Bacteria attached to charcoal could help keep an infamous ‘forever chemical’ out of waterways

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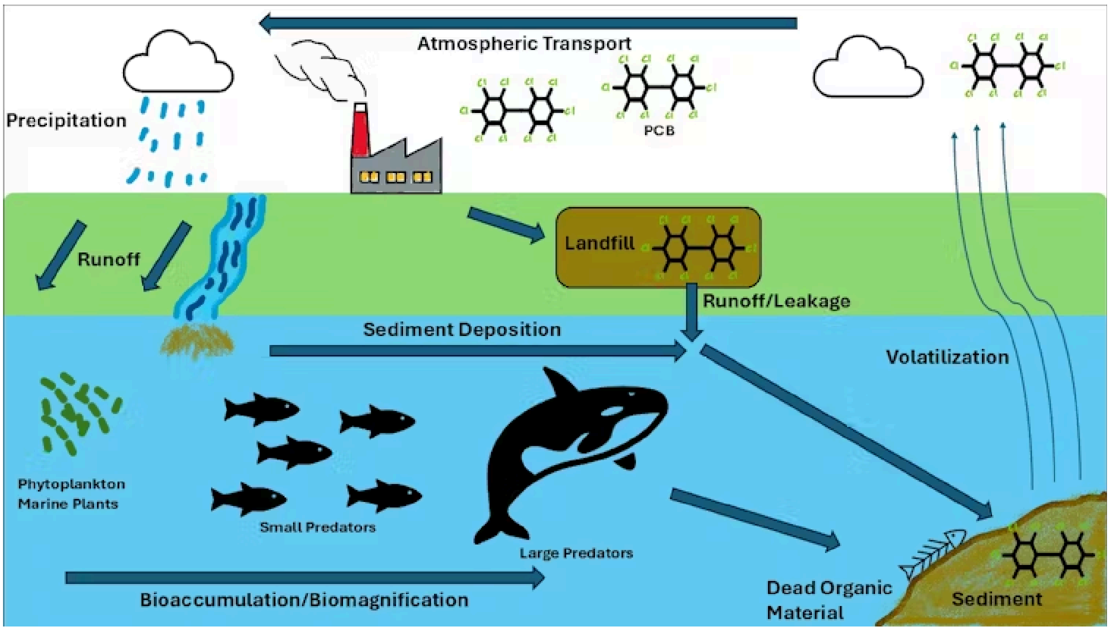
Biochar, which can be made from corn, is a versatile material.

Polychlorinated biphenyls, or PCBs, a class of fire-resistant industrial chemicals, were widely used in electrical transformers, oils, paints and even building materials throughout the 20th century. However, once scientists learned PCBs were accumulating in the environment and posed a cancer risk to humans, new PCB production was banned in the late 1970s, although so-called legacy PCBs remain in use.

Unfortunately, banned isn't the same as gone, which is where scientists like me come in. PCBs remain in the environment to this day, as they are considered a class of "forever chemicals" that attach to soil and sediment particles that settle at the bottom of bodies of water. They do not easily break down once in the environment because they are inert and do not typically bind or react with other molecules and chemicals.



PCBs can enter the environment through landfill runoff and cycle through land, air and water.
David Ramotowski

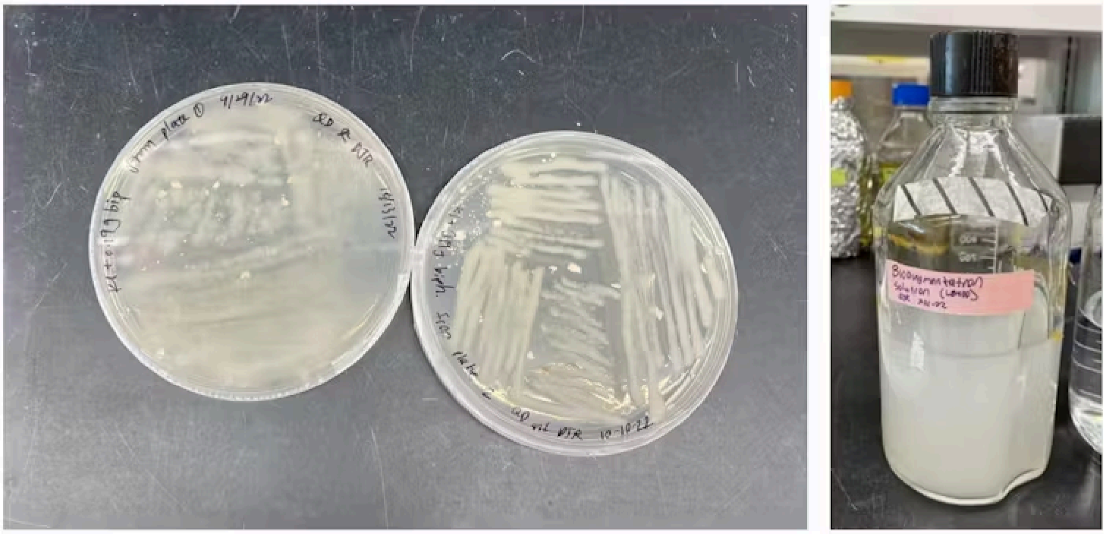
Some sediments can release PCBs into water and air. As a result, they have spread all over the world, even to the Arctic and the bottom of the ocean, thousands of miles from any known source.

