



HOW SOIL INVERTEBRATES DEAL WITH MICROPLASTIC CONTAMINATION

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Small animals living in soils, called soil invertebrates, represent a very diverse group of soil inhabitants. They include earthworms, woodlice, spiders, springtails, mites, and some insects. Soil invertebrates feed on dead plants, on fungi and bacteria, or on other soil invertebrates. The many ways soil invertebrates interact with each other, and the large number of different species, make life in soils complex and difficult to understand. Unfortunately, soil invertebrates have been dealing with soil pollution, including contamination with tiny particles of plastic called microplastics for decades now. But are microplastics harmful to these organisms? Can microplastics be passed between soil invertebrates when one feeds on another? Most questions about microplastics and soil invertebrates have been investigated using earthworms, but a few studies on others, like

springtails, mites, and nematodes, also exist. In this article, we summarize the effects of microplastics on soil invertebrates.

WHO ARE THE HIDDEN SUPERHEROES IN THE SOIL AND WHAT ARE THEIR JOBS?

Many animals live in soils, but... why can we not see them all? The tiny animals living in soils are called **soil invertebrates**, and they vary greatly in size. Some species are even smaller than the diameter of a human hair! We can classify soil invertebrates into three main groups based on their sizes [1] (Figure 1). Macroinvertebrates are big invertebrates like earthworms, woodlice, spiders, millipedes, centipedes, and some insects like beetles. They are bigger than 2 mm and can create their own living spaces in soils. Mesoinvertebrates have an intermediate size (0.1–2 mm) and live in air-filled pore spaces in soils. Examples include springtails [2], mites, and potworms. Microinvertebrates are <0.1 mm, so small that we cannot see them without the help of a microscope. They live in the water that is present around soil particles. Examples include nematodes, rotifers, and water bears.

Each soil invertebrate group likes different foods [3]. In general, some soil invertebrates, like spiders, feed on other soil invertebrates. Others, like springtails, feed on microbes like fungi and bacteria; and still others, like earthworms, feed on dead plants. These feeding relationships are part of a complex food web that is composed of many species (Figure 2) and many interactions.

SOIL INVERTEBRATES

Small, soil-dwelling animals without backbones or bony skeletons.

Figure 1

Examples of soil invertebrates of different size. (A) water bear, (B) wheel animal, (C) nematode, (D) potworm, (E) springtail, (F) mite, (G) spider, (H) beetle, (I) woodlouse, (J) earthworm, (K) centipede, and (L) millipede. Illustrations do not represent the actual size of the soil invertebrates.

