Degradation of biobased plastics in the soil: Microbial community defies climate change

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GCEF experimental plot (conventional farming). PBSA samples were placed in the middle of the plot. Credit: Purahong / UFZ

The idea of biodegradable plastics sounds good at first. However, very little is known about how they are degraded in the soil and how this is influenced by climate change. In two recent studies, soil ecologists at the Helmholtz Centre for Environmental Research (UFZ) have shown which microbial community is responsible for degradation, what role the climate plays in this process, and why biodegradable plastics could still be problematic.

Plastic that ends up in soils, oceans, or inland waters can harm the organisms living there and lead to serious and long-term disruptions in the ecosystems. The development and increased use of biodegradable plastics is therefore the focus of a more ecological economy. "But despite the positive image of biodegradable plastics, we still know very little about how they act in the soil or how they are degraded," says Prof. François Buscot, soil ecologist at the UFZ.

In order to shed more light on this, Buscot's research team investigated the following questions in a recent study published in *Environmental Science and Technology*: How quickly does biodegradable plastic degrade? Which micro-organisms are involved? How do they interact? Which conditions promote the degradation process? And which inhibit it? "We also wanted to know how the changing temperatures and precipitation levels resulting from climate change affect the degradability of the plastics," explains Dr. Witoon Purahong, also a soil ecologist at the UFZ and lead author of the study.

To this end, experiments were conducted at the Global Change Experimental Facility (GCEF) in Bad Lauchstädt, which is currently considered as one of the world's largest outdoor climate experiment in terms of area. The researchers investigated the consequences of climate change on land use and ecosystems. The focus was on mulch and horticultural films, which are used to cover the soil. These are typically made of polyethylene (PE), a plastic produced from fossil raw materials. For technological reasons, residues of the films often remain in the soil. This leads to contamination with microplastics in the medium term. Switching to biodegradable alternatives would therefore make a lot of sense here. But are there side effects of using such alternatives?

240 days degrading PBSA film in conventional farming (future climate) plot. Credit: Purahong / UFZ

In order to find out, the team investigated how polybutylene succinate-co-adipate (PBSA), a bio-based mulch film partly produced from plants (corn, sugarcane, cassava), biodegrades under the natural conditions of an agricultural field. The researchers distinguished between today's climate conditions and simulated climate conditions as projected for Germany around 2070. They used modern molecular biology methods (next generation sequencing) to determine which microbial community had colonized on the plastic itself as well as in the surrounding soil.

"We were able to show that after just under a year, around 30% of the PBSA had already degraded. This is quite a lot under the climatic conditions that currently prevail in Germany," says Purahong. "The main actors are fungi, which are supported by a diverse bacterial community and several other micro-organisms. These include bacteria that supply the fungi with nitrogen (which is rare in plastic) or bacteria and archaea that utilize toxic degradation products. "An intelligent degradation and recycling community is forming on and around the plastic—even with a similar degradation rate under the simulated future climate conditions, adds Purahong. The changed climate apparently does not harm the PBSA-degrading fungi. The microbial community around them is slightly different—but the degradation result is similar. "We hadn't expected such good news."

In another study published in Environmental Science Europe, the UFZ researchers examined the community of micro-organisms under more stringent conditions. They investigated how the community changes when large amounts of PBSA enter the soil as well as what happens when high concentration of nitrogenous fertilizer is applied. "Large amounts of PBSA actually make the microbial community in the soil quite different," says doctoral candidate Benjawan Tanunchai and lead author of the study. With a 6% increase of PBSA in the soil, the diversity of fungal species decreased by 45% and that of archaea by 13%. On the other hand, the high load of PBSA in combination with the fertilization of the area led to the proliferation of Fusarium solani, a widespread plant-damaging fungus.

The two UFZ studies thus yield one piece of good news and one piece of not-so-good news: PBSA in the soil can be degraded comparatively quickly and efficiently—even under future climate conditions. However, if PBSA is present in large quantities together with high concentrations of nitrogenous fertilizer, PBSA degradation can have a negative impact on agricultural production as a result of a disturbed microbial community and the increased presence of pests. "When large amounts of plastic end up in the environment, it is never good—even if it is a biodegradable plastic," says Buscot. "The best thing would be to avoid plastic altogether. However, because this is currently an unrealistic goal, we should at least rely on biodegradable plastics everywhere possible and know as much as possible in advance about their degradation properties and consequences."

More information: Witoon Purahong et al, Back to the Future: Decomposability of a Biobased and Biodegradable Plastic in Field Soil Environments and Its Microbiome under Ambient and Future Climates, *Environmental Science & Technology* (2021). DOI: 10.1021/acs.est.1c02695

Benjawan Tanunchai et al, Analysis of microbial populations in plastic–soil systems after exposure to high poly(butylene succinate-co-adipate) load using high-resolution molecular technique, *Environmental Sciences Europe* (2021). DOI: 10.1186/s12302-021-00528-5

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