Title
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THE FUTURE OF BACTERIA CLEANING OUR PLASTIC WASTE

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REVIEWING PROGRESS IN CLEANING PLASTIC-FILLED OCEANS USING NOVEL BIOLOGICAL METHODS

Everything has a beginning and an end. An apple core thrown into the dirt can be consumed by a worm, which then excretes nutritious waste for new plants to grow on. However, man-made items such as plastics, styrofoam, rubber, and aluminum are defying this natural cycle that allows growth in our ecosystem. What happens to the plastic water bottle you might have used the last time you went hiking? While an apple can be recycled into new material within two months, a plastic bottle can take more than 400 years to decompose. Plastic waste chokes the normal cycles of our ecosystem, and it is critical to find ways to flush the durable material out without harming the environment even more.

While we may think of plastic as cheap, lightweight, and disposable, like our to-go package: plastic spoon, fork, container, cup, and bag, it doesn't just "disappear" after thrown away. Instead, much of it actually collects in the ocean.

IN 2015, IT WAS ESTIMATED THAT MORE THAN 5 TRILLION PLASTIC PIECES WEIGHING OVER 268,940 TONS WERE AFLOAT AT SEA,

not including the larger plastic debris.[4] How did it get there? One of the most common ways that marine debris travels from land to water is by being swept through storm drains during rain storms. Rivers and waterways also wash trash into the bay. While we do not see the supposed amount of used plastic on land, most of it collects in our oceans. Most critically, the plastic in the ocean endangers marine life because it is a choking hazard and toxic. Marine animals such as sea turtles, mammals, seabirds, and crustaceans are vulnerable to entanglement encounters, which can lead to mortality. Plastics, especially polyvinyl chloride, or PVC, are toxic for our health and the environment.[9] PVC releases mercury, dioxins, and phthalates, which could lead to life-long health threats, such as cancer and damages to the immune or reproductive system.[3]

Plastics take a long time to decompose- but what about biodegradable plastics? Contrary to what one might expect,

BIODEGRADABLE PLASTICS MAY NOT ACTUALLY BIODEGRADE QUICKLY,

due to the fact that most of it ends up in the ocean. Even in favorable environments, such as in the soil with bacteria, fungi, or hot temperatures, biodegradable plastic bags only half-decompose after 389 days.[2] Degradation of biodegradable plastics takes approximately 3 years underwater, since these biodegrading conditions differ from what we see on land. In addition, heavier plastics would not be able to break down by UV light if they sink. While there may be ways to remediate the harm done, sea debris continues to increase, making cleanup programs insufficient.

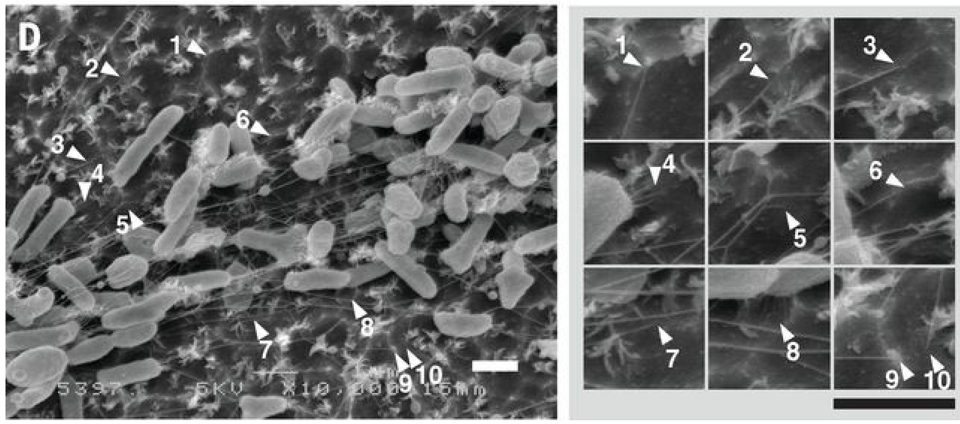
IN ORDER TO STOP PLASTIC WASTE FROM ACCUMULATING, THERE MUST BE A CHANGE IN THE SOCIAL ASPECT OF UNDERSTANDING PLASTIC WASTE.

One poll done found that "biodegradable plastic" is more likely to be littered since people assume it is alright to and it can degrade.[8] Educating and changing the mindset of treating plastics as a temporary item would help solve plastics from entering the ocean. Ultimately, we need to find a way to stop plastic littering, and integrating recycling into social behavior is the key.

Meanwhile, there have been new ideas to help clean the large plastic soup either by reducing carbon dioxide release, or using less material or energy to degrade plastic. Although it may be a long while away until a workable solution is found,

THERE IS A LEAD IN SOLVING THE PROBLEM: PLASTIC-EATING BACTERIA.

