Case Study: Clearing Harmful Algal Blooms

AECOM, Ecosa, ENGraphted, and Opto 22 team up for a new solution to a complex environmental problem

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THE CHALLENGE

If you were headed to Florida as a tourist in 2016, you would have been sadly disappointed. Due to massive algae blooms along the east coast, Governor Rick Scott declared a state of emergency and closed all beaches in three counties.

In July 2018 the problem came back, but worse: beaches on both coasts were closed and invasive, toxic blue-green algae choked many freshwater lakes, rivers, and residential waterways as well. The freshwater problem originated in Lake Okeechobee, the largest lake in Florida. Massive rainfall that year required the U.S. Army Corps of Engineers, which manages the lake's levels, to discharge billions of gallons of water to prevent flooding. The water coursed through the Caloosahatchee and St. Lucie Rivers, bringing with it rich nutrients that fueled the algae overgrowth downstream.

Faced with the ugly, slimy, stinky water, not just tourists but residents and business owners who did not have the ability to leave the area were stuck and left to suffer. The toxic slime threatened human health and devastated tourism-related businesses, as dead fish and aquatic life piled up along the shorelines.

Algae in Lee County, Florida (August 9, 2018)

An Increasing Problem

Harmful algal blooms, or HABs, are an increasingly complex and dangerous environmental problem worldwide in both freshwater and saltwater. The Environmental Working Group (EWG), a watchdog group for environmental issues, tracked an increase of more than 500% in news reports of algal blooms from 2010 to 2020 in the U.S. Although not all of these blooms were toxic, EWG notes that even nontoxic blooms "may have a negative effect on recreation, tourism, local economies, aquatic ecosystems and wildlife."[1]

Dense blooms block sunlight from reaching underwater plants and animals that need it and can clog the gills of fish and other aquatic animals, so they cannot breathe. When the bloom dies off and decays, it uses up oxygen in the water, killing fish and producing noxious odors. Some bloom-forming algae produce potent toxins that can harm the health of humans and land animals as well.

The U.S. National Oceanic and Atmospheric Administration (NOAA) estimated that "HABs cause about $82 million in economic losses to the seafood, restaurant, and tourism industries each year."[2]

HABs pose a severe problem for drinking water reservoirs, because the toxins are challenging to treat and the algae can affect treatment processes. Sometimes treatment can produce potable water, but if it doesn't, affected water districts must provide bottled water to customers for drinking. As a 2019 California Department of Water Resources news bulletin reported: "Common water purification techniques such as camping filters, tablets, and boiling do not remove toxins."[3]

1. https://www.ewg.org/interactive-maps/algal_blooms/map/
2. https://oceanservice.noaa.gov/facts/why_habs.html
3. https://water.ca.gov/News/News-Releases/2019/May/Lake-Perris-Algal-Bloom-Closure-May-17-2019

Existing Approaches

How can these dangerous HABs be treated or controlled? In one of four ways, according to the U.S. National Office for Harmful Algal Blooms[1]:

- **Environmental**—These methods change the habitat that favor HABs, for example by controlling the nitrogen and phosphorus pollution that feeds the blooms, or by circulating the water.
- **Biological**—In some cases a parasite is used to kill the algae, but the longer-term effects of introducing the parasite in the water are unclear.
- **Chemical**—Sprinkling the water's surface with copper sulfate is a common chemical method. The copper sulfate kills the algae, but it is toxic to fish. And while the green color goes away for a couple of months, nutrients remain, so the problem recurs quickly. Hydrogen peroxide is also widely used as a chemical agent to kill cyanobacteria, but it can also be harmful to aquatic life.
- **Physical or mechanical**—For example, clay can be spread on the water's surface. The tiny, dense clay particles combine with other particles in the water, including algae cells, and then sink to the bottom.

These methods can be effective to an extent, but they have drawbacks. Environmental treatments are important for the future, especially reducing the nutrient pollution that feeds algal blooms, but they take time and require legislation or regulatory changes for industry, farmers and ranchers, and residents. Biological treatments are risky in the long term, as their future effects are unknown.

