Scientists are designing accelerators that one day could help clean the environment

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It's been 30 years since a pilot project in Miami-Dade County found that blasting wastewater with electrons could clean it up, removing all kinds of nasty stuff, from mircroorganisms to harsh chemicals.

All that was needed was some intrepid scientist or engineer to come up with an accelerator that was cost-effective, compact and user-friendly enough to clean wastewater on an industrial scale.

The world is still waiting for it.

Many countries have been inching forward in using accelerators for environmental remediation—removing toxic dyes from wastewater at a textile factory in South Korea, for instance, or sulfur dioxides and nitrogen oxides from flue gases at a power plant in Poland. But such devices are still too big and unreliable. In this country, studies and technology demonstrations continue, but are making incremental progress.

Physicists at Jefferson Laboratory are working on two designs they hope could change that.

Fay Hannon is dreaming up a low-energy, portable accelerator for environmental cleanup, while Gianluigi "Gigi" Ciovati is figuring out how to use a commercial cryocooler to stabilize a more powerful accelerator he's designing.

"I'm of a generation where environmental protection really weighs on your mind," said Hannon. "In this case, wastewater treatment is not my specialty, but providing the resource that can do that is."

Originally from England, Hannon considers herself an electrical engineer turned physicist. She's been at Jefferson Lab for 15 years working on a range of projects.

"I've always been interested in things working nicely and neatly and being able to predict it," she said.

Now she's trying to design a nice, neat and predictable accelerator.

"It's the wall-plug power, what you're pulling from the grid to operate this, and how much dose you get from that—that's the real step forward that we're trying to make," Hannon said.

Charles Bott, director of water technology and research at the Hampton Roads Sanitation District, has taken notice. A couple of years ago, Bott was giving a presentation at the lab and learned of Hannon and Ciovati's work. Bott was familiar with various demonstrations and studies over the years using electron beams to clean up wastewater, but the devices were always too big and expensive.

So HRSD signed on to consult on Hannon's project, and Bott says he's excited about the partnership and "cautiously optimistic" about the potential.

"I think it's important to note that, in my opinion, this is never going to be competitive with our existing technologies for water and wastewater treatment," said Bott. "It's to go after some very specific contaminants that are hard for our existing processes and technologies to deal with."

An accelerator would most likely augment—not replace—current treatments, which string together "various physical, chemical and biological treatment processes in whatever way it takes to meet a set of treatment objectives at the lowest cost," he said.

Electron beams work by breaking down water molecules into smaller charged particles that can effectively break down most contaminants.

One possible target, Bott said, would be 1,4-Dioxane, an industrial chemical found in deodorants, shampoos, cosmetics, dyes, greases, antifreeze and fluids used to de-ice planes. Another would be PFAS, or per- and polyfluoroalkyl substances, found in common consumer goods like cookware, food packaging and stain repellents, as well as firefighting foams.

Drinking water can be a source of PFAS, which makes effective water treatment an even greater imperative: The EPA says PFAS were found in the blood of nearly everyone that was tested for them.

Electron beam irradiation is already used in industry and in health care to pasteurize food and cook dog food, for instance, and to sterilize medical devices and in diagnostics. Hannon is also partnering with ScanTech Sciences, a Georgia-based food pasteurization company, to see if her design could sterilize liquid consumables.

"Our design is actually a lot more efficient than what is out there right now," Hannon said.

Her accelerator would measure about 2 meters long and fit inside a standard shipping container far smaller than Jefferson Lab's massive CEBAF accelerator, which speeds and directs electrons around an underground racetrack nearly a mile long, inside a tunnel lined with the liquid helium infrastructure needed to keep it supercooled. Hers would operate at room temperature at much lower energies, which would also make it safer to use.

She envisions the accelerator deploying one day to treat graywater at mobile military installations, to clean up hydraulic fracturing fluids and tailings ponds at oil sands mining operations, to strip mercury, nitrogen oxides and sulfur dioxides from flue gases, and to clean wastewater aboard cruise ships.

Or it could be used right here by HRSD to clean up wastewater before it's injected underground to replenish the Potomac Aquifer.

Hannon will be pursuing funding next year to build a prototype.

Ciovati's device is further along in development. His is a higher-powered, superconducting accelerator that would require cooling, but not by costly liquid helium. Instead, it would use an off-the-shelf cryocooler, far cheaper and already used in devices like MRI machines.

"We saw the convergence of the different technologies as an opportunity to apply our technology to a more direct societal need," Ciovati said. "We just saw these pieces of the puzzle and decided it was worth trying to put them together."

His accelerator would be relatively compact—about 6 meters long, 2 meters wide and 2 { meters high. Because it would operate at higher beam power, it could treat denser materials such as sludge or medical waste, and a greater flow of pollutants at bigger wastewater treatment or power plants, he said.

There's a bonus: The electrons trigger a chemical reaction that converts nitrogen oxides and sulfur dioxides into ammonium nitrate and ammonium sulfate, which are used to make fertilizer.

Originally from Italy, Ciovati has been with the lab for nearly 20 years. He's partnering in his accelerator design with General Atomics, a defense and technology development company based in California.

As a research facility under the Department of Energy, which is funding this work, Jefferson Lab pursues industry partners that can help test and spin off new technologies into the mainstream.

"We don't want to be in the business of building accelerators ourselves," said Hannon. "We're trying to provide the design and the building blocks and the improvements, and then industry would take up the manufacture and the use of that."

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