A solution for reclaiming valuable biofuel resources flushed down the drain

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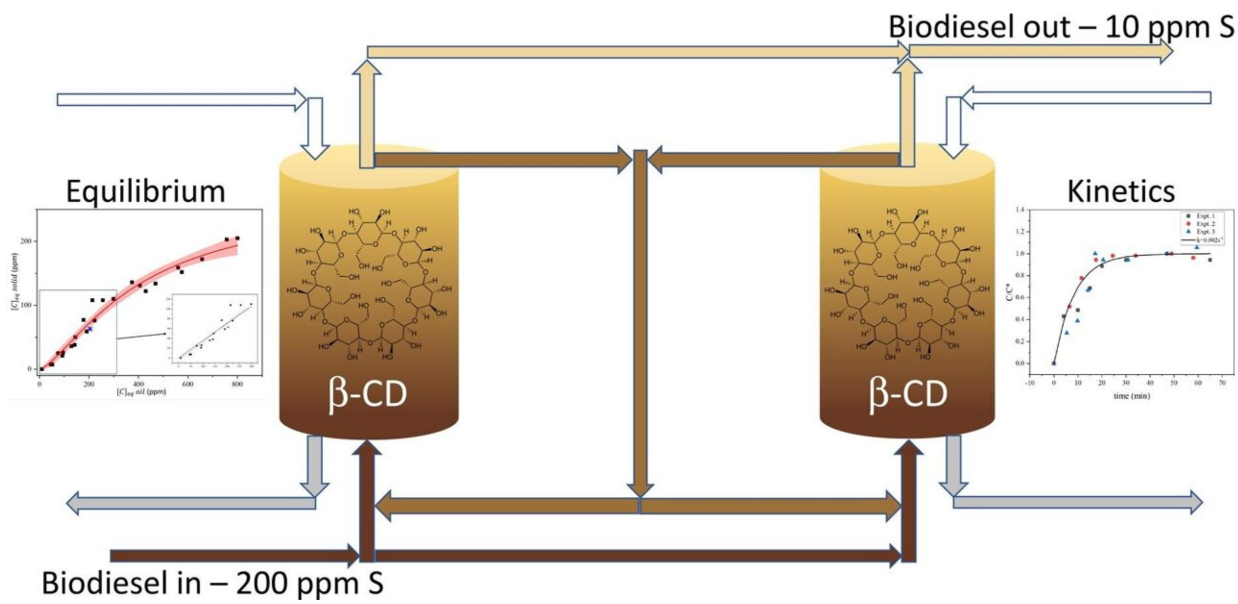

Graphical abstract. Credit: *Separation and Purification Technology* (2022). DOI: 10.1016/j.seppur.2022.122417

For the everyday products we use, a pattern has become numbingly familiar: Something is made, we use it, we throw it away. Yet, for a sustainable future—one where we don't simply extract and toss resources—we need to make this linear process circular, says UConn Department of Chemical and Biomolecular Engineering Emeritus Professor Richard Parnas.

Parnas and his team research biodiesel and how to make it out of waste resources. Parnas also co-founded REA Resource Recovery Systems, which supported UConn Chemical Engineering graduate student Cong Liu Ph.D. '22 to develop technology to improve a critical process of removing sulfur from biodiesel made from waste materials.

In this case, the materials originate from sewage, and the technology is being implemented in a project at Danbury's John Oliver Memorial Sewer Plant scheduled to go into operation in January 2023 that will convert fats, oils, and grease into biodiesel whose lifecycle emissions are more than 74% lower than petroleum-based diesel.

The FOG Problem

Parnas explains that, in one way or another, fats, oils, and grease (FOG) end up at the wastewater treatment plants, some of it delivered by truck, and some of it arriving via the main pipes. FOG is also contaminated with soaps, detergents, and of course, in this case, sewage. At wastewater treatment plants, the FOG is separated from the water and purified into something called "brown grease."

Dealing with FOG is also expensive because it must be moved off-site, either to a sanitary landfill or as is the case in Connecticut, an incinerator. Unless it is removed it can cause big problems for the plant, because FOG smothers the microbial communities needed to break the sewage down. This could lead to shutdowns lasting weeks to months, and can be disastrous for these critical sanitation facilities. The nature of the water treatment plants means it can be a tough sell to convince the plant's civil engineers to adopt new technologies.