Chemical treatments may be toxic to fish, and both chemical and physical treatments just push algae to the bottom, where they decompose. But algae cells contain about 70% carbon, and when they decay they can release methane, a powerful greenhouse gas that warms the atmosphere 80 times more than carbon dioxide in the short term. And even though the algae are killed, the nutrients remain, so the problem comes back quickly and often to a greater degree than before the treatment.

Even nontoxic blooms "may have a negative effect on recreation, tourism, local economies, aquatic ecosystems and wildlife."

- Environmental Working Group

Lake Elsinore in California was closed for recreation due to dangerous levels of algal toxins in all but five weeks from August 2022 to April 2023.

Clearly a new solution is needed, and Dan Levy at AECOM has found an excellent one: physically remove both the algae and its nutrients, and return clear, fresh water.

THE TEAM

AECOM is a large engineering firm that focuses mainly on infrastructure, both within the U.S. and globally. Due to the size and complexity of their projects, the company often coordinates with universities and government agencies. Dan Levy, National Director of Algae for AECOM, and Bill Colona, Operation Manager for Algae, have made it their mission to develop technologies that can mitigate and restore nutrient-impacted waterways.

During their research for a new solution, Dan and Bill collaborated with David Pinelli, president of Ecosa Process Technologies and a technical expert in liquid/solid separation systems. David worked at a company that was developing algae-based biofoam to replace commercial plastics, and he knew that the process he developed for recovering algae could be effectively scaled up. Dan recognized that this could be an innovative solution for waterways, and the two then collaborated to develop the patent-pending Hydronucleation Flotation Technology (HFT) for harvesting algae

HFT separates algae from water without rupturing the algae cells—a key point, because algae cells release toxins

1. https://hab.whoi.edu/response/control-and-treatment/

when ruptured. And because algae contain nutrients, the process also removes the nutrients so they cannot trigger another bloom.

To advance the technology, David reached out to Guy Chetrit, P.E., an old friend with whom he'd worked in a previous company. Guy's expertise is industrial process design and automation, and with a strong background in the environmental sector, he was a good fit to help execute the HFT process at full scale. Familiar with the engineering aspects relevant to this technology, Guy designed an automated system in close collaboration with David and Dan.

Guy notes that he is a mechanical engineer who learned early on the value of automation. He was first exposed to Opto 22 hardware 20+ years ago and kept up with the company's technology offerings through various projects. In 2000 he formed ENGraphted Engineering Solutions. For this state-of-the-art algae harvester, Guy chose Opto 22's latest technology, *groov* EPIC®.

"David and Guy are almost an extension of staff," says Dan Levy, and the team "came up with a unique solution."

Despite having the technology, there was still a gap in engineering a solution that would work effectively with nature in restoring damaged ecosystems. To address this issue, Dan contacted Dr. Tammy Karst-Riddoch, AECOM's senior limnologist and algae expert, who is based in Canada and has extensive experience in studying algae and devising strategies for managing HABs. Tammy's expertise filled the gap.

THE PROCESS

The resulting process is a comprehensive solution to one of our nation's most complex and environmentally challenging problems.

Wild algae are harvested using the hydronucleation flotation technology to gently separate algae from the water column. Algae are naturally buoyant and accumulate near the water surface to photosynthesize. The HFT separates the algae from the water column using extremely small (nano size) air bubbles, which take advantage of the algae's proclivity to float.

HFT prevents damage to the algae cells and allows for efficient removal of nutrients and atmospheric carbon, while preventing the release of cyanotoxins.

The process is simple and effective:

- Water is pumped from the affected waterway to the HFT unit. A treatment solution helps the algae coagulate and flocculate into larger particles before separation.
- The water containing coagulated algae is then directed to a flotation chamber. Nano-sized bubbles are introduced into the chamber; they attach to the algae and carry it to the surface as the bubbles rise. Once enough algae floc has accumulated on the surface, a skimming system physically removes the algae from the water column.
- The clean, clarified water is then returned. The returned water is highly oxygenated from the hydronucleation process and provides additional benefits by increasing oxygen levels in the waterway, which can be very low in these impacted water bodies.
- The recovered algae biomass, rich in nutrients and carbon, can be transformed into a variety of green products including biofertilizers, clean energy (both biocrude and biogas), and commercial biofoam products, which will help offset the demand for fossil fuels.

