Accumulation des microplastiques dans les bassins de rétention

Microplastic Accumulation in Wet Detention Ponds

Morgan H. Chaudry, Stefanie L. Whitmire, Ph.D., Sarah E. Waickowski, Ph.D.

Clemson University, Baruch Institute of Coastal Ecology and Forest Science
(mchaudr@clemson.edu)

RÉSUMÉ

Le plastique a apporté de nombreux avantages à la société, cependant sa surconsommation et surproduction ont entrainé le rejet de déchets plastiques. Ces déchets plastiques persistent dans l'environnement avant de se dégrader en particules fines appelées microplastiques (<5 mm), ces dernières peuvent alors facilement se propager dans l'environnement dû à leur petite taille, faible densité et durabilité. Les bassins de rétention sont couramment utilisés pour la gestion des eaux de ruissellements afin de réduire l'érosion des sols, de minimiser les inondations et d'empêcher les polluants de pénétrer dans les cours d'eaux. Bien que ces bassins soient souvent utilisés pour améliorer la qualité des eaux, peu d'études ont évalué leur capacité à contenir les microplastiques et à empêcher leur rejet dans les eaux en aval. Notre étude a mesuré la distribution, l'abondance, le type et la taille des microplastiques dans les sédiments de neuf bassins de rétention situés sur la côte de Caroline du Sud, aux États-Unis. L'objectif de cette étude était d'évaluer la distribution spatiale des microplastiques dans les sédiments des bassins afin de comprendre leur capacité à retenir ces polluants et à améliorer la qualité de l'eau en aval. Nous prévoyons, une fois les résultats obtenus, d'émettre des recommandations pour la gestion des eaux pluviales permettant d'améliorer l'élimination des microplastiques. Cette présentation inclut les résultats préliminaires de la répartition spatiale et les types de microplastiques présents dans les sédiments des bassins de rétention du littoral de Caroline du Sud.

ABSTRACT

Plastic has provided many benefits to human society; however, the overreliance and overproduction of plastic have resulted in a large proportion of plastic waste entering the natural environment. Plastics persist in the environment before degrading into smaller pieces called microplastics (< 5 mm), pollutants that can easily spread through aquatic ecosystems due to their small size, low density, and durability. Wet detention ponds are commonly used stormwater best management practices (BMPs) in coastal regions to intercept runoff during flashy rain events to reduce soil erosion, minimize flooding, and prevent pollutants from entering local waterways. Although detention ponds are often used to help manage water quality, little work has been done to evaluate their potential to retain microplastics from being released to downstream waters. In this study, we measured the distribution, abundances, types, and sizes of microplastics in the sediments of nine wet detention ponds from across coastal South Carolina, USA. The goal of this study was to evaluate how microplastics are spatially distributed in pond sediments to understand their capacity to retain these pollutants and improve downstream water quality. With this information, we plan to develop management recommendations for stormwater practices to improve microplastic removal. In this presentation, preliminary findings of the spatial distributions and types of microplastics in coastal South Carolina wet detention pond sediments will be shared.

KEYWORDS

Microplastic, Plastic, Pollution, Ponds, Stormwater, Microplastiques, Plastique, Pollution, Étangs, Eaux Pluviales

1 INTRODUCTION

The overproduction of plastic over the last few decades has resulted in a large proportion of plastic waste entering the natural environment and threatening water quality across the globe. Recent estimates suggest that more than 20 million metric tons of plastic waste end up in the environment every year (OECD 2022), of which approximately 80% of plastic debris in the marine environment is derived from land base sources, particularly from densely populated or largely industrialized regions (Li et al. 2016). Plastic waste endures in the environment before it degrades through weathering forces, such as ultraviolet radiation, wind, and wave action, into smaller pieces called microplastics (< 5 mm).

