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New study finds bio-based plastic and plastic-blend textiles do not biodegrade in the ocean

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Cage design used for the sea surface experiment that took place off the Ellen Browning Scripps Memorial Pier at UC San Diego's Scripps Institution of Oceanography in 2019. Credit: Sarah-Jeanne Royer

Plastic pollution is seemingly omnipresent in society, and while plastic bags, cups, and bottles may first come to mind, plastics are also increasingly used to make clothing, rugs, and other textiles.

A new study from UC San Diego's Scripps Institution of Oceanography, published May 24 in the journal *PLOS One*, for the first time tracked the ability of natural, synthetic, and blended fabrics to biodegrade directly in the ocean.

Lead author Sarah-Jeanne Royer conducted an experiment off the Ellen Browning Scripps Memorial Pier and found that natural and wood-based cellulose fabrics degraded within a month. Synthetic textiles, including so-called compostable plastic materials like polylactic acid (PLA), and the synthetic portions of textile blends, showed no signs of degradation even after more than a year submerged in the ocean.

"This study shows the need for standardizing tests to see if materials promoted as compostable or biodegradable actually do biodegrade in a natural environment," said Royer, who performed the research while a postdoctoral scholar in the Dimitri Deheyn laboratory at Scripps Oceanography. Royer currently remains affiliated with Scripps Oceanography as a visiting scholar from Hawaiʻi Pacific University. "What might biodegrade in an industrial setting does not necessarily biodegrade in the natural environment and can end up as marine and environmental pollutants."

Startling images of landfills stacked with mountains of thrown away clothing in Chile and Kenya show the global ramifications of fast fashion. An estimated 62% of textiles —68 million tons—are now made from plastic fibers and plastic blends, which can persist in the environment for decades to centuries. Synthetic textiles also create plastic pollution from microfibers shedding during regular wearing and washing. Most washing machines are not designed to filter for microfibers, that then end up in wastewater, and ultimately the ocean.

Bio-based plastics made from renewable natural resources such as cornstarch or sugar cane have been marketed as a potential solution to the plastic problem. PLA is one such polymer in the bio-based plastics market, often labeled as biodegradable and compostable. The team chose this textile for the study given its extensive use as a replacement for oil-based materials.

Deployment of the sea surface experiment that took place off the Ellen Browning Scripps Memorial Pier at UC San Diego's Scripps Institution of Oceanography in 2019. Credit: Dimitri Deheyn

For the experiment, ten different types of fabrics were used including wood-based cellulose (known commercially as Lyocell, Modal, and Viscose); natural cellulose (organic virgin cotton and non-organic virgin cotton); bio-based plastic (PLA); oil-based plastic (polyethylene terephthalate and polypropylene), and fabric blends of Lyocell mixed with polyester and polypropylene. All these are commonly used in the textile industry. Polyethylene terephthalate is a type of polyester often marketed as a recycled textile. Polypropylene is used in textiles, carpets, geotextiles, packaging materials, and disposable medical textiles such as masks.

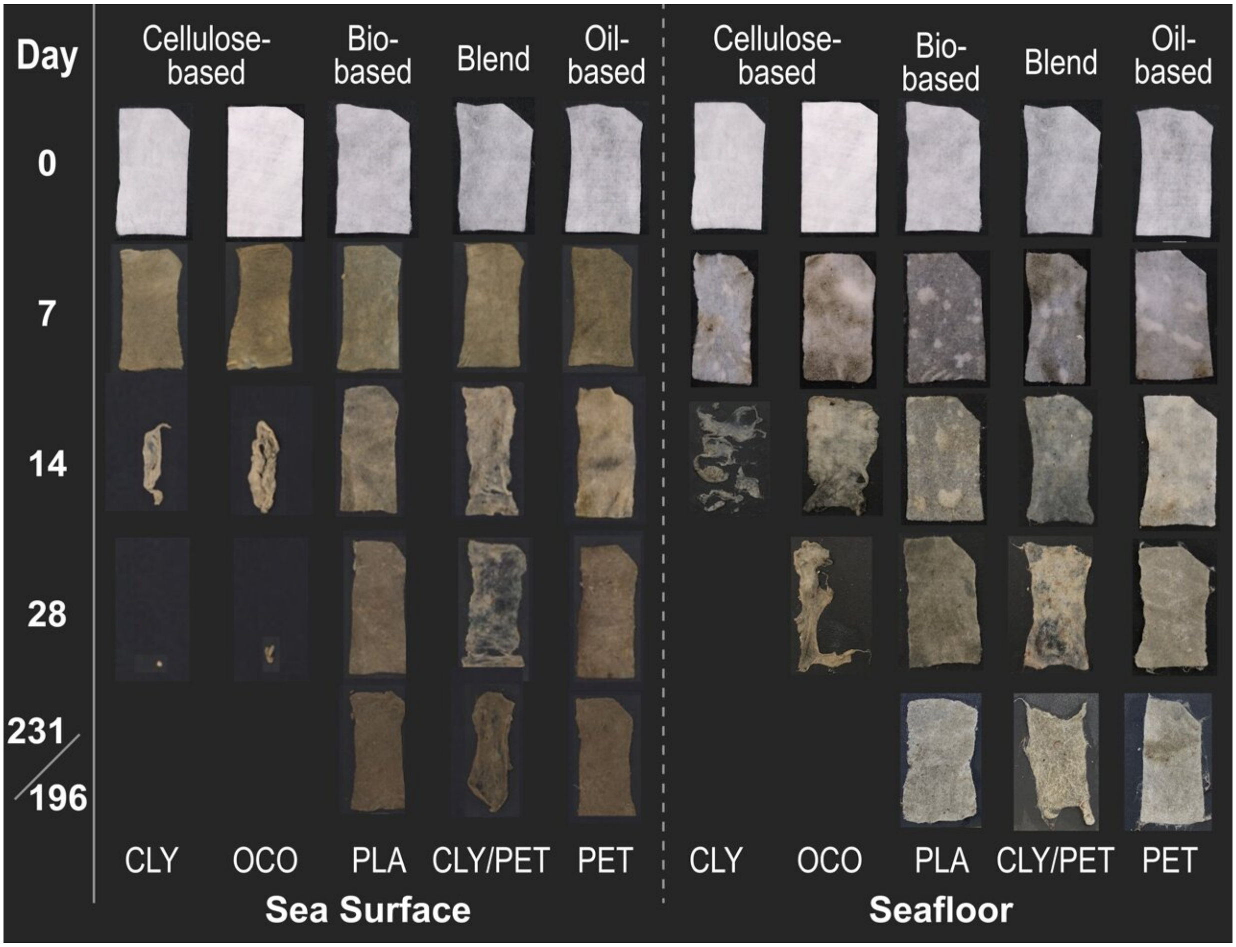
The textile samples were placed in flow-through containers deployed both at the sea surface and at the seafloor approximately 10 meters (32 feet) deep. Samples were examined every seven days with images taken, and small pieces removed from duplicate samples for further examination in the lab. This included scanning electron microscopy to examine the fibers at high resolution, and Raman spectroscopy to gain information about the chemical composition and molecular structure of the fibers. The samples were then submerged again, in a process that lasted for 231 days at the sea surface and 196 days at the seafloor.