Although environmental conditions (temperatures, turbidity, pH, chlorophylls, dissolved oxygen, and more) vary in HAB-impacted waterways, the HFT can be designed

Recovered algae biomass from the harvesting operations

From left to right: raw lake water, HFT-clarified water, and recovered algae biomass

and operated to effectively remove the algae in all cases. For each location, using bench scale testing techniques, David dials in the harvester treatment regimen to optimize performance.

MECHANICAL DESIGN

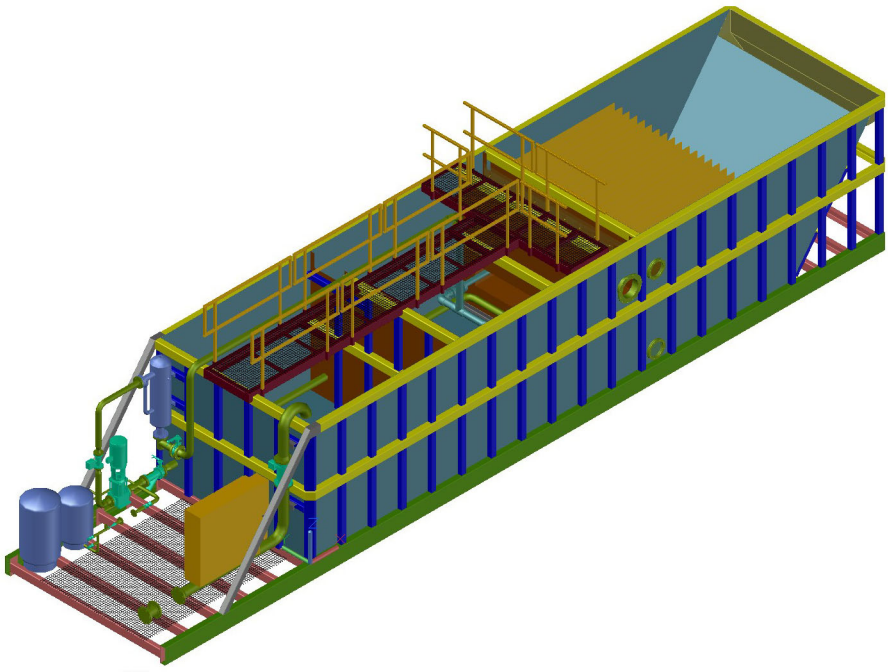
Turning the concept and processing requirements into a full-scale functional system is where Guy Chetrit came in. The processing skid was first modeled in 3D CAD to visualize the design progression in detail. Process control parameters include flow rates, mixing effectiveness, contact times, hydraulic loading, solids loading, skimming rate, and more. Structural considerations were closely modeled as well.

The system was designed for outdoor placement in remote locations and is self-sufficient. Only an external power source is required, either a generator or a power grid connection, if available. Cellular telemetry provides remote connectivity wherever cellular service is available. Electrical components are rated NEMA 4x, and all components are corrosion resistant. Not only wetted components, but the entire skid—including its structural members—is constructed of stainless steel.

To reduce material costs and use raw materials efficiently, the team produced creative solutions that decrease waste. They minimized the use of plastics for sustainability and environmental reasons, and developed custom structural profiles to meet size and strength requirements.

Individual steel components were optimized for strength. They used finite element analysis (FEA) to model and evaluate the completed skid under all loading conditions, from analysis for transportation and hoisting of the empty system, to stationary hydrostatic loading when all compartments are filled with water.

Fabrication as well as field deployment were ongoing considerations. Detailed and certified fabrication drawings were released incrementally to meet deadlines. Guy, David, and the fabrication facility closely collaborated on design progression, with shop visits for inspections and testing.



