



Engineering of a Microbial Consortium to Degrade and Valorize Plastic Waste

Project Overview

How do microbial communities degrade polyester plastics? Can we use these principles to help design bioreactors for remediating and/or recycling plastic waste?



Marc Foster

Bulk polymeric materials in the open ocean are regarded as exceedingly slow to break down and as such, little is known about their biodegradation pathways. This project demonstrates the degradation and consumption behavior of a naturally-derived marine microbial community isolated from the Mediterranean Sea acting on complex co-polymer polyesters. While no individual species in the community was able to completely mineralize the bulk polymer, the results show that several bacteria species perform distinct steps of the polymer mobilization and degradation process. The work was led by MIT graduate student Marc Foster and Professors Otto Cordero and Desiree Plata (Civil and Environmental Engineering).



Otto Cordero

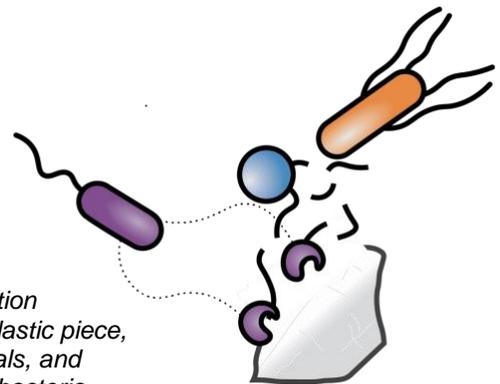
The results have implications for the mechanistic understanding of polymer fate in the marine environment, which could inform Earth-compatible sustainable material design and biological remediation strategies leveraging microbial consortia. The works also highlights the promise of stable isotope tracing using natural abundance carbon isotopes.



Desiree Plata



The project aligns closely with the MCSC's Circularity pathway.



Cartoon showing degradation products forming from a plastic piece, bacteria eating the materials, and enzymes excreted by the bacteria degrading the plastic. Credit: Marc Foster

Findings & Outcomes

The team investigated a unique experimental system based on marine microbes to degrade bio-based polymers. The results show how bacteria break down industrial-relevant plastics into dissolved chemicals that are then available for consumption.

The results of this study explicitly show how bacteria break down industrial-relevant plastics into dissolved chemicals that are then available for consumption or destruction to CO₂. Such mechanistic understanding of biodegradation processes has implications for sustainable material design and the development of principles for engineered or natural biological remediation of industrial pollutants.

The main outcome is the comprehensive degradation scheme illustrating bacteria that degrade the bulk polymer but do not consume all mobilized degradation products, while other bacteria further process these breakdown products and consume those products.

The demonstrated control of degradation product accumulation through microbial community composition changes suggests microbiome engineering could be a feasible research investment for valorization of biodegradable polyester waste (e.g., recovery of terephthalic acid from biodegradation cultures of aromatic polyesters).

This deepened understanding of the microbial ecology in plastics' end-of-life environment can inform the design of new polymers engineered to degrade in the natural world.

Opportunities for Implementation

Research

- Further investigation into the enzymatic mechanisms underpinning bulk mobilization and subsequent breakdown of these mobilized products is needed to advance the efficacy of using these bacteria in bioreactor settings.
 - Mechanistic research will allow for metabolic engineering, microbial community composition engineering, and bioprospecting for bacteria with specific enzymatic functions to enhance microbial consortia for bio recycling applications.
- Investigate recovery of valuable materials (i.e., monomer products) from select co-culture incubations.

Implementation

- Identify interested parties who would like to pilot a small-scale bioreactor to test the feasibility of monomer recovery or biological degradation enhancement.