Innovative Chemical Clean-Up Techniques Help Restore The Earth

Univerersity of Connecticut
University of Connecticut

Long before George Hoag took an academic interest in the environment, he forged a personal connection with it. “As a child, I just loved being outdoors,” he says. “Camping, skiing, biking, you name it.” Hoag, an avid hiker, later realized the human race didn’t always tread lightly on the planet. That steered him toward a career path dedicated to cleaning up the chemical mess industry can leave in its wake, wreaking havoc on soil and water.

In 1983, Hoag earned a doctorate in environmental engineering from the University of Connecticut in Storrs, Conn., and applied his knowledge to methods that could help rid the environment of contaminants. He wasn’t impressed with conventional methods used to accomplish that goal. Typically, the technique used on contaminated sites involved pumping chemicals out of the ground and disposing of them as a hazardous waste or digging them up and hauling them to landfills.

> *I just didn’t think moving contamination from one place to another was the best way for our*

> *society to manage the problem.*
>
> George Hoag

Instead, Hoag discovered a new cleanup method that targets contamination at its source. So far, it's helped restore soil and water quality at hundreds of sites around the world.

Trouble with Chlorinated Solvents

While Hoag was immersed in his doctoral studies, the U.S. federal government was also taking a closer look at environmental issues. That included the creation of Superfund, the Environmental Protection Agency's (EPA) program to clean up hazardous waste areas. According to the EPA, the program has helped restore nearly 1.3 million acres of land for productive use during the past 30 years, ranging from bird sanctuaries to golf courses. But there's still much work left to be done. As of April 2011, the EPA had 1,290 contaminated sites on its priority list of Superfund sites.

In the 1990s, Hoag became interested in a pervasive toxic culprit — a type of chemical compound called chlorinated solvents. About 80 percent of all Superfund sites with groundwater contamination have chlorinated solvents, according to Strategic Environmental Research and Development Program, the U.S. Department of Defense's environmental science and technology program. An example is perchloroethylene, the chlorinated solvent most widely used by dry cleaners. It's a suspected carcinogen and has been detected in soil and groundwater near some dry cleaning facilities. If left untreated, the effects of chlorinated solvents can linger for many decades.

United Technologies Corp. (UTC), based in Hartford, Conn., had concerns about those long-term problems. Like many other large manufacturers, it had chlorinated solvents on itsproperty. In 1997, UTC turned to Hoag for help. The companyneeded to clean up sites contaminated with trichloroethylene,a chlorinated solvent commonly used to clean industrial machinery.One of the decontamination methods available at thetime entailed pumping out polluted water and then treating it.It was a costly approach and not a particularly effective one.While the pump-and-treat method does clean affected water, itoften fails to neutralize the pollution's origin, which can lurk undergroundfor decades. Seeking a better solution, UTC fundedHoag's research at University of Connecticut laboratory to findnew methods that could target the contaminant source.

Putting Free Radicals to Work

To accomplish this daunting task, Hoag researched a group of substances called chemical oxidants. When injected into the ground, chemical oxidants can convert hazardous contaminants to less toxic compounds.

One of the initial chemical oxidants Hoag studied was potassium permanganate — but it was only effective on a limited spectrum of compounds. He also tested the effects of hydrogen peroxide, after adding a catalyst and prompting it to make free radicals.

Most people think of free radicals as something to avoid, and rightfully so. Free radicals can destroy cells and cause disease. But the properties that make free radicals harmful in people also make them function as a helpful, hard-working cleanup crew. "The free radicals from hydrogen peroxide are phenomenally good at destroying a broad range of organic chemicals in water, like pesticides, herbicides and PCBs," says Hoag.

But the catalyzed hydrogen peroxide had a significant shortcoming. When injected into soil, it decomposed much too quickly. That prevented the helpful free radicals from reaching the contamination source.

"So I asked myself the question, is there anything else that makes free radicals and could potentially be used in the ground?" says Hoag. With the help of colleagues — Pradeep Chheda, Ph.D., a postdoctoral fellow at the University of Connecticut; and Bernard Woody, M.Sc., and Gregory Dobbs, Ph.D., both from United Technologies Research Center — he found the answer in a chemical oxidant called sodium persulfate.

Specifically, the researchers studied activated sodium persulfate — which means it's exposed to a catalyst, like heat or iron. When injected into the ground, activated sodium persulfate lasted longer and traveled farther than hydrogen peroxide and was practically as good at making free radicals.

"This technology has a lower carbon footprint than, say, digging things up," says Hoag. Plus, it could neutralize a wider array of contaminants than potassium permanganate: In addition to cleaning up chlorinated solvents, sodium persulfate could handle petroleum-based contaminants.

UTC's funding for Hoag's work included treating a site owned by the company. During the field trial to destroy contamination at the site, Hoag learned persulfate could travel up to 50 feet in ground water.

The field trial revealed a surprise, too: The technology worked even better than Hoag had suspected. That's because the persulfate stimulated naturally occurring bacteria in the soil, which were able to help break down contaminants (chlorinated compounds and petroleum compounds) present at the site.

"That was very exciting to find out," says Hoag.