Schematic of a one million gallons per day (1 MGD) HFT algae harvester

CONTROL SYSTEM

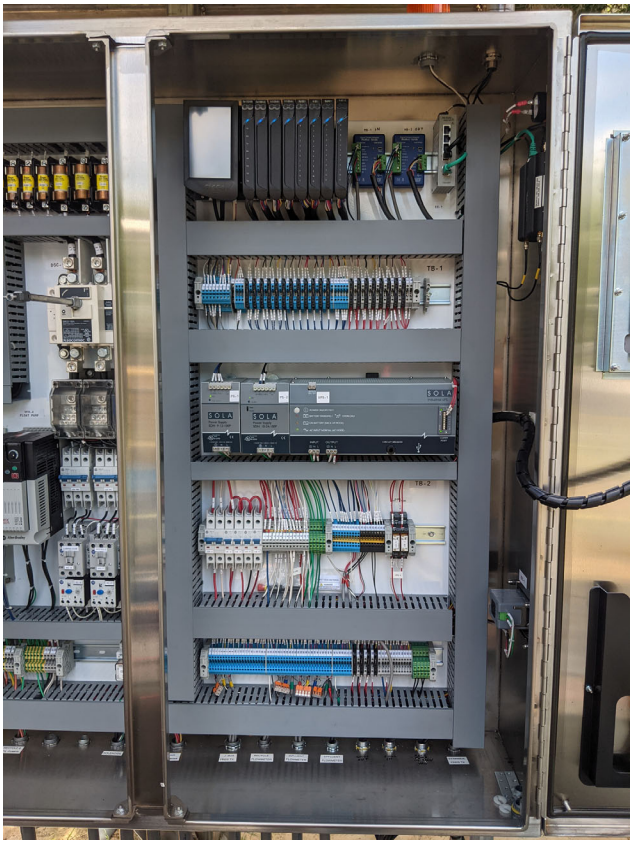
To control the process, collect and distribute data, and provide a user interface for operators and observers, the algae harvester employs a *groov* EPIC system from Opto 22. Guy Chetrit has used Opto 22 products for some years and has been to Opto 22 factory training twice, most recently in late 2019, when he trained on the *groov* EPIC system.

He noted the ways in which the EPIC differs from other industrial controllers and chose EPIC for the harvester system based on the features he needed for the project:

- Real-time control
- Easy-to-use tools for programming and HMI
- USB flash drive capability for logging data
- Built-in Modbus communications via a USB-to-serial adapter
- VPN client
- Additional cloud communication capabilities for future expansion

The harvester's *groov* EPIC system consists of an industrial Linux®-based edge programmable industrial controller, power supply, and the following I/O modules, all mounted on a single chassis:

- One 12-channel AC discrete input module
- One 12-channel DC discrete input module



The *groov* EPIC System (center top) provides real-time control, connectivity to all parts of the process, data storage and communication, and the operator interface.

"I've used Opto 22 hardware on many projects in the past 20 years. The components are made in the U.S. and their exceptional technical support is in the U.S. Most of the components have a lifetime warranty and the cost is appealing. It's a no-brainer to use Opto."

- Guy Chetrit, P.E., ENGraphted Engineering Solutions

- Three 8-channel AC/DC electromechanical relay output modules
- One 24-channel analog input module
- One 8-channel analog output module with chassis-powered loop
- One 4-channel serial communication module

The system also includes a cellular router for remote access and for automated reporting via email. Because the EPIC system was designed to handle data communication from the edge of a network to the cloud, it offers built-in security features and connectivity options in addition to controlling the process and communicating with other elements of the overall system.

Guy uses one of the USB ports on the EPIC processor for removable data storage. When the program detects end-of-day, whether at midnight or during an orderly shutdown, data summaries are automatically emailed for off-site storage and reporting, and a new daily file is started.

Data reports include operational parameters, power usage, system status details, and an extensive set of analytical data collected via influent and effluent water quality sondes (sounding devices containing sensors) attached to the harvester.

The program also detects end-of-month events and starts a new monthly file at that point. Both daily data and cumulative monthly data are stored locally and emailed daily, with a daily summary in the body of the email.