After the conclusion of the Scripps Pier experiment, the samples were moved to the Experimental Aquarium at Scripps Oceanography, where samples were exposed to controlled conditions of flowing seawater. While the natural, cellulose-based textiles repeatedly disintegrated in 30–35 days, the oil-based and bio-based materials showed no sign of disintegration even after a total of 428 days.

"The natural, cellulose-based materials would disintegrate in about one month, so we would exchange for a new sample after the old one disintegrated," said Royer. "The natural samples were replicated five times, while the plastic samples remained the same for more than a year."

Examining the samples via electron microscopy allowed Scripps marine biologist Dimitri Deheyn, senior author of the study, to measure the size and structure of each fiber. The natural fibers became thinner with time, while the diameter of the plastic fibers remained the same showing no sign of biodegradation. Study co-author Francesco Greco performed the Raman spectroscopy analysis at the Department of Geology of Northwest University, China, looking at the structural-chemical degradation of the fibers. Greco, now at the Weizmann Institute of Science, found significant changes in the chemical fingerprint of the cellulose-based materials, while bio- and oil-based plastics remained unchanged.

Fiber blends, which interweave natural fiber strands with bio- or oil-based plastic strands, are often promoted as a more sustainable alternative to textiles made entirely from synthetic plastics. This study showed, however, that only the natural part of the fiber degraded, with the plastic portion of the blend remaining intact.



Disintegration time in days for five selected types of material exposed to coastal waters at the Ellen Browning Scripps Memorial Pier located at UC San Diego's Scripps Institution of Oceanography in La Jolla, California. Credit: Royer, et al.

Additionally, the same type of fabrics were tested in a closed-system bioreactor by an independent company, which replicates a marine environment in an enclosed, indoor system. The bioreactor allowed measurements of the percent of carbon dioxide produced by microbial activity using the fabrics as nutrients, which was thus used as a proxy for measuring biodegradability. The cellulose-based materials showed complete biodegradation within 28 days, whereas the oil-based and bio-based fibers did not show any sign of biodegradation.

Study authors note that the bio-based polylactic plastic, marketed as an ecologically promising material, and the oil-based polyethylene terephthalate and polypropylene, represent an important source of human-caused pollution, and the fate of how these materials act in a natural environment should be further explored.

"This comparative study highlights how crucial our language is around plastics," said Deheyn. "Indeed, a bioplastic like PLA, commonly assumed to be biodegradable in the environment because it contains the prefix 'bio,' is actually nothing like that."

Given these results, Royer and the team hope consumers will become more aware of the power of their own choices.

"Consumers who are concerned about microfiber plastic pollution should be mindful of the materials they are buying," said Royer. "We should all aim to buy fewer garments, opt for high-quality, cellulose-based materials like cotton, merino or wool that will last longer, or look to more circular and sustainable options that repurpose items like clothing swaps and Buy Nothing groups."

More information: Not so biodegradable: polylactic acid and cellulose/plastic blend textiles lack fast biodegradation in marine waters, *PLOS ONE* (2023). DOI: 10.1371/journal.pone.0284681

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