THE EARTH AND ITS RESOURCES
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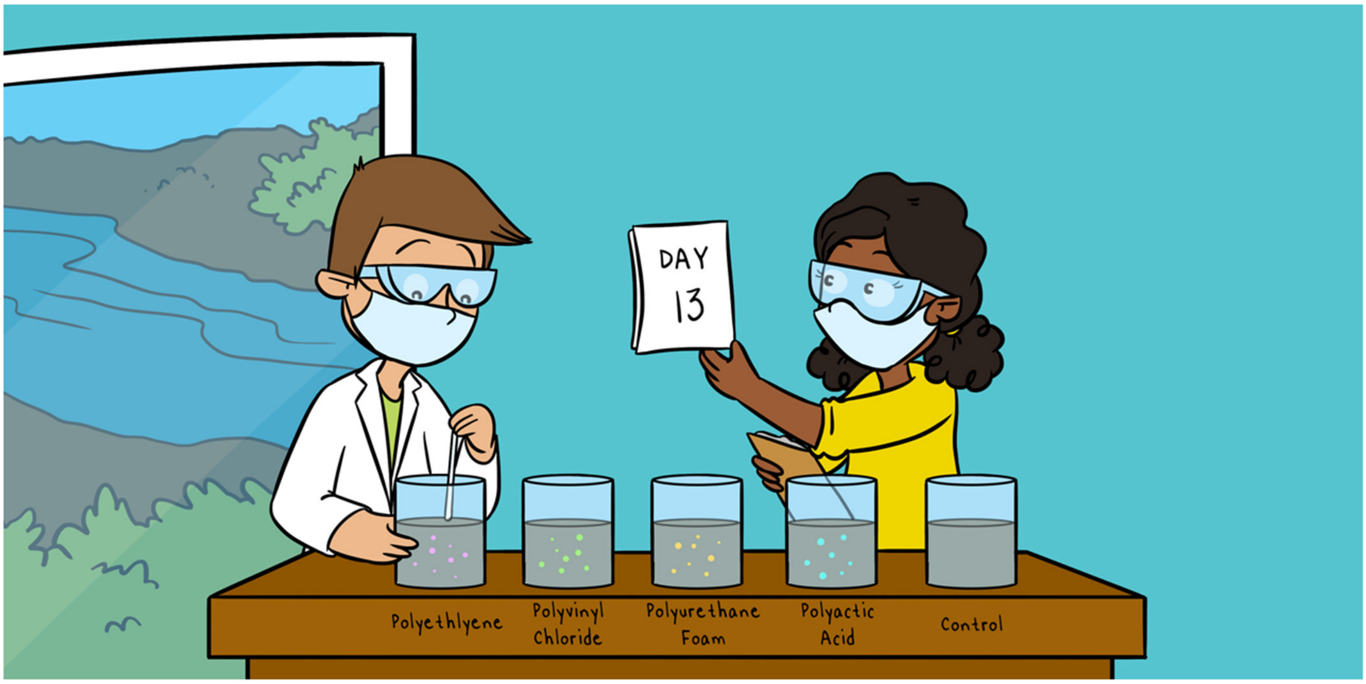

CAN MICROPLASTIC POLLUTION CHANGE IMPORTANT AQUATIC BACTERIAL COMMUNITIES?

Meredith Evans Seeley*, Bongkeun Song and Robert C. Hale

Virginia Institute of Marine Science, William & Mary, Gloucester Point, VA, United States

YOUNG REVIEWERS:

LAUREL
AGE: 9

SAMEEN
AGE: 15

ZAINAB
AGE: 12

Scientists have discovered that microplastics are polluting many environments worldwide, including our oceans and coastlines. Some of these plastics will make their way into a particularly important environment—coastal sediments, or the layer of mud below the water. This sediment is home to diverse bacterial life, which plays a key role in nutrient cycles of the ecosystem. These bacteria are critical for healthy environments, but are also easily affected by environmental pollution. Unfortunately, little is known about how the bacteria respond to microplastic pollution. We studied the effects of different microplastics on bacteria living in marine sediments, as well as the subsequent impacts on nutrient cycling. We found, for the first time, that different microplastics can significantly alter these bacterial communities and the nitrogen cycle, which should be studied further to understand lasting impacts on our natural environments.

