Tidal marshes trap microplastics, raising risks for ecosystems and people

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The John Heinz National Wildlife Refuge is a freshwater tidal marsh in Philadelphia. Credit: Lisa Emili

Freshwater tidal marshes, critical for wildlife and coastal protection, are now serving as microplastic catch basins, according to a team of researchers at Penn State. They recently found that these marshes trap large amounts of diverse plastics, with concentrations and ecological risks increasing downstream.

The study, available online now ahead of publication in the December issue of the journal *Marine Pollution Bulletin*, found that the most hazardous polymers—such as the large molecules found in single-use plastics—are posing significant environmental dangers.

"Estuaries and the tidal marshes at their fringes are highly productive and diverse habitats because they are areas where fresh and saltwater mix," said Nathaniel Warner, associate professor of environmental engineering and corresponding author. "The accumulation of plastic and the estimated toxicity associated with it could reduce the overall productivity of estuaries and threaten the health of fisheries and their economic viability."

In this study, the researchers analyzed sediment from the John Heinz National Wildlife Refuge outside of Philadelphia, the largest remaining freshwater tidal marsh in Pennsylvania. They identified 4,590 microplastic particles and 29 polymer types, with polypropylene, polyurethane and tire rubber being most common.

Jutamas Bussarakum, lead author and doctoral student in the Department of Civil and Environmental Engineering, said that this contamination can also introduce microplastics into the food chain, where they can accumulate in humans and may affect the immune system, metabolism and even brain function.

"It is also important to note that tidal marshes, estuaries and other coastal areas are often located near large urban populations," said Lisa Emili,

associate professor of physical geography and of environmental studies at Penn State Altoona and member of the research team. "This means human exposure comes from two directions: urban sources that release microplastics into these environments and the added risk of living near marshes where plastics accumulate."

To determine which types of microplastics pose the greatest ecological risks, the team focused on the most common plastics, evaluating both their relative toxicity with the polymer hazard index, which incorporates chemical composition, the hazard score, and their abundance in their samples to develop a risk score.

"We considered the potential for plastics to cause carcinogenic, mutagenic or toxic effects on systems, including reproductive, immune and endocrine," Bussarakum said. "Plastics made from raw materials that contain carcinogens were classified as high risk, posing significant threats to both the environment and human health."

The team discovered that polypropylene was the most common plastic in the tidal marsh. Polypropylene is widely used in single-use products such as food containers, straws and cups. The findings strongly suggest that single-use plastics are a major source of microplastic pollution in this area, the researchers said.

"Because so much of what we found was linked to single-use plastics, our research could inform laws, policies and educational programs that aim to decrease the production and use of these items as well as expand the recycling efforts of these products," Emili said. "Our findings on toxicity also provide a simple, quantitative way to describe ecological risk, from minor to extreme danger, which can be used to educate the public about risks to both ecosystems and human health."

For example, researchers can calculate a single score based on how much

plastic is present, what type it is and how toxic that polymer is. A score below 150 indicates only minor risk, while one above 1,200 signals extreme danger. This allows complex data to be communicated as an easy-to-understand risk scale.

Raymond Najjar, professor of oceanography and member of the research team, said that even though the team's sampling focused on one freshwater tidal marsh in Philadelphia, what they found reflected data from around the world when comparing to other studies, underscoring their work's global relevance.

"Efforts are underway to establish a global plastics treaty that addresses plastics from production through disposal," he said. "Studies like ours provide essential data to support science-based policy."

Najjar said this work also helps address the "missing plastics paradox," which refers to the fact that there appears to be less plastic in the ocean than expected based on river inputs.

"One explanation is that estuaries act as traps for plastics," Najjar said. "Our results support this idea by showing significant plastic accumulation in tidal marshes. By comparing data worldwide, we found that estuaries and marshes play a measurable role in storing plastics long term."

Bussarakum said that while plastics improve many aspects of life, their widespread use and mismanagement cause them to leak into the environment.

"Future research should focus on identifying specific products that contribute most to microplastic pollution," she said. "By tracing not only the polymer type but also the product source, we can either redesign materials, reduce their use or replace problem products entirely."

Another priority is developing strategies to remediate existing plastics in the environment, said Bussarakum.

"Even if we reduce plastic use, plastics already present will continue breaking down into micro- and nanoparticles, which may enter food chains and eventually our bodies," she said.

Najjar said there is a need to refine the global plastics budget.

"While we have strong data on how much plastic is produced, we still don't know enough about how much enters the environment, how it moves and where it ultimately ends up," Najjar said. "Answering these questions will be critical for protecting both ecosystems and human health."

As a part of their project, the research team used laser direct infrared spectroscopy (LDIR) at Penn State's Environmental Contamination Analytical Laboratory, a rapid imaging tool that identifies the size and chemical makeup of plastic particles.

"At Penn State, we were fortunate to have access to several techniques for identifying microplastics," Emili said. "Our work contributes to the growing body of research using LDIR for microplastic identification."

More information: Jutamas Bussarakum et al, Microplastic polymer accumulation, distribution, and toxicity in sediment of a freshwater tidal marsh, USA, *Marine Pollution Bulletin* (2025). DOI: 10.1016/j.marpolbul.2025.118566

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