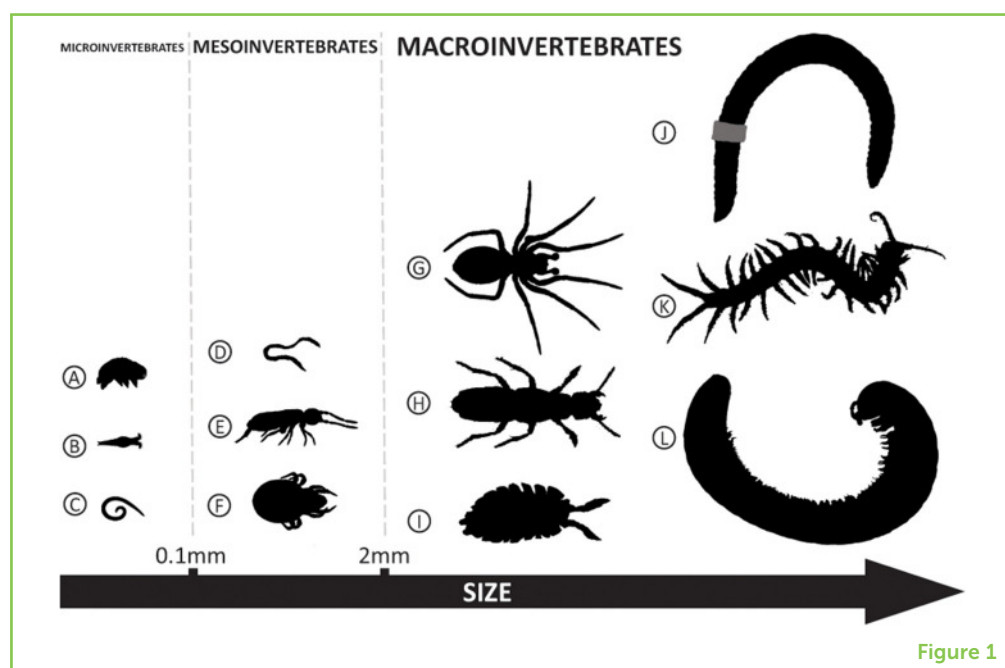


Figure 1

Figure 2

Examples of soil invertebrates. Microinvertebrates (<0.1 mm) include (A) water bears and (B) nematodes; mesoinvertebrates (between 0.1 and 2 mm) include (C) potworms, (D–G) springtails, and (H,I) mites; macroinvertebrates (>2 mm) include (J) woodlice, (K) beetles, (L) earthworms, (M) millipedes, (N) centipedes, and (O) spiders (photo credits: A,C–O: Frank Ashwood; B: Devdutt Kamath).



Figure 2

All soil invertebrates are important for the environment. For example, water bears can colonize new environments and serve as food for other organisms. Nematodes can help cycle nutrients through the soil, with the help of springtails, mites, woodlice, and earthworms. Woodlice, springtails, and some mites [4] help decompose leaves and other formerly living materials in the soil [5], and they also help trap carbon from the atmosphere in the soil. Earthworms help rainwater to infiltrate into the soil. Some soil invertebrates may feed on organisms that cause plant diseases, protecting plants from these pests. Each in their own way, these creatures help to keep the soil healthy, which is also necessary to ensure the quality of our food.

MICROPLASTICS

Small plastic particles (<5 mm) which can be harmful to soil and aquatic life.

THE THREAT OF MICROPLASTICS

Unfortunately, the homes of many soil invertebrates have been invaded by pollutants such as **microplastics**. Microplastics are small particles (<5 mm) that are created in many ways (Figure 3; Box 1). For example, when cars are driven on roads, their tires wear out and

Figure 3

Examples of microplastics. (A) Springtail and urea-formaldehyde particles. (B) Springtail and plastic scraped off a pop bottle. (C) Polypropylene microbeads. (D) Polypropylene microfibrils. (E,F) Adult nematodes with fragments of polystyrene. (G) Particles formed by tire abrasion. (H) Close-up of a polyurethane sponge. (I) Powder-like polypropylene (photo credits: A,B: C. Reinhart and D. Daphi, C,I: Stefanie Maaß, D: Carlos Barreto, E,F: Shin Woong Kim, G: Eva Leifheit, H: Walter Waldman).

