

Portland Community College  
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## A Broadened Understanding of Plastic: Popular Misconceptions, Current Research, & Innovative Solutions to Plastic Waste



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# Plastic: Why is it an environmental problem?

How can such a simple, organic chemical compound cause so much havoc on the natural world? The answer to this question lies in the durability of the polymeric bonds. Polymers are monomers "stacked together" with hundreds to thousands of tightly interlocking chains. Less tightly packed chains of ethylene make Low Density Polyethylene (LDPE), which is what your average grocery bag is made of. Tightly interlocking chains make High Density Polyethylene, which is much harder and used for medical and military applications (Beckman, Eric, Quecholac-Piña, Xochitl, et al.).

# Plastic by the Numbers

It is estimated that in the 1950's world plastic production was 0.5- 2 million tons, compared to 260-380 million tons in 2015 (Thompson, Richard C, et al; Geyer, Roland, et al). As of 2015, 8300 million tons of virgin plastic have been produced. The most commonly produced types of non-fiber plastic are polyethylene (PE) 36%, polypropylene (PP) 21%, polyvinyl chloride (PVC) 12%, polyethylene terephthalate (PET) <10%, Polyurethane (PUR) <10%, and polystyrene (PS) <10%, for a total of 7300 million tons produced total (Table 1). Polyester, polyamide and acrylic fibers account for the last 1000 million tons, 70% of which is polyester (Thompson, Richard C, et al, Geyer, Roland, et al.)

# End of Life Options for Plastic

Between 1950 and 2015, 6300 million tons of plastic waste was created. 800 million tons (12%) have been incinerated, 600 million tons (9%) have been recycled (only delaying final discard), 4900 million tons (60%) are accumulating in landfills or natural environments. (Production, fate of all, Degradation of plastics under Anaerobic Conditions)

# White Rot Fungi- Tearing Plastic Apart

White rot fungi form networks of mycelia, which in turn produce exopolysaccharides that aid in the colonization of plastic's surface. They produce extracellular enzymes such as ligninases, cellulases, hemicellulases, which hydrolyse hydrophilic and hydrophobic polymers, generating smaller subunits. *Pleurotus ostreatus* was shown to decrease the static contact angle of LDPE's surface, causing ablations that it can colonize with mycelium. *P.ostreatus* further helped oxidize C-O and CO-H bonds. Plasma treatment makes the surface more hydrophilic, allowing microbial enzymes to oxidize high molecular weight polymers. This creates even more functional groups that create a positive feedback loop that further increases hydrophilicity. If moisture is high, the aqueous environment forces polar groups to the surface, maintaining hydrophilicity (Ojha, Nupur, et al, Moreno-Bayona, Diana A, et al).

# Landfill Inhabiting Bacteria

*Aspergillus fumigatus*, *Aspergillus Niger*, *Penicillium chrysogenum*, *Cladosporium Herbarum* families have been known to degrade polyethylene. Novel strains of *Penicillium oxalicum* NS4 (KU559906) and *Penicillium chrysogenum* NS10 (KU559907) isolated from landfill soil have been shown to effectively break down polyethylene.

In lab experiments where the plastic was the sole carbon source, NS4 caused HDPE 17-58.598% reduction in weight, and 19.32-34.35% reduction in LDPE weight. NS10 showed 24-55.34% reduction in HDPE and 16.72-36.60 in LDPE. These strains deformed the surface of the polyethylene using similar mechanisms to *P. ostreatus*. However, to show the diversity of microbial action, NS4's solution to the problem of plastic was a robust network of spores and biofilm on the plastic surface, while NS10 produced less biofilm, but caused more warping of the plastic surface. These strains harbor enzymes capable of oxidizing alkene bonds to carbonyls and carboxylic acids, which eliminates the need of prior oxidation (Ojha, Nupur, et al.).

# Endophytic Microorganisms

Endophytic microorganisms penetrate the interiors of plants and can break down tough lignocellulosic polymers. In a survey of soil based endophytes from the Amazon jungle, strains of *Pestalotiopsis microspora* showed the ability to efficiently degrade polyurethane as their sole carbon source when grown anaerobically. The time for complete degradation of PUR by *P. Microspora* in a liquid culture was 16 days. *P. Microspora* E2712A shows equivalent rates of degradation under anaerobic and aerobic conditions, meaning that it could be a candidate for future anaerobic digestion inoculum (Russell, Jonathan R, et al)

Degradation zones happened a significant distance from the site of fungal growth, suggesting secretion of serine hydrolase extracellular enzymes in the presence of PUR. In addition, the serine hydrolase enzymes could be filtered from the solution and would break down PUR suspensions on their own, meaning this highly active enzyme could be useful in degradation processes in the future (Russell, Jonathan R, et al.).

# Conclusions

Plastic is a huge problem that seems like it doesn't have a simple solution. Plastic is composed of carbon and hydrogen, and many species of microorganisms show similar abilities in its biodegradation.

Landfills, incineration, and anaerobic digestion of plastic all have serious issues of their own, and cannot be looked at as viable solutions in the long term. The only safe way to dispose of plastic is by complete biological degradation into biomass using microorganisms. In the future, much more research needs to be done testing out different types of plastic with different types of organisms, trying combinations of organisms in tandem, or designing organisms that do the job faster.