Microplastics are a threat to biota and the environment. The physical characteristics of microplastics, such as their small size, hydrophobicity, low density, and durability, allow them to remain in the environment, increasing their long-term effects on wildlife and the environment alike. Microplastics can threaten wildlife through entanglement, ingestion, and dermal exposure, and have been reported to cause a variety of health problems in wildlife, including harm to their reproductive, neurological, immune, and endocrine systems (Mao et al. 2022). Additionally, phthalate and non-phthalate plasticizers can be leached from microplastics, increasing their toxicity (Li et al. 2024). Many other environmental pollutants have been found to adsorb to microplastics, including per- and polyfluoroalkyl substances (Yu et al. 2024), polychlorinated biphenyls (PCBs), heavy metals (Brennecke et al. 2016), drugs, and herbicides (Amelia et al. 2021), increasing the microplastic's toxicity. Additionally, unique bacterial assemblages can colonize microplastics and be transported around or between ecosystems (McCormick et al. 2014), allowing microplastics to be vehicles for disease-causing bacteria through watersheds.

Microplastics come from a variety of marine and land-based sources, especially urban land use (Li et al. 2016). Stormwater runoff has been found to be an important transport mechanism of microplastics to aquatic ecosystems (Werbowski et al. 2021), transporting non-point sources of microplastics like urban litter or road dust into adjacent waterways during rainfall (Ledieu et al. 2022). Highly developed areas, where impervious surfaces that prevent runoff from permeating into the soil (such as roads or sidewalks) are more prevalent, are especially likely to be a pathway for microplastics into local waters. Managing stormwater flow and movement through stormwater practices, such as engineered infrastructure like bioretention cells and wet detention ponds, can help prevent microplastics from being transported to downstream waters (García-Haba et al. 2023).

Wet detention ponds are a popular type of stormwater practice used in coastal regions to adhere to stormwater control regulations enacted in 1992 (Drescher et al. 2007). These ponds reduce the effects of flashy rain events, such as soil erosion and flooding, and prevent pollutants from entering downstream waterways by taking them up via algal uptake, adsorption, vegetation uptake, or sedimentation (Vulava et al. 2019). Although wet detention ponds are often used to help manage water quality, little work has been done to evaluate their abilities to retain microplastics from entering downstream waters. Microplastics enter ponds through direct discharge or via stormwater runoff running over the terrestrial environment into the pond and occupy either the water column or fall into the pond's sediments, although their behavior and fate is largely defined by their density, size, and shape (Chubarenko et al. 2016). Efforts have been made to evaluate the types and sizes of microplastics entering and falling out into stormwater ponds (Ahmadi et al. 2022, Brooks et al. 2023, Ashiq et al. 2023, Mbachu et al. 2023), but it is difficult to identify trends of which microplastics are more likely to settle out. Understanding where and what types of microplastics are likely to settle out in these systems could be used to improve BMP design plans for microplastic mitigation.

With so few studies having been done to measure microplastics in stormwater practices, little is known about the transport and fate of microplastics in these systems. The settling process of microplastics into the sediments of these systems must be evaluated to understand the fate of microplastics in these stormwater practices. As such, more research on the types and abundance of microplastics in stormwater pond sediments is needed. We aimed to address this research gap. Specifically, the goals of this study were to measure the abundance of microplastics in stormwater pond sediments to identify the spatial distribution, and identify the most common polymer types and particle shapes that accumulated within the pond sediments. The information from this study will add to the limited knowledge on microplastic accumulation in stormwater pondsand be used to develop stormwater management decisions targeted at pollutant removal.

2 METHODS

To gain a representative set of sediment samples from coastal wet detention ponds, three ponds were surveyed from each of the following coastal South Carolina counties: Horry, Georgetown, Charleston, and Beaufort. Pond size was kept within 5% of the median stormwater pond, which is 0.47 acres (Smith et al. 2019). The most recent available aerial imagery in addition to surveys of the pond's surface area were used to delineate the wet detention ponds footprints and to create the grids in Autodesk Civil3D.

Sediment sampling occured during dry weather, with an antecedent dry period of at least two days (Liu et al. 2019). From each pond, 18 sediment samples were collected in a stratified random sampling approach, with sampling points randomly selected within a representative grid of the inlet, middle, and outlet based on the pond surface area to better understand the spatial resolution of microplastic accumulation (Figure 1).