Commercializing the Cleanup Technology

The university's technology transfer office — the Center for Science and Technology Commercialization (CSTC) — guided the patent process for Hoag's discovery. The CSTC also coordinated efforts to introduce the new cleanup technique in the marketplace.

Some of those initial discussions included the possibility of creating a spin-off company. But years ago, Hoag had worked on a spin-off company for another technology — and he wasn't eager to revisit that experience. "It took an awful lot of time and energy," he says.

Instead, the university chose a licensing approach. "The technology transfer office really helped a lot, in terms of working through that process," says Hoag. "They identified companies to license it to."

In 2000, the CSTC began arranging nonexclusive licenses with about a half-dozen environmental remediation companies. At first, adoption of the new technology fell short of expectations. Says Michael Newborg, Ph.D., executive director of the university's CSTC: "The licenses we had in place weren't generating a whole lot of income, which implied that this particular technology wasn't being broadly used."

That changed in 2005, when the technology caught the attention of FMC Corp., a chemical company. FMC is the world's largest manufacturer of sodium persulfate, and the only company that produces it in North America. At the time, FMC already sold persulfate for many applications, from manufacturing printed circuit boards to bleaching hair in salons. Philip Block, Ph.D., remediation technology manager at FMC, heard about Hoag's work and saw the potential to expand that range of use.

"I was looking for new applications, so when I saw University of Connecticut had done a fair amount of work on the use of persulfate in the environmental market, I found that quite exciting," says Block.

The university negotiated an agreement with FMC in 2006 to give the company licensing rights for using activated persulfate in environmental cleanup projects. “It was definitely a pleasure working with the University of Connecticut,” says Block. “I think the relationship has been financially beneficial to both organizations.”

FMC now markets the product under the name Klozur Activated Persulfate. Whenever the company sells persulfate for environmental cleanup that uses Hoag’s technique, FMC is able to grant a sublicense for use of the technology. In return, the university receives a royalty on the amount of Klozur sold by FMC. That’s not the only advantage of the agreement. “Many more companies are using the technology now, compared to those we had licenses with initially,” says Newborg. That broader adoption gives the technology a better chance to prove its effectiveness.

A Novel Approach Becomes an Industry Standard

Before FMC established the licensing agreement with the university, the company had a very small environmental group. Now that business is burgeoning, says Block. Since the launch of Klozur Activated Persulfate, revenue for its environmental group has reached double-digit growth each year. Block notes that in the United States, the two driving forces behind environmental projects are regulatory requirements and real estate (properties that must be decontaminated before they can be sold and redeveloped).Even when real estate projects took a hit, demandstayed strong in other areas. Groundwater protection, for example,isn’t influenced by the U.S. economy. “The EPA is goingto make you clean up the site, regardless,” says Block.

Persulfate’s ability to target a range of hazards — chlorinated solvents as wells as petroleum-based substances — gives it an advantage over many other technologies, says Block. He’s observed several indicators that underscore the effectiveness of this particular decontamination technique. For starters, FMC has received many repeat customers for Klozur Activated Persulfate. Not only has the number of cleanup projects increased significantly, but the size of those projects has grown too. About five years ago, the average persulfate environmental project used about 10,000 pounds of Klozur Activated Persulfate. Today, that number can exceed 100,000 pounds for an average cleanup site, says Block: “That’s a good measure of success.”

The decontamination technique has come a long way in just a few years. At a major environmental conference in 2004, Block recalls only one persulfate presentation on the schedule. “In 2010, at the same conference, there were whole sections devoted to persulfate-related talks,” says Block. “It’s now considered one of the industry standards.”

In the United States alone, Klozur Activated Persulfate has been used in more than 600 decontamination projects, including large Department of Defense and Department of Energy sites. International demand for the product is rising too. FMC currently sells it in 16 countries, and customers outside the United States account for 20 percent of sales for Klozur Activated Persulfate.

More Innovation on the Horizon

“There have probably been a minimum of 100 journal articles written on different aspects of using this technology,” says Hoag. “I’m very pleased a technology I discovered has had the widespread positive environmental impact that it has.” That doesn’t mean he plans to kick back and bask in the glow of success. “People who know me know that I’m very passionate about this field,” says Hoag, who founded and directed the University of Connecticut’s Environmental Research Institute. “I’m very committed to applying technology to obtaining a cleaner planet.”

Hoag left the university in 2003 to do consulting work, helping companies apply his new persulfate method. In 2005, he channeled that entrepreneurial spirit into the co-founding of VeruTEK Technologies Inc., a Bloomfield, Conn., company that develops environmentally friendly decontamination technologies using green chemistry. His company funds the research of a few University of Connecticut chemistry faculty members and doctoral students. (VeruTEK jointly holds patents with the university for inventions by some of those faculty and students too.)

"We're working on licensing from the university some of the new technologies we've developed, some of which are an outgrowth of the original work I did on sodium persulfate," says Hoag.

He notes that more innovation is needed to keep up with hazardous waste. That's especially true for the chemical pollutants that proliferate in rapidly industrializing countries with lax environmental regulations. Still, Hoag has faith in the problem-solving power of science. "There's a lot of great work being done in this field," he says. The persulfate technique represents an important part of those ongoing efforts. By cleaning up contamination at its source, Hoag's discovery can do good things for the great outdoors.

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