MICROPLASTIC POLLUTION

You may have heard of **microplastics**, but you may not know what they are or why everyone seems to be talking about them. Microplastics are simple—they are small bits of plastic, generally 5 mm wide (about the size of a pencil eraser) or smaller. Plastics can be manufactured to be microplastic size, such as small beads that are added to skin care products or toothpaste. Most often, however, microplastics come from the breakdown of larger pieces of plastic. This is especially true in the ocean environment, where a lot of plastic trash accumulates over time and is exposed to wind, waves, and sunlight, eventually creating microplastics [1]!

MICROPLASTIC

A plastic particle that is <5 mm in the longest direction, often formed by the breakdown of larger pieces of plastic in the environment.

While this sounds simple, microplastics in the environment are extremely complex. This is because there are many different kinds of plastics. The building blocks or "backbone" of any plastic are called **polymers**. Common plastics are most often named after their polymer, for example, polyethylene or polyvinyl chloride. In addition, other chemicals are often added to help a plastic product serve its purpose. These so-called additives vary, but can include color dyes, for example. As such, no two microplastics are identical to each other [2].

POLYMER

Large chemicals that form the building blocks of plastics, often called the plastic "backbone."

In recent years, scientists have discovered that microplastic pollution is widespread, and is growing due to population rise and increasing plastic usage. Microplastics have been found in oceans, lakes, rivers, and soils, on remote mountain tops, inside glacier ice, and suspended in the air [1]! In aquatic environments, microplastics accumulate in **sediment**—the layers of mud and dirt that settle to the bottom, below the water. Many different animals live in the sediment and may interact with the microplastic pollution. Scientists have been working to understand the effects that diverse microplastics might have on living things [1].

SEDIMENT

The layers of mud and sand that settle below the water.

THE SEDIMENT BACTERIAL COMMUNITY

If you explore sediments in streams, lakes, and rivers, you will discover many living organisms—worms, clams, and crabs, to name a few. But if you explore sediment with a microscope, you will see that there is also a rich community of microbes (i.e., organisms that cannot be seen with the naked eye)! Bacteria are a type of microbe that are very abundant in sediments. Thousands of species of bacteria co-exist, forming a **bacterial community**. Scientists describe bacterial sediment communities by the kinds of species and how many of each species are present. These bacterial communities perform very important jobs for the entire ecosystem.

BACTERIAL COMMUNITY

A group of different species of bacteria that live in the same environment.

One of the roles of sediment bacterial communities is transforming nutrients. Nutrients are needed by plants and animals (including humans) to build essential biomolecules, including proteins and DNA.