Airborne PCBs particularly affect people living near contaminated sites. Current cleanup methods involve either transferring contaminated sediment to a chemical waste landfill or incinerating it, which is expensive and could unintentionally release more PCBs into the air.

I'm a Ph.D. candidate in civil and environmental engineering at the University of Iowa. My research seeks to prevent PCBs from getting into the air by using bacteria to break down the PCBs directly at contaminated sites – without needing to remove and dispose of the sediment.

Introducing bacteria to the environment

I work with a bacteria species called Paraburkholderia xenovorans LB400, or LB400 for short. First discovered in 1985 in a New York chemical waste landfill, LB400 has since become one of the most well-known aerobic, or oxygen-using, PCB-degrading bacteria, able to work in both freshwater and saltwater sediments. LB400 can effectively break down the lighter PCBs that are more likely to end up in the air and pose a threat to nearby communities.



The bacteria Paraburkholderia xenovorans LB400 on a petri dish, left, and in its liquid state, right.
David Ramotowski

LB400 degrades PCBs by adding oxygen atoms to one side of a PCB molecule. This ultimately results in the PCB splitting in half and producing compounds called chlorobenzoates, along with other organic acids. Other bacteria can degrade these compounds or turn them into carbon dioxide. My colleagues and I plan to measure them in our future work to ensure that these byproducts do not pose a threat to LB400 and other life forms.

However, LB400 cannot survive for very long in most PCB-polluted environments, so it can’t yet clean up these chemicals at a larger scale. For example, in some places with historically high levels of contamination, such as the harbor of New Bedford, Massachusetts, strong currents can wash the bacteria out to sea as soon as they’re introduced. Additionally, changing oxygen levels at high and low tide and salinity in the harbor may harm them.

Where biochar comes in

Because it is difficult to introduce bacteria on its own into the environment, I am working on a delivery mechanism that involves attaching the bacteria to the surface of biochar.

Biochar is a charcoallike material made from heating plant materials at very high temperatures in low-oxygen conditions in a process called pyrolysis.

Combined with bacteria, biochar could become an effective one-two punch to keep PCBs out of our air. The biochar provides a safe habitat for the bacteria, and it can attract PCBs from sediment through adsorption, bringing the PCBs into contact with the bacteria on the surface, which will break down the PCBs.

My colleagues and I still need to figure out the specifics of adding the bacteria-coated biochar into the environment. Right now, the idea is that the biochar will sink to the bottom where sediments are. But if the biochar doesn't travel on its own to where we need it to be, we may need to look into other delivery methods, such as injecting it directly into the sediment.