Modbus is used for communication to the multi-parameter sondes. Separate influent and effluent sondes each include multiple probes that monitor water quality and system performance, including temperature, pH, turbidity, chlorophyll levels, dissolved oxygen, and more. The sondes communicate via a Modbus adapter directly to the serial module on the EPIC. The EPIC's programming controls the

sensors' reading, cleaning, and recording cycle.

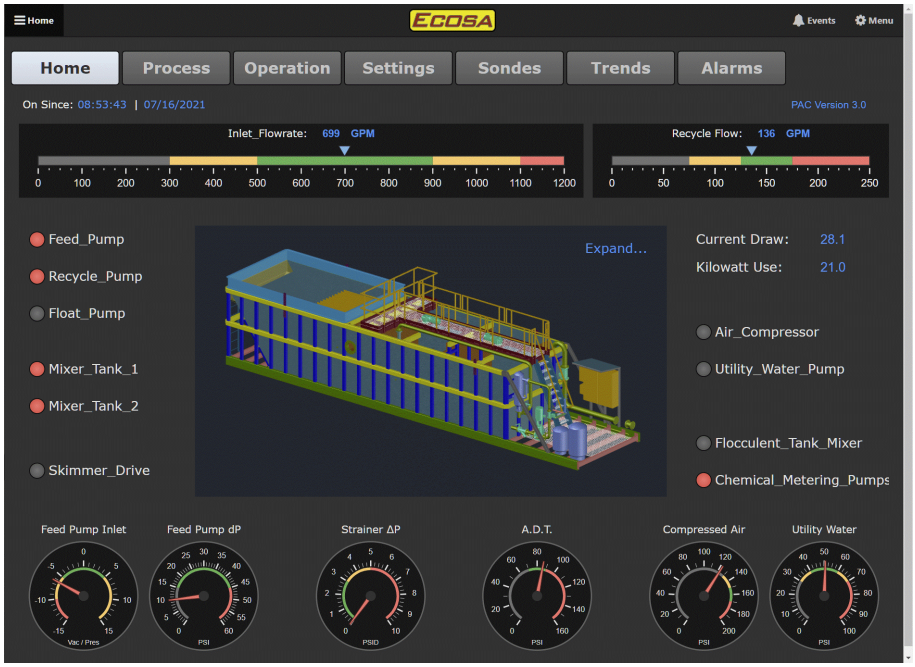
Guy reached out to Dave Engsberg with Tellus, a long time colleague and an Opto 22 expert, for help in developing Modbus communication, data handling, and emailing charts and subroutines.

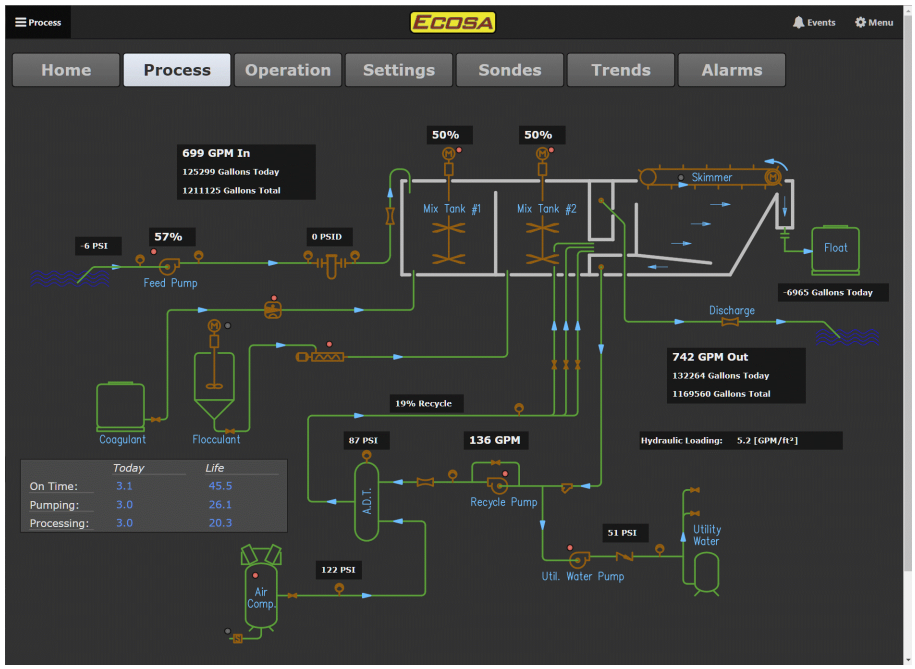
The HMI Guy built using the EPIC's included *groov* View® software is "permission-driven," he explains, "so an operator sees different screens than someone reviewing data and operations."