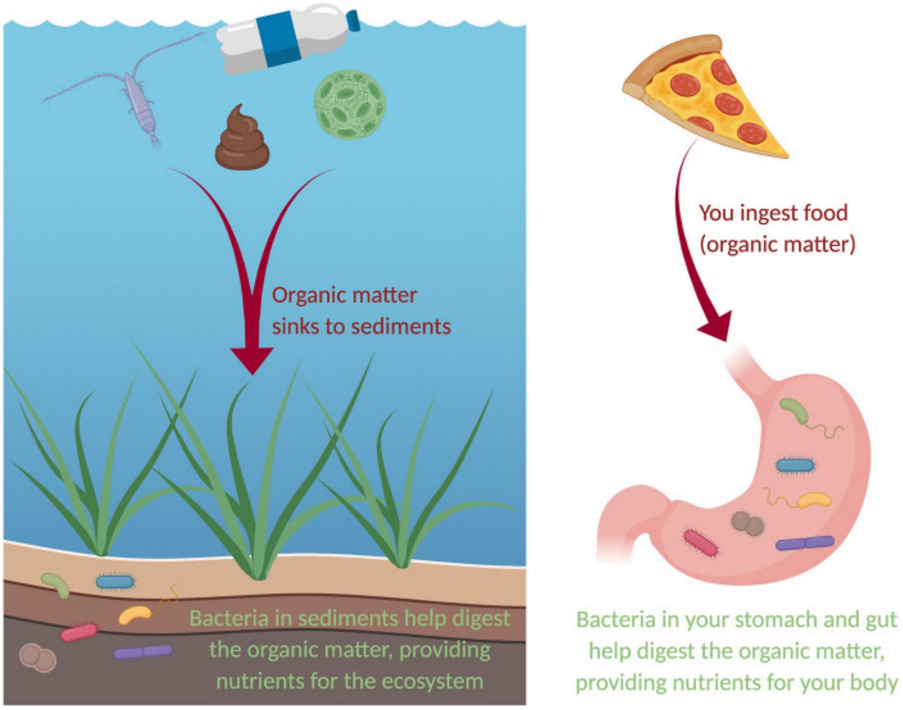

Figure 1

Figure 1

The bacteria in sediments and those in your gut serve similar roles—helping to process nutrients! The left side of the figure illustrates how this works in the aquatic environment, where organic matter (generally dead organisms and wastes, but more recently, plastic) is processed by bacteria in the sediments. The right side compares this to your gut, where bacteria help process the organic matter (i.e., food) that you eat every day! (Created with BioRender.com).

You get nutrients from food, with the help of bacteria inside your gut. When you eat food, bacteria in your digestive tract help process the food to release the nutrients that your body needs. Sediment bacteria do the same thing for organisms in the water. When organic material, such as dead organisms or feces, sink to the sediments, most nutrients are still trapped inside and not available for other living organisms to use. The bacteria in sediments break down organic material, releasing nutrients for themselves and for other organisms (Figure 1). At the same time, they also make sure there is not too much of any one nutrient, which may cause harm. Thus, the bacterial community affects the types and health of higher organisms that can live in that environment.

THE SEDIMENT NITROGEN CYCLE

An important nutrient that sediment bacteria help regulate is **nitrogen** [3]. The nitrogen cycle is complex, so we will only focus on a few of its features. In sediments and water, many different chemicals contain nitrogen, including ammonium (NH_4^+) and nitrate (NO_3^-). Different bacteria can transform these compounds from one form to another. Two very important transformations in sediments are **nitrification** and **denitrification**. Both processes can work in combination to convert ammonium to nitrate via nitrification, and nitrate to dinitrogen gas (N_2) via denitrification (Figure 2A).

NITROGEN

An essential element that is used to build many of the compounds that living things need to survive.

NITRIFICATION

A process that converts one form of nitrogen, ammonium (NH_4^+), to another form, nitrate (NO_3^-), which is made possible by microbes.

DENITRIFICATION

A process that converts one form of nitrogen, nitrate (NO_3^-), to another form, nitrogen gas (N_2), which is made possible by microbes.