In March 2016, a Japanese research team found a bacteria that could completely degrade Polyethylene terephthalate, or PET, within 6 weeks. This plastic is found in water bottles, clothing, and packaging, and has known to be very non-biodegradable. No organisms were found to be able to biodegrade PET prior to this discovery. Out of a variety of microbes, one was responsible for PET degradation: *Ideonella sakaiensis.*[5] It damaged PET film extensively and almost completely degraded it after 6 weeks at 30ºC. When sequencing the genome of this bacterium to find the

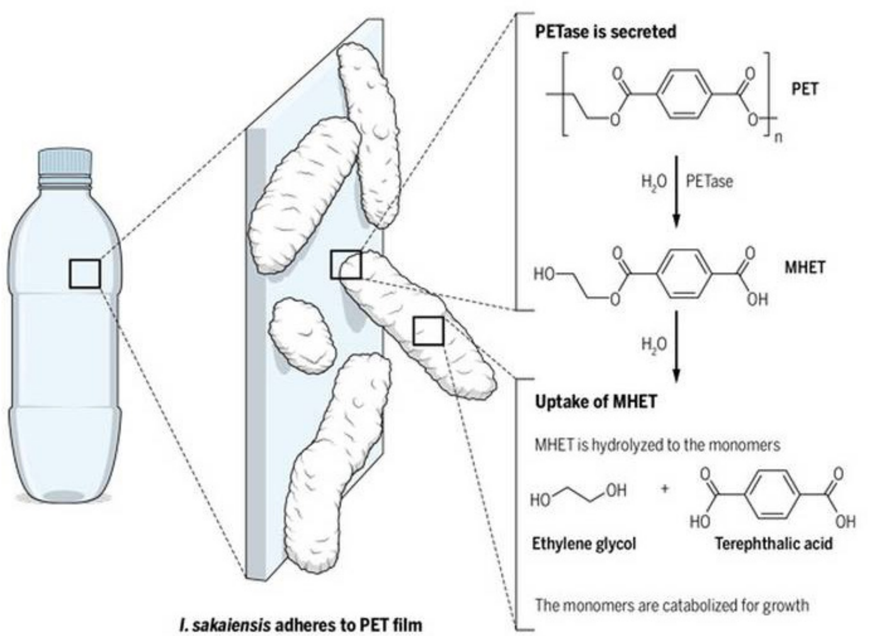


SEM images of *I. sakaiensis* cells grown on PET film for 60 hours. Arrow heads in the left panel indicate contact points of cell appendages and the PET film surface. Magnifications are shown in the right panel. | Science

main contributors to the PET hydrolytic activity, they found an enzyme this bacterium secretes: a PETase. This enzymse generates and intermediate MHET, which is taken back up by the cell and hydrolyzed by a second enzyme. This second MHET hydrolase converts MHET into two environmentally benign monomers: terephthalic acid and ethylene gylcol. The organism then uses these monomers to facilitate its growth.

Despite breakthrough discoveries such as these, it is still not clear how plastic-eating bacteria can contribute to our ocean problem unless we modify them or create a system to make them self-sustainable, efficient, environmentally friendly, or less-costly than current ways.[1] Current recycling ways include using chemicals and heating with more than 700ºF. Heating releases the chemicals in the plastic into the environment, and requires proper disposal of the ashes.

An improvement could be made



The I. *sakaiensis* bacterium discovered by Yoshida et al. (5) can attach to PET. It produces two hydrolytic enzymes (PETase and MHETase) that catalyze the degradation of the PET fibers to form the starting monomers. The monomers are then used as a carbon source by the bacterium.

> "We need to find a way to stop plastic littering, and integrating recycling into social behavior is the key"

"In March 2016, a Japanese research team found a bacteria that could completely degrade Polyethylene terephthalate, or PET, within 6 weeks."

to the bacteria by engineering them or its enzymes.[6] Molecular biotechnology allows researchers to transfer units of genetic information between organisms.

THIS ABILITY TO TRANSFECT AND CONTROL EXPRESSION OF GENES OPENS THE DOOR TO A NEW FIELD OF SYNTHETIC BIOLOGY.

One possible implementation of using bacteria to clean plastic waste is through a controllable bioremediation system.[7] One suggested bioremediation system in Indonesia involved the use of a whole-cell biocatalyst that can degrade PET component in plastic waste. In their devised plastic degradation system, researchers could use synthetic bacteria to degrade plastic. Because the plastic products are harmful to bacteria, they could design the bacteria to use the waste as an energy source instead, and continue growth. Therefore, there would be no need to input more material, as the bacteria are self-sustaining, unlike chemical pools or furnaces.

Plastic is a critical harm to our ecosystem. Production of plastic harms workers, slow degradation of plastic in the ocean risk sea animals' lives, and current methods of recycling plastic can be improved to reduce energy costs. Recent discoveries in plastic-degrading bacteria are a hint to cleaning up the plastic in the ocean. Bacteria can be self-sustaining on plastic, and can also be modified to produce less harmful waste. While modifications in the bacteria can make a better system to degrade the plastic, there has to be more active participation in properly recycling plastic in order for less plastic to be washed to sea.

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Small round-shaped bacteria and diatoms (tiny algae) are seen on a 5-mm-long plastic in waters off the island of Tasmania, Australia. | AFP-JIJI