is important to establish the current contribution of stormwater to microplastic pollution to the marine environment as well as to account for seasonal variation in MP concentrations. In addition to providing baseline data, the work produced from this study helps to refine the methodology to ensure consistency across the two-year sampling period.

Conclusion

While the scope and the sample size of this study is limited, conclusions can still be drawn about the occurrence and transport of MPs on the Oregon Coast. The calculated stormwater MP concentration and the proportion of tire wear particles is comparable to similar studies. These results show that stormwater is a likely source of MPs on the Oregon Coast and that tire wear particles are the dominant particle type. In Cannon Beach and other communities along the Oregon Coast, stormwater is expelled into the ocean without treatment or filtration to remove MPs. Localized mitigation efforts, such as storm drain filters, will be imperative to reducing MP pollution from urban runoff. By quantifying the current concentration of MPs in stormwater, the efficacy of reduction strategies can be tested and subsequently implemented at a larger scale if shown to be successful.

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