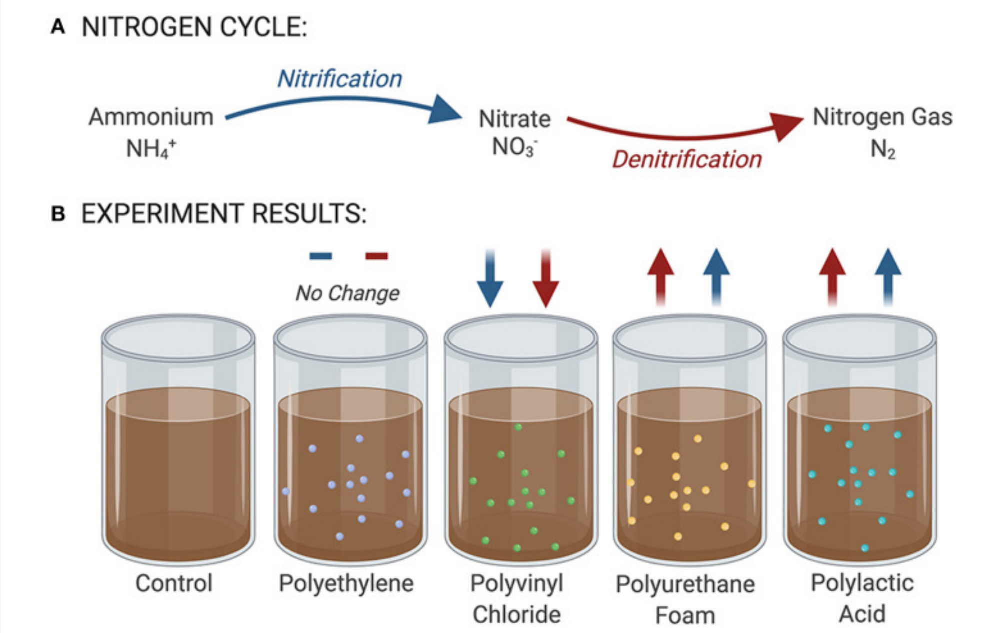

Figure 2

Figure 2

(A) Key components of the nitrogen cycle in aquatic sediments. **(B)** The changes to nitrification (blue) and denitrification (red) that we saw in our experiment are shown above the microcosms containing each type of plastic added to sediments. Both polylactic acid and polyurethane foam microplastics increased nitrification and denitrification; polyvinyl chloride decreased both processes; polyethylene did not significantly change either process compared to the control with no added microplastics (Created with BioRender.com).

Having the right bacteria in the right amounts ensures that the correct level of ammonium and nitrate are present in an ecosystem. If the balance is wrong, the ecosystem can be changed or harmed. Specifically, there should be sufficient bacteria that complete nitrification and denitrification to remove excess ammonium (which can harm the environment), but not too much to completely remove ammonium (which, in the right amount, is an important nutrient for other organisms). All bacterial species that are important for different steps of nitrogen cycling have a different genetic code. Scientists can read this code to see which bacterial species are present and what roles in the nutrient cycle they perform. We decided to use this tool to ask two important questions.

OUR EXPERIMENT

Our two questions were: Do different microplastics in sediments change the bacterial community composition? And if so, does this also affect nitrogen-transforming activities? To answer these, we set up an experiment! We collected sediment from a local marsh, distributed it into containers, and added water to create smaller replicas of the natural ecosystem, called **microcosms**. We added four different types of microplastics to the sediments in the different containers: polyethylene, polyvinyl chloride, polyurethane foam, and polylactic acid. These microplastics were made by grinding larger pieces of plastic in a specialized grinder. These microplastics are used for different purposes, so they contain different polymers and additives that could affect the bacterial community differently. We also made one container with no added microplastics, to represent a normal

MICROCOSM

A small replica of a natural environment, used by scientists to answer research questions about how different things may change that environment.

situation. This is called a control. The containers were monitored over 16 days.

We analyzed the bacterial communities in the sediments before, during, and after the experiment by reading the genetic codes of the bacteria present in each microcosm. First, we used this information to characterize the bacterial community—what species are present and how abundant are they? Then, we specifically looked for the parts of the genetic code responsible for nitrification and denitrification. We compared our findings between the different microcosms, to see if the microplastics changed the bacterial community or nitrogen cycling.

We discovered that the communities containing added microplastics were indeed different from the control, and the polymer types resulted in different changes! We also found that the microplastics affected nitrogen cycling activities; i.e., they altered the abundance of species capable of performing nitrification and denitrification. We found that polyvinyl chloride-treated sediments had the biggest change in the bacterial community at the end of the experiment. In sediments with polyvinyl chloride microplastics, nitrification and denitrification were significantly reduced. In the microcosms with polylactic acid and polyurethane foam microplastics, however, nitrification and denitrification were elevated. The microcosms with polyethylene microplastics were similar to our control, suggesting this plastic did not affect the sediment bacterial community as much as the other plastics (Figure 2B). This experiment told us that microplastic pollution in the environment may affect key bacterial communities and the nitrogen cycle.

WHY DOES THIS MATTER?

Scientists have long known that sediments play an important role in nutrient cycles, driven by the bacteria. Nutrient cycles are critical to organisms living in the sediments, but also those in the overlying water and beyond. Scientists have recently learned that large amounts of microplastics are polluting aquatic sediments globally, and our research is the first report that microplastics can affect the sediment bacterial community, and therefore affect their nitrogen-cycling activities. The balance of the nitrogen cycle in sediments keeps the nutrients at the right levels for the health of the animals present, including worms, fish, phytoplankton, and aquatic grasses! With this knowledge, we can follow up with important research questions: Which types of plastic cause the most harmful effects? Is that harm caused by the polymer or the additives? And how much plastic must be in those sediments to affect the bacterial community? When we have this knowledge, scientists can work with policy makers to help protect coastal zones from the harmful effects of microplastic pollution.