"The consequences of failure are enormous, and this leads to a conservative type of industry where if they have something that works, they really don't want anybody to interfere with it, if the wastewater treatment plant is working, the general feeling is to leave it alone," Parnas says.

However, Parnas says once the plant operators understood that this technology is a means to dispose of FOG and that there would be zero interference with plant operation, their interest was piqued.

Parnas' technology takes the FOG, cleans it up, and makes it into biodiesel. The critical, and difficult, part is ensuring the produced biodiesel is clean enough, with as much sulfur removed as possible.

"Brown grease has anywhere from 600 to 1000 parts per million sulfur in various molecular forms," Parnas says. "The standard in the United States for biodiesel and other diesel fuels is 15 parts per million sulfur or less. In Europe and China, the standard is 10 parts per million. We must get about 99% of the of the sulfur out."

The plant in Danbury will do this in a process that first esterifies free fatty acids with methanol to make what's called a fatty acid methyl ester, which is the biodiesel molecule, explains Parnas. Then they trans-esterify any triglycerides in the mixture, as part of the process further cleaning the biodiesel to levels of around 200 parts per million sulfur—still not pure enough, explains Parnas.

"The technology that's being implemented in Danbury is what's called a vacuum distillation process where we heat the material up to about 400 degrees Fahrenheit and apply vacuum pressure," he says. "By doing that, we're able to take out the sulfur fractions and keep all the good biodiesel but this is an intensive process."

'A total shot in the dark'

The intensity of the process got Parnas and his team thinking that there must be a simpler solution. They began experimenting with many different types of filters and compounds, with little success, until they happened upon one that worked very well—a material called beta-cyclodextrin. They detail the work in a recently published paper in *Separation and Purification Technology*, and have filed a patent application to use the material in the process of making biodiesel.

"Cyclodextrins have been around for a while in the pharmaceutical and food industries because dextran is a carbohydrate and is basically non-toxic," Parnas says.

"It's used in enormous numbers of things at this point, for example, Febreze, the deodorizer spray has cyclodextrins in it, because cyclodextrins are excellent at absorbing odor-causing molecules. In the drug industry, cyclodextrins are good at stabilizing water-insoluble molecules so they can be put into a pill and go through a water-rich environment, like our own bodies, can get into the bloodstream, and then to target areas."

"We started asking ourselves if cyclodextrins might absorb the molecules we are interested in. It was a shot in the dark, and we got lucky because it worked very well."

After studying the kinetics of the reaction, the team designed a prototype process that will be implemented in future facilities, as sort of a version 2.0, says Parnas, and is slated for their next project, either here in Connecticut or in Washington State after some additional development work.

Raring, and ready to go

The Danbury plant is relatively small, treating around 10 million gallons of water per day, and the FOG reclamation facility will make about

300,000 gallons of biodiesel per year.

With hopes of expanding, Parnas says they have done a survey of all the waste treatment plants in Connecticut and come up with a plan involving three main hubs, one in Hartford, one in New Haven, and one other location in Connecticut where it would be possible to make approximately 10 million gallons a year of biodiesel—right here in Connecticut, with something currently considered waste.

"It seems like a lot, but it's not a large percentage of the total fuel that we use," says Parnas. "The more important thing is that we clean up a very nasty waste disposal problem we face worldwide, and in the cleanup effort we could make around two to three percent of the diesel fuel we use in the United States. We can help convert the problem into a revenue stream to support the cleanup efforts and have a small impact on the renewable energy landscape."

This is a great example of the possibilities within a circular economy, where things aren't flushed or thrown 'away' but where we find a new use for waste. Parnas points out that this is how things work in nature, where resources are readily recycled. Fortunately, this technology to circularize FOG is here, it can be widely deployed within a couple of years if the interest and support are there says Parnas,

"The technology is ready to go, right now."

More information: Cong Liu et al, Desulfurization of biodiesel produced from waste fats, oils and grease using β-cyclodextrin, *Separation and Purification Technology* (2022). DOI: 10.1016/j.seppur.2022.122417

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