Sustainable plant-based polymers could replace endocrine-disrupting plastics

ASU researchers developing alternatives that are safer, easier to recycle

By Joe Rojas-Burke, ASU News
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We humans produce enormous volumes of plastic waste, and we recycle very little — just 14% of the 590 billion pounds discarded in one recent year, worldwide.

To make matters worse, exposure to some widely used plastics can have harmful health effects. Plastics made with the chemical called BPA, for example, can interfere with the body's hormones and worsen risks of heart disease, cancer and infertility.

About this story

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Seeking safer and more sustainable alternatives, researchers at Arizona State University are developing plant-based plastic materials suitable for use in water filtration and medical devices, such as kidney dialysis machines, in which BPA-based plastics may otherwise be used.

“In the short term, we need to phase out problematic uses of BPA. In the longer term, the plastic industry has a much bigger challenge, which is the billions of pounds of plastics waste that we're producing,” says Matthew Green, an associate professor in the School for Engineering of Matter, Transport and Energy at ASU. “Finding natural products that could potentially replace petroleum-based materials, improve performance and also avoid human health concerns is a win-win-win.”

provides that universities would not only undertake the research but would also build the necessary infrastructure in exchange for grants from the government.

That agreement and all the economic and societal benefits that come from such research have recently been put at risk.

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A big focus of the research in Green’s lab is the design of advanced membrane materials to be used in applications such as purifying water and capturing carbon dioxide gas from the atmosphere. But the lab also focuses on sustainability and developing materials that are easier to recycle, biodegradable and not synthesized from coal or oil.

Plastic from wood waste

The building blocks of the new BPA alternative come from lignin, a natural compound that gives stiffness and strength to wood and other plant tissues. Lignin is an abundant byproduct of paper manufacturing. Pulp mills generate tens of millions of tons per year and burn most of it. Less than 5% is recovered for material applications.

Green took an interest in lignin after visiting scientific colleagues Thomas Epps III and LaShanda Korley at the University of Delaware, who have worked extensively to identify new chemical products that can be derived from natural polymer, a very large molecule made of simpler units bonded together. The three co-authored a paper describing progress toward BPA-free polymers for filtration applications.

The process starts with breaking down lignin into its building blocks, and then modifying those building blocks and using them to assemble new polymers with desirable properties.

“The chemistry is not straightforward,” Green says.

Researchers in Green's lab, led by Hoda Shokrollahzadeh Behbahani, now a postdoctoral researcher at the University of Pennsylvania, had to make adjustment after adjustment to get polymers comparable in strength and temperature endurance to materials made with BPA.

One key difference in the lignin-derived materials turned out to be extra advantageous.

“These materials have an additional functional handle that allows us to tune the properties in ways that we couldn't tune the petroleum-derived, BPA-based material,” Green says.

The functional handle is a cluster of carbon and hydrogen bonded to oxygen, called a methoxy group. Changing the number of these attached methoxy groups makes it possible to change the lignin-derived polymer's affinity for water — that is, how hydrophilic it is.

That's critical for a material designed for filtration. The interaction of a polymer membrane with water dictates how fast water can move through a filter, what kinds of chemicals the membrane can separate out of the water and the efficiency of filtering. More efficient filters produce less wastewater.

“The fact that we can change how much that material likes water is a really beneficial feature,” Green says. “It's hard to overstate how important and critical that really is.”

No endocrine-disrupting effects

BPA has been phased out of many products, but some of the petroleum-derived replacements are chemically similar to BPA and have posed some of the same concerns about toxicity and sustainability.

The lignin-derived building blocks don't interact with hormones the way BPA does. Testing in the Epps lab detected no endocrine disrupting effects. The lignin-derived building blocks showed minimal developmental toxicity in lab tests.

Green and collaborators are planning more in-depth water treatment and separation studies to demonstrate performance in filtering applications. They are also working to adjust certain properties of the lignin-derived polymers to optimize the ability to be recycled. Plant-based materials are well suited for that.

“Nature typically provides you with more functional handles to be able to reuse materials,” Green says.

The ideal scenario is a circular life cycle, in which the building blocks of a polymer material can be disassembled and built into something else that has a second life, and the process can be repeated to give the building blocks a third life as another material, and further rounds, for as long as possible.

“As you look at nature, there's many examples of this kind of circular life cycle,” Green says. “We don't do that as well in our consumer-focused economy, but we need to.”