Most microplastics are formed when bigger pieces of plastic break down in the environment. So, if we want to stop microplastic pollution, we must stop plastic pollution! Plastic pollution does not only happen when we litter, though. Humans produce a lot of plastic trash and, sometimes, it escapes into the environment before it reaches the landfill. This can happen because of an overflowing trash can, a trash bag being lost off a truck, or trash that is swept away in a storm and reaches a local river, lake, or ocean. If we reduce our plastic waste, there will be less that can leak into the environment. You may think of some ways that you can reduce the plastic trash you generate every day, or places where plastic debris leaking into the environment could be captured. Both are critical steps toward reducing microplastic pollution!

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REFERENCES

1. Hale, R. C., Seeley, M. E., La Guardia, M. J., Mai, L., and Zeng, E. Y. 2020. A global perspective on microplastics. *J. Geophys. Res. Ocean* 125:e2018JC014719. doi: 10.1029/2018JC014719
2. Rochman, C. M., Brookson, C., Bikker, J., Djuric, N., Earn, A., Bucci, K., et al. 2019. Rethinking microplastics as a diverse contaminant suite. *Environ. Toxicol. Chem.* 38:703–11. doi: 10.1002/etc.4371
3. Ward, B. B., and Jensen, M. M. 2014. The microbial nitrogen cycle. *Front. Microbiol.* 5:553. doi: 10.3389/fmicb.2014.00553

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CONFLICT OF INTEREST: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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YOUNG REVIEWERS

LAUREL, AGE: 9
I love reading Harry Potter books. My favorite characters are Ginny and Hermione. I also like animals. My favorite subjects in school are art, music, science, and math.

SAMEEN, AGE: 15
Hello, I am Sameen from Pakistan and I have a strong interest in science, and I like studying biology the most. I love to explore natural processes, particularly in aquatic ecosystems. I love to read science articles in the newspaper and learn new languages. Besides all this, I also participate in environmental clubs and am doing field trips. I want to study freshwater ecosystems and molecular biology when I grow up.

ZAINAB, AGE: 12
Hi, my name is Zainab, and I live in a small village. I am excited about species relationships and environmental changes, that is perhaps why I love learning about species and ecosystem biology. Apart from that, I want to learn about the history of species and their environment. I like to go to the countryside and see the variety of land plants and animal species. I am also doing online learning activities related to biology and ecosystems.

AUTHORS

MEREDITH EVANS SEELEY
Meredith Evans Seeley is a marine scientist interested in the fate and effects of pollutants, particularly microplastics. Currently, she is a Ph.D. student at the Virginia Institute of Marine Science. She previously studied oil spills as a Master's student at the University of Texas Marine Science Institute. She is interested in using her research to inform policy that can protect and preserve our oceanic ecosystems in the face of increasing human influence. In her free time, she loves traveling and exploring the outdoors. *meseeley@vims.edu

BONGKEUN SONG

Bongkeun Song is the Clark and Elizabeth Diamond Associate Professor of Marine Sciences at the Virginia Institute of Marine Science (VIMS) and William & Mary. He received his Ph.D. in Environmental Science at Rutgers, the State University of New Jersey. He has been studying a broad range of research topics, including microbiome responses to natural and human disturbances, the roles of microbiomes in marine organismal health, novel microbes and processes in the biogeochemical nitrogen cycle, microbial regulation of greenhouse gas emission in soils, and microplastic contamination in natural and engineered environments.

ROBERT C. HALE

Robert C. Hale is a Professor of Marine Science at the Virginia Institute of Marine Science (VIMS), William & Mary. He received his Ph.D. from William & Mary examining the levels in, and consequence of, contaminants on marine crustaceans. Over the last 37 years of research, most of his emphasis has been on aquatic environments, but his interests include terrestrial and human systems, as all are interconnected. Rob's work often melds chemistry, biology, and toxicology, and uses chemical analysis techniques to track pollutants, which include historic and emerging contaminants, such as microplastics and polymer additives.