Soil Bacterium Upcycles Motley Plastic Waste

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(https://www.genengnews.com/wp-content/uploads/2022/10/marc-newberry-9vcEn3BJyy8-unsplash-scaled.jpg)

Credit: Marc Newberry/Unsplash

Recycling and reclamation operations are overwhelmed by the volume of plastic waste in landfills, which has led to a global pollution crisis. Miscellaneous plastic waste could be put to good use as a source of useful chemicals. Researchers have explored chemical and biological processes to develop recycling systems to convert mixed plastic waste into commercially valuable chemicals. However, a roadblock in such upcycling efforts is the shear chemical diversity and complexity of plastic waste.

A new study (https://www.science.org/doi/10.1126/science.abo4626) published in the journal *Science* on October 13, reports a two-step process that combines chemical and biological mechanisms to convert mixed plastic waste into advantageous chemicals. Chemical engineers at the National Renewable Energy Laboratory and the BOTTLE Consortium in Golden, Colorado, Oak Ridge National Laboratory in Tennessee, Massachusetts Institute of Technology, and the University of Wisconsin Madison, developed the hybrid process and illustrated its ability to generate usable chemicals.

"Sullivan *et al.* highlight how hybrid chemical and biological processes can enable plastic recycling that is otherwise unachievable," wrote Ning Yan, PhD, an associate professor in the department of chemical and biomolecular engineering at the National

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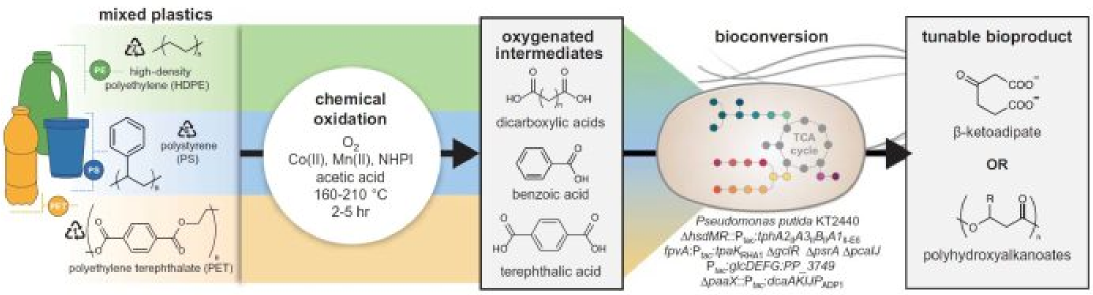
University of Singapore, in a related Perspective article in the same issue of the journal. (Yin was not involved in the study).



Novel upcycling approach converts mixed plastic waste through tandem chemical oxidation and bioconversion into useful chemicals [Adapted from Sullivan KP, et al., Science, 2022]

In the first step of the hybrid process, the researchers depolymerized comingled polymers into miscellaneous, small, oxygenated molecules, using a metal-catalyzed chemical autoxidation reaction. Autoxidation is a complex chemical process that generates organic radicals that react with gaseous oxygen and undergo chain propagation to form oxygenated products. The conversion of xylene to terephthalic acid (known as the Amoco process) is a notable example of industrial autooxidation. These small molecules generated through the initial autoxidation step provide suitable substrates for biological conversion. The researchers then genetically engineered a soil bacterium, Pseudomonas putida, to generate useful chemicals from these oxygenated compounds in a tandem bioconversion step. To illustrate the application, the scientists converted mixtures of high-density polyethylene (HDPE), polystyrene (PS), and polyethylene terephthalate (PET)—the most abundant components of plastics waste—into b-ketoadipate or polyhydroxyalkanoates.

"We engineered two strains of Pseudomonas putida: first, to convert acetate, C4 to C17 dicarboxylates, benzoate, and terephthalate to polyhydroxyalkanoates, a natural polyester with growing industrial applications, and second to use acetate and dicarboxylates for growth while converting benzoate and terephthalate to β-ketoadipate, a monomer for performance advantaged polymers," the authors noted.

Current plastic recycling practices require challenging and expensive sorting of plastic types and yield end products of lower quality and value. This new two-stage approach is effective in converting mixtures postconsumer plastic waste into valuable specialized chemical products.

Polyhydroxyalkanoates are a family of bioplastics suitable for various medical materials and other applications. On the other hand, the β-ketoadipate pathway, found widely in soil bacteria and fungi, degrades a variety of compounds, including benzoates and lignins, to β-ketoadipate, which in turn can be converted to intermediates of the tricarboxylic acid (TCA) cycle, the major energy-generating biological mechanism.

While the authors demonstrated the approach by producing β-ketoadipate or polyhydroxyalkanoates, they noted that genetic engineering of microbial metabolic pathway components could enable tailored mixed plastic conversion into a variety of platform or specialty chemicals.

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