ACS central science

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A Conversation with Kristopher McNeill

Mark Peplow

The environmental chemist hopes to reduce our impact on the planet by planning ways to tackle pollution before it happens.


Credit: Courtesy of Kristopher McNeill

The chemicals we manufacture inevitably find their way into the environment. Kristopher McNeill, an environmental chemist at the Swiss Federal Institute of Technology (ETH), in Zurich, is pre-empting pollution problems by designing remediation strategies for products before they reach the market. He discussed his strategy for "greening ahead" with Mark Peplow.

Why are you trying to anticipate contamination that does not yet exist?

The standard paradigm of environmental chemistry is that we chase the effect of a chemical in the environment, so there's a lag between discovering a problem and then 10 years later developing a solution. In the 1970s and 1980s, the targets were pesticides, then chlorinated solvents in the 1990s. And in the 2000s, people focused on pharmaceuticals, and then nanomaterials. It's driven in part by funding or regulatory agencies: The Environmental Protection Agency gets interested in pharmaceuticals and personal care products, and then suddenly there are 20 groups working on it. It's like the molecule-of-the-month club.

I'm interested in solving problems for the future. I was a synthetic organometallic chemist for a long time, and no one who works in a lab can ignore that there are some pretty toxic compounds. When you're filling up your waste bottle, it's like a cauldron of poison. I wanted to use chemistry to lessen the impact of humans on the planet.

Why do you choose to focus on remediating fluorocarbons?

There has already been a huge boom in perfluorinated compounds, like Scotchgard. Now fluorine is increasingly showing up in drugs and pesticides. The C–F bond is strong, and this stability can be a curse because it allows molecules to persist in the environment for a long time.

It's not like they're a scourge, but there are some data on environmental toxicity for certain fluorocarbons. So we've worked on ways to remediate them under mild conditions, and discovered a rhodium-based catalytic system to dehalogenate fluorobenzene rings. We designed it to work in water at room temperature, because fluorocarbon contamination is largely a groundwater problem.

The next step would be to try it out on a contaminated site. We don't know of any that are accessible to us so far—I only know of one reported site—so we could also look at a model of a contaminated site.

Why not prevent the pollution in the first place?

That's where our other project comes in. We're working on biodegradable polyesters that don't pollute. They could replace the polyethylene sheets that farmers use to cover agricultural fields to reduce water demand, soil loss, and pesticide or herbicide load. When farmers recover the sheeting, there's a lot of plastic left in the soil, which can reduce soil fertility. There's also a disposal problem, with tons of sheeting at the end of the growing season.

Published: January 15, 2016

DOI: 10.1021/acscentsci.5b00405
ACS Cent. Sci. 2016, 2, 4–5

In contrast, polyesters can biodegrade to small molecules that are easily taken up by microorganisms, so you could compost the sheeting. We are looking at the environmental fate of these polyesters. For example, if you find a polymer that is degradable in a certain soil pH, would it work in a different field? These findings can feed back into their design.

One of the end points we look for is mineralization, where all the polyester's carbon has turned into carbon dioxide. We add ^{13}C labels to the polymers to distinguish the CO_2 from the gas produced naturally by the soil. We measure the CO_2 using a type of infrared spectroscopy called cavity ring-down spectroscopy.

How does that work?

You arrange mirrors to make a triangular optical cavity for the sample, and put a detector behind one of the mirrors. The laser beam goes round and round these mirrors, so that the effective path length of the cell is 40 km. Every circuit we get a hit on the detector, and the beam's intensity decays—or "rings down"—over time, partly due to the sample in the cavity. It's a workhorse of atmospheric chemistry.

The clever engineering part is that we have a valve system that can switch between 36 different bottles in an incubator, all connected to an automatic sampler, to check the $^{13}CO_2$ emissions. We can study a lot of different conditions at the same time, which is pretty nice because these experiments literally take a year before we get good data.

Knowing the maximum extent of degradation is very important for regulation. For composting, you might want more than 90% of the polymer carbon to end up mineralized. The use of biodegradable plastics in soil has not been regulated yet, so the companies need to know what levels of mineralization they should be lobbying for. What we do know is that biodegradable polymers are coming to the market, and I hope we provide some input to help them come to market as effectively as possible.

Mark Peplow is a freelance contributor to Chemical & Engineering News, the weekly newsmagazine of the American Chemical Society. Center Stage interviews are edited for length and clarity.