Figure 1. Ponds with an example grid point design to randomly select sampling locations. The blue section represents the inlet, green represents the middle, and red represents the outlet. Maps created in QGIS.

At each point location along the grid, the top layer of sediment was collected using an Eckman dredge and deposited into a metal tin. A metal measuring cup was used to transfer 300 mL of wet sediment subsamples from the tin to clean glass ball jars to prepare for microplastic analysis. Additional subsamples were collected to measure sediment particle size, which allowed for a comparison of particle size and microplastic accumulation.

The collected sediment samples were prepared using the methods described by Mausra et al. (2015) and Hurley et al. (2018). The wet sediment samples were homogenized using a glass rod and then dried in a 60 degree C drying oven. The dry samples were then broken up using a mortar and pestle and sieved with a 2 mm metal sieve to remove any particles larger than 2 mm. A subsample of 50 g dry weight will be aliquoted out for further analysis.

Each subsample was digested using 7% hydrogen peroxide at 60°C to remove any organic material every 24 hours until the solution was clear. Following digestion, a density separation using magnesium chloride ($MgCl_2$; 2.32 g/cm^3) (Liu et al. 2023) was performed to allow any plastics to float to the surface of the solution. After the addition of the salt solution, the samples will be shaken for 1 hour to thoroughly homogenize the solutions. The samples then sat for 24 hours to allow the plastics and sediment to separate. The solution supernatant was sieved over stainless-steel mesh and washed into 20 mL of absolute ethanol for polymer type and size analysis using the Agilent 8700 Laser Direct Infrared (LDIR) Chemical Imaging System (Agilent Technologies Inc., 8700 LDIR, California, USA).

All statistical analyses were conducted using R statistical software. To identify significant differences between microplastic abundance across and within the sampled ponds using factors like sediment grain size, polymer type, microplastic shape, and distance from the pond inlet, a one-way analysis of variance (ANOVA; when parametric) or a Kruskal-Wallis (when non-parametric) test. A geospatial analysis of microplastic abundance throughout the pond was conducted to identify trends in microplastic accumulation.

LIST OF REFERENCES *(only for scientific papers)*

Ahmadi, P., H. Elagami, F. Dichgans, C. Schmidt, B. S. Gilfedder, S. Frei, S. Peiffer, and J. H. Fleckenstein. 2022. Systematic Evaluation of Physical Parameters Affecting the Terminal Settling Velocity of Microplastic Particles in Lakes Using CFD. Frontiers in Environmental Science 10.

Amelia, T. S. M., K. W. M. A. W. Mohd, M. C. Ong, S. Y. Ta, P. Hui-Juan, and B. Kesaven. 2021. Marine microplastics as vectors of major ocean pollutants and its hazards to the marine ecosystem and humans. Progress in Earth and Planetary Science 8.

Ashiq, M. M., F. Jazaei, K. Bell, A. S. A. Ali, A. Bakhshaee, and P. Babakhani. 2023. Abundance, spatial distribution, and physical characteristics of microplastics in stormwater detention ponds. Frontiers of Environmental Science & Engineering 17:124.

Brennecke, D., B. Duarte, F. Paiva, I. Caçador, and J. Canning-Clode. 2016. Microplastics as vector for heavy metal contamination from the marine environment. Estuarine, Coastal and Shelf Science 178:189–195.

Brooks, J. M., C. J. Stewart, C. J. Haberstroh, and M. E. Arias. 2023. Characteristics and fate of plastic pollution in urban stormwater ponds. Environmental Pollution 320:121052.

Chubarenko, I., A. Bagaev, M. Zobkov, and E. Esiukova. 2016. On some physical and dynamical properties of microplastic particles in marine environment. Marine Pollution Bulletin 108:105–112.

Drescher, S., M. Messersmith, B. Davis, and D. Sanger. 2007. State of Knowledge Report: Stormwater Ponds in the Coastal Zone.