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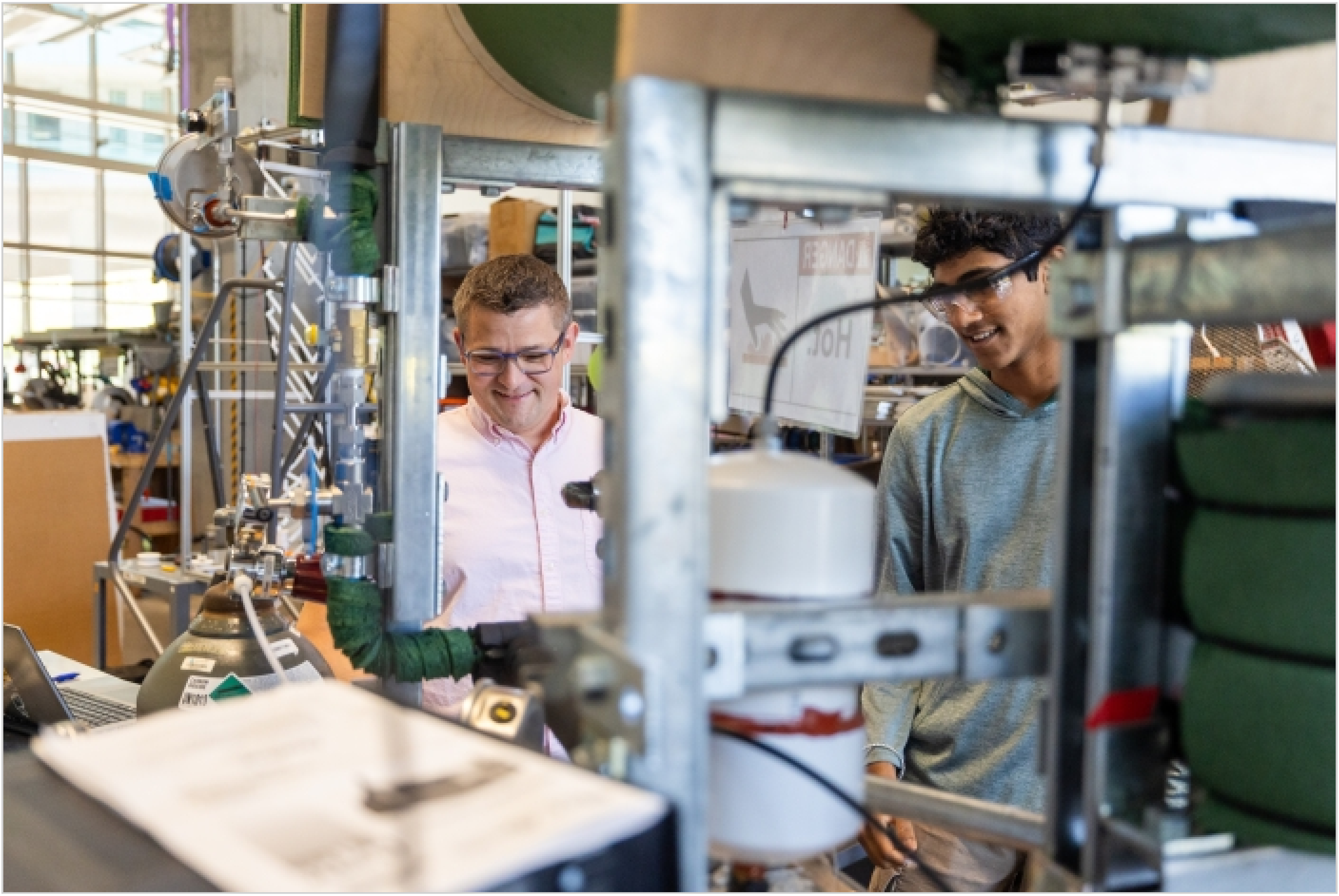
Main image



Matthew Green (left), an associate professor in the School for Engineering of Matter, Transport and Energy at ASU, works with a student in his lab. A big focus of research in Green's lab is the design of advanced membrane materials to be used in applications such as purifying water and capturing carbon dioxide gas from the atmosphere. But the lab also focuses on sustainability and developing materials that are easier to recycle, biodegradable and not synthesized from coal or oil. Photo by Deanna Dent/ASU