The corn-kernel biochar prior to being used in the lab. I grind the kernels to increase the surface area for the bacteria to attach, similar to the principle of grinding coffee beans before brewing.
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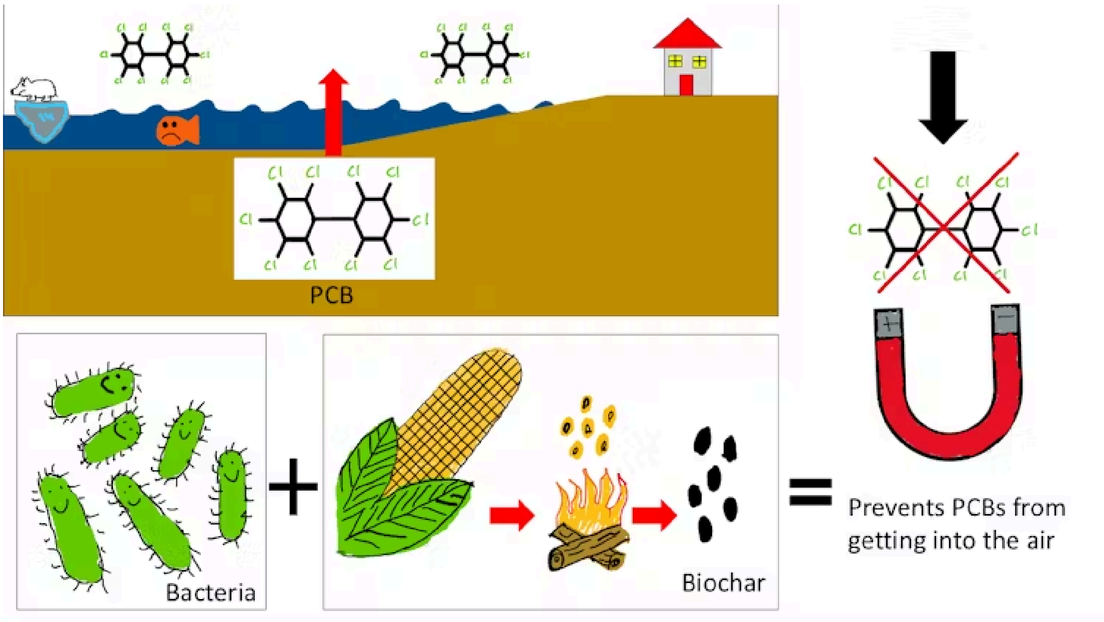

Scientists may be able to use two unlikely heroes – corn and bacteria – to protect communities from airborne PCBs.

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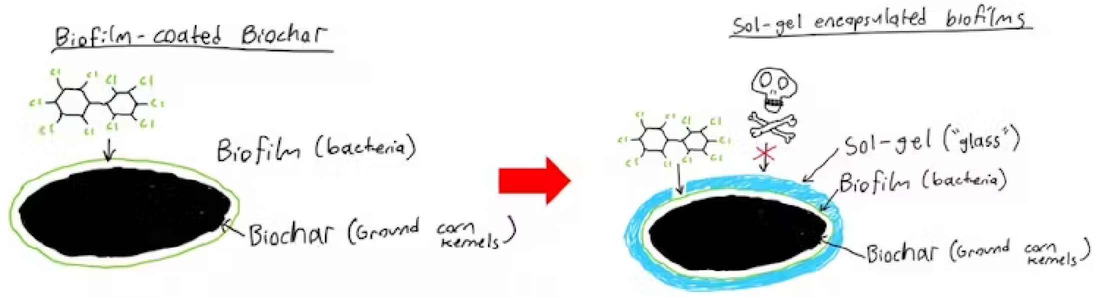
In addition, my research group has tested different types of biochar materials and found that biochar made from corn kernels worked best with the bacteria. For the 2025-2026 market year, the United States is projected to produce over 400 million tons of corn, making it a stable, abundant, homegrown resource for this research.

Before any federal, state or city-level agencies can use this PCB cleanup method on a large scale, I need to solve two important problems. First, I must determine the correct amount of biochar to use. Too little would have no significant effect because there would not be enough biochar to attract PCBs and not enough bacteria to break them down. But too much would be too expensive and impractical.

Additionally, my colleagues and I are working to further protect the bacteria attached to biochar by surrounding it with a protective “sol-gel” material, which we are working to patent. Due to its high porosity and ideal pore size, this gel allows pollutants such as PCBs in while keeping out toxins that could pose a threat to LB400. The sol-gel also helps prevent strong currents from detaching the bacteria.



This diagram shows how applying a glasslike ‘sol-gel’ coating can further protect the bacteria in the environment by allowing in PCBs while keeping other harmful toxins out. The sol-gel also helps prevent bacteria from being detached from the biochar.

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This sol-gel could further extend the bacteria’s useful life, which will make the treatment more cost-effective and practical for communities affected by airborne PCBs.

While our methods have not yet been used at a large scale, my research group and I are currently working on testing this hypothesis in the lab. If successful, we could then begin to conduct field trials and work toward scaling up this method for use at PCB-contaminated sites nationwide.

My research team hopes the combined forces of bacteria and corn-kernel biochar can potentially one day give communities the freedom to flourish in a world free from PCBs.

David Ramotowski receives funding from the National Institutes of Health (NIEHS P42ES013661) and previously from the University of Iowa Post-Comprehensive Fellowship.