García-Haba, E., C. Hernández-Crespo, M. Martín, and I. Andrés-Doménech. 2023. The role of different sustainable urban drainage systems in removing microplastics from urban runoff: A review. Journal of Cleaner Production 411:137197.

Hurley, R. R., A. L. Lusher, M. Olsen, and L. Nizzetto. 2018. Validation of a Method for Extracting Microplastics from Complex, Organic-Rich, Environmental Matrices. Environmental Science & Technology 52:7409–7417.

Ledieu, L., R. Tramoy, S. Ricordel, D. Astrie, B. Tassin, and J. Gasperi. 2022. Amount, composition and sources of macrolitter from a highly frequented roadway. Environmental Pollution 303:119145.

Li, W. C., H. F. Tse, and L. Fok. 2016. Plastic waste in the marine environment: A review of sources, occurrence and effects. Science of The Total Environment 566–567:333–349.

Li, Y., C. Liu, H. Yang, W. He, B. Li, X. Zhu, S. Liu, S. Jia, R. Li, and K. H. D. Tang. 2024. Leaching of chemicals from microplastics: A review of chemical types, leaching mechanisms and influencing factors. Science of The Total Environment 906:167666.

Liu, F., A. Vianello, and J. Vollertsen. 2019. Retention of microplastics in sediments of urban and highway stormwater retention ponds. Environmental Pollution 255:113335.

Liu, Y., Y. Lin, J. Xie, P. Li, Y. Zhou, P. Wang, and Y. Wu. 2023. A Method to Replace NaCl as a Flotation Solution for Extracting MPs in Soil: A Case Study of the Jiaxing Agricultural Soil from China. Bulletin of Environmental Contamination and Toxicology 110:96.

Mao, X., Y. Xu, Z. Cheng, Y. Yang, Z. Guan, L. Jiang, and K. Tang. 2022. The impact of microplastic pollution on ecological environment: a review. Frontiers in Bioscience-Landmark 27:46.

Mausra, J., J. Baker, G. Foster, and C. Arthur. 2015. Laboratory Methods for the Analysis of Microplastics in the Marine Environment:39.

Mbachu, O., Kaparaju ,Prasad, and C. and Pratt. 2023. Plastic pollution risks in bioretention systems: a case study. Environmental Technology 44:2525–2538.

McCormick, A., T. J. Hoellein, S. A. Mason, J. Schluep, and J. J. Kelly. 2014. Microplastic is an Abundant and Distinct Microbial Habitat in an Urban River. Environmental Science & Technology 48:11863–11871.

OECD. 2022. Global Plastics Outlook: Economic Drivers, Environmental Impacts and Policy Options. OECD.

Smith, E. M., D. M. Sanger, A. Tweel, and E. Koch. 2019. Chapter 1 – A Pond Inventory for the Eight Coastal Counties of South Carolina. Pages 1–14 Stormwater ponds in coastal South Carolina: 2019 state of the knowledge full report. S.C. Sea Grant Consortium.

Vulava, V., B. Beckingham, and T. J. Callahan. 2019. Chapter 2 – Environmental Factors and Design Features that Control Stormwater Transport and Contaminant Fate in Ponds. Page S.C. Sea Grant Consortium.

Werbowski, L. M., A. N. Gilbreath, K. Munno, X. Zhu, J. Grbic, T. Wu, R. Sutton, M. D. Sedlak, A. D. Deshpande, and C. M. Rochman. 2021. Urban Stormwater Runoff: A Major Pathway for Anthropogenic Particles, Black Rubbery Fragments, and Other Types of Microplastics to Urban Receiving Waters. ACS ES&T Water 1:1420–1428.

Yu, F., J. Wu, H. Wang, Y. Bao, H. Xing, W. Ye, X. Li, and M. Huang. 2024. Interaction of microplastics with perfluoroalkyl and polyfluoroalkyl substances in water: A review of the fate, mechanisms and toxicity. Science of The Total Environment 948:175000.