The HMI consists of several screens. Operator screens are for setting and operating pumps, pressures, tanks, agitator, and the skimmer, which can run continuously or intermittently. Other screens show alarms, power usage, processing, data from the process and sondes, and trends over time.

The HMI is accessed via a panel-mounted touchscreen connected to the HDMI port on the EPIC. The HMI can also be accessed remotely through the cellular router.

In *groov* View, Guy adapted all HMI screens to a fully functioning mobile device interface so that operators can use it in Opto 22's *groov* View app. (The screenshots that follow show the touchscreen view, not the mobile view.)



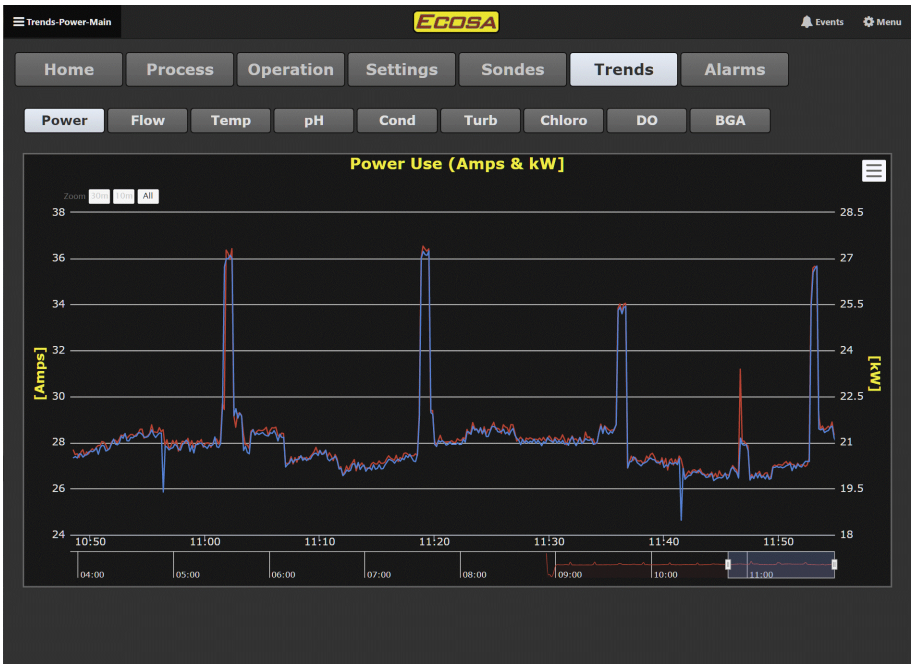


Guy Chetrit built the operator interface using *groov* View, HMI software included with the *groov* EPIC. The HMI can be viewed locally and by authorized users on PCs or mobile devices anywhere in the world.

"This equipment is totally accessible for me coming as a mechanical engineer," says Guy. "I can build a system without being a system integrator.

"I've used Opto 22 hardware on many projects in the past 20 years. The components are made in the U.S. and their exceptional technical support is in the U.S. Most of the components have a lifetime warranty and the cost is appealing. It's a no-brainer to use Opto."

AECOM technicians operate each system, and the VPN client on the *groov* EPIC processor makes it possible to securely access the EPIC from just about anywhere.



"They love the remote access, and so do I," Guy says. From his office in Minnesota, he can log in at any time to any unit in the field, just to check on it or to update its control program or HMI.

Guy has found this project rewarding. "It's nice to solve a problem that hasn't been solved in this way before. And have the liberty to do it high class—with all stainless steel construction and an elaborate control system."

Now that the prototype has proved successful through testing and deployment at multiple sites, Guy and David look forward to building additional systems based on their successful mechanical and control system designs.