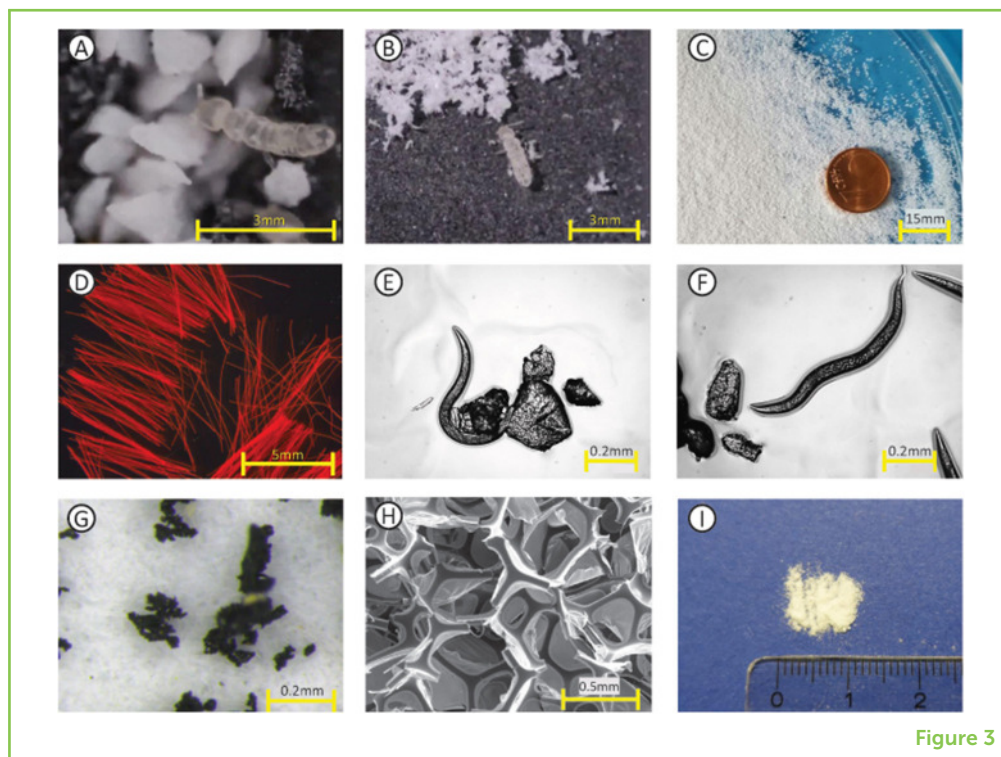


Figure 3

lose microplastics, which can be picked up by the wind and end up in soils. Also, when we do laundry, plastic fibers are released from the clothes into the water. One fleece coat alone can release up to one million fibers per wash cycle! Many of these plastic fibers end up in the sewage, which is a problem because treated sewage can be used to fertilize the soil that crops are grown in. Microplastics can also enter the soil through plastic trash and rainwater.

Microplastics have a huge range of chemical and physical properties. Plastic materials often contain **additives**. These additives can make microplastics even more harmful to the environment, especially once the microplastic particles start to undergo **degradation**. Plastic particles become increasingly brittle due to sunlight, water, and the surrounding soil particles that rub on them. Over time, microplastic particles fall apart into even smaller particles, called nanoplastics. During degradation, the additives slowly start to **leach** out of the microplastics, into the soil. The particles can also leach into the tissues of organisms if they are eaten. Unfortunately, we still do not know much about the effects that leaching of additives from plastics can have on the environment.

So, microplastic particles can clearly affect the soil, but how do they affect soil invertebrates? [6] If we look at earthworms, with their constant appetite for dead leaves and their intense digging activities, we can easily imagine that they regularly ingest microplastic particles and transport them deep into the soil. Not only by feeding, but also on their skin, they can transport these particles. The same has

ADDITIVES

Chemicals that make the plastic more colorful flexible, or less flammable.

DEGRADATION

The breakdown or separation of something into simpler/smaller parts.

LEACHING

When a liquid substance is released away from its solid source.

Box 1 | Sources of microplastics in soils.

Object	Plastic (formal names)	Comment
Paints	Epoxy and alkyd resins	Microplastics are formed from sanding painted surfaces and when paint peels off walls or other structures.
Plastic bags	Low-density polyethylene (LDPE)	When plastic bags are discarded improperly, they might end up on the ground and get degraded by the sun, eventually forming microplastics.
Mulching films	Low-density polyethylene (LDPE)	Some farmers use plastic mulching films to protect plants from water loss. These plastics will break down from sun exposure and form microplastics.
Tires	Polyisoprene (natural rubber)	Although tires are made primarily of natural rubber, they also contain additives and their toxicity is currently being tested.
Foam	Polystyrene (PS)	Foams are widely used in house insulation and in packaging to protect products during transport and storage. Damage and breakdown of foams produce microplastics.
Glitter	Polyethylene terephthalate (PET)	Glitter spreads easily and can detach from makeup and toys and contaminate soil.
Water bottles	Polypropylene (PP)	Breakdown of improperly disposed water and soft drink bottles can contaminate the soil.
Soft drink bottles	Polyethylene terephthalate (PET)	
Clothes	Polyesters and polyamides	Synthetic fibers release microfibers during washing, and they end up in the soil <i>via</i> fertilizers prepared from sewage.

been shown for springtails. What does this mean? On the one hand, the microplastic particles will become more degraded as they pass through the guts of soil organisms. But on the other hand, once particles are carried deeper into the soil, degradation slows down due to the absence of sunlight and reduced microbial activity. In other words, the deeper the particles move into the soil, the longer it takes for them to totally degrade.

MICROPLASTICS CAN AFFECT THE HEALTH OF SOIL ORGANISMS

Soil organisms feel sick when they eat microplastics, and this has been reported for earthworms and springtails. After feeding on microplastic particles, earthworms suffered from several health problems, including inflammation and damage to the gut [7]. Additionally, ingestion of microplastics put the immune system of the earthworms on higher alert than usual. Springtails that ingested microplastics suffered changes in the helpful bacteria living in

their digestive systems [8]. Both earthworms and springtails grew more slowly, had fewer offspring, and died more often after they ingested microplastics.

This sounds like bad news for nematodes, but here is the good news: scientists have not seen a build-up of microplastic particles in organisms over time, which means that they might not suffer that much harm after all. However, it is likely that microplastic particles can be passed on along through the soil food web, from microbes like fungi, to springtails, to predatory mites; or from microbes to earthworms, and then to chickens [9]—and maybe also to humans! We still do not know much about how microplastics move through the soil food web, but research is progressing quickly on that topic. Despite these concerns, scientists have found a gleam of light! One research group reported that certain bacteria in the guts of earthworms can digest ingested microplastics, leading to high degradation rates [10]. This means that bacteria might be able to speed up the destruction of microplastics in soil. Can other soil invertebrates do the same? We simply do not know yet.

WHAT CAN WE DO TO PROTECT SOIL INVERTEBRATES?

You might wonder why scientists have not made more progress answering important questions about the effects of microplastics on soils and the organisms that live there. Unfortunately, these studies face numerous difficulties. For example, we do not yet have a reliable method for measuring the amount of all types of microplastics in all types of soil. Also, many studies consist of short-term experiments that are done in the lab, instead of long-term studies done outdoors in the soil. The huge diversity of plastic types and additives makes it impossible to test everything under real-world conditions. Lab experiments are only informative to a certain degree. Lab experiments are also difficult because not all soil organisms will survive in the laboratory environment. But rest assured: scientists are doing their best to solve these problems. In the meantime, there are ways that *you* can help!

We should all try our best to minimize the future addition of plastics of any type and size into the environment. You may already know some of the most important ways! Avoid single-use plastic items like plastic cups or straws. Choose your favorite metal or reusable plastic cup, and a metal straw, and keep them handy in your lunch bag! It is also important to put plastic waste in the correct recycling container: This can help reduce the amount of plastic that ends up in the water and soil. Additionally, avoid beauty products that have microplastics in their ingredients, like some conditioners! There are alternative products that are free of microplastics, and some smartphone apps can help you choose the best ones for you. To reduce the number of plastic fibers released into the environment, try not to throw away old clothes

just because you do not want them anymore! Instead, try to sell, donate, or reuse them in a creative way. Let's join forces and save our tiny soil superheroes from further microplastic pollution. It is worth every effort!

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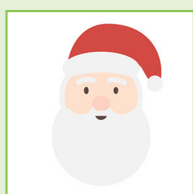
ASTÈRE, AGE: 8

My age is 8. I like reading, doing DIY, drawing, coloring, art, maths, writing, and history. My favorite books are Harry Potter and Percy Jackson.



JUNIE, AGE: 10

I have many hobbies but the ones that I do the most are cooking, reading, drawing, and sewing. I go to a primary school in a big city in the UK and my age is 10. My favorite books are Percy Jackson, books by Judy Blume, Scarlet and Ivy, and North child.



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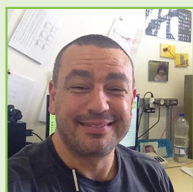
CARLOS BARRETO

At a very young age, Carlos realized that he liked animals, maybe too much. In school, science was always his favorite discipline, all the way through to high school. That is when he decided that he wanted to do something that involved science and animals. He tried to be a vet; it did not work out. No regrets. So, he became an ecologist a few years later, and since then, he has been working with little animals (mostly insects and mites) in tropical forests, iron ore and limestone caves, boreal forests, urban fields, and peatlands on three continents: South America, North America, and Europe. *cbarreto@uwo.ca; †orcid.org/0000-0003-2859-021X



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Matthias likes soil and all the critters in it, not just the animals. Actually, his favorite are the fungi. His favorite soil process is soil aggregation, the formation of the little crumbs of soil. Matthias is a professor at Freie Universität Berlin and gets to think about soil and what is going on in there all day. Currently he is very interested in how soils are being affected by a wide range of factors, including microplastics. †orcid.org/0000-0003-3541-7853



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Walter is a proud Brazilian chemist who loves music, chemistry, food, cinema, and polymers. His first experiment involved chewing gum and the hair of an ex-friend. The experiment did not end well for all the participants, but the adhesive power of polyisoprene was confirmed, and a polymer scientist was born that day. Now he tries to understand the role of polymer degradation on the impact of microplastics. When he has some free time, you can find him reading something about chemistry and polymers. And eating... †orcid.org/0000-0002-7280-2243



STEFANIE MAAß

Stefanie wanted to become a make-up artist or costume designer but due to lack of art skills, she moved on to something completely different: biology. When she was introduced to tropical insects and mites of tree bark during her studies, she became fascinated by their beauty and diversity. She then worked on soil insects and mites and has become a passionate and curious soil ecologist who wants to understand the feeding relationships, reactions to pollutants (like microplastics), and distribution patterns of her beloved soil creatures. †orcid.org/0000-0003-4154-1383