THE RESULT

Today, the team has developed a comprehensive restoration program that can be scaled to any size and used throughout the U.S.—and the world. The technical process has proven to be safe, highly effective, and efficient, achieving algae removal percentages in the high 90s. And unlike other methods, it removes nutrients as well as algae, so blooms are less likely to recur.

"We turned on the harvester at 8:00 a.m. and by noon had a biocrude product that can be further processed for fuel."

- Dan Levy, AECOM

The algae biomass solids offer many opportunities for beneficial use to promote sustainability and help decarbonize our planet. The team is actively exploring several promising uses, including conversion to biocrude oil, biofertilizer, biofoam, and bioink. In all forms of reuse, toxins are destroyed in the transformation process.

To provide a closed-loop system with virtually no waste, AECOM has been working with industry leaders to transform the recovered algae into clean, carbon-neutral energy. Last summer in Ohio, AECOM conducted the first ever field-scale algae-to-fuel demonstration project. A 1-MGD harvester was used to remove algae from Harsha Lake, a drinking water source and recreational water body outside of Cincinnati.

On the spot, the recovered algae was transformed into a biocrude oil using hydrothermal liquefaction. This process uses heat and pressure just like the natural process of producing oil, but it's completed in 30 minutes instead of the millions of years that nature takes.

Biocrude product from algae, ready for processing into fuel

"We turned on the harvester at 8:00 a.m. and by noon had a biocrude product that can be further processed for fuel," says Dan.

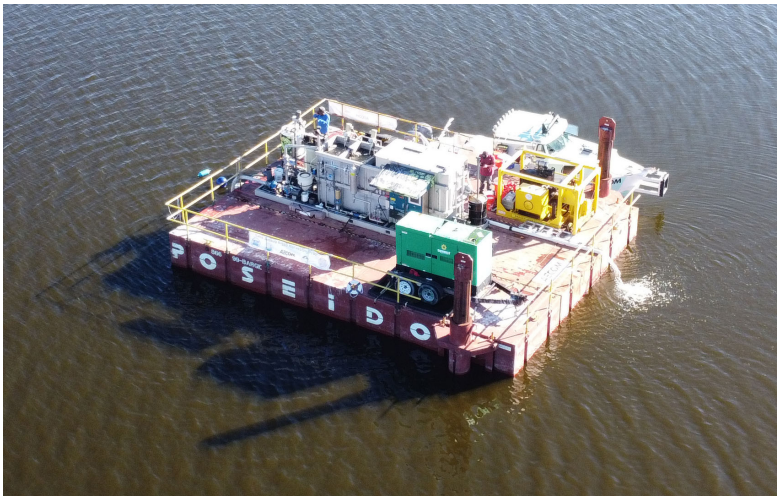
HARVESTER OPTIONS

Both land-based and barge-mounted systems are in use now, and more are in production.

The 700 GPM (1 MGD) skid-mounted HF-1016 S harvesters are modular and can be arrayed in semi-permanent operations. Fully mobile HF-1016 M harvesters can also be arrayed in batteries for processing many millions of gallons per day. A smaller version of the harvester, the 150 GPM HF-0450, is barge mounted.

With their larger treatment volume and grid-based electrical usage, the land-based systems are more cost-effective than barge systems. But barges can move easily within a water body to clogged areas for emergency cleaning, or to follow as algae moves. Both systems have their uses, both have been proven in action, and both are currently operating.

Observers watch the land-based 1 MGD harvester operating at the award-winning project site at Harsha Lake in Ohio, September 2022.



A barge-mounted HFT algae harvester removes algae and nutrients in Lake Jesup, Florida.

PUBLIC SUCCESS AND AWARDS

AECOM's algae harvesters have proven their value in several locations in Florida, New York, Ohio, and California.

David's vision was always an automated system that required a very limited onsite presence. He knew that Guy's process control expertise and Opto 22 products would achieve a system that's not labor intensive but automated, with technicians able to monitor and control the harvesters either onsite or remotely. And Guy can use his office in Minnesota as a central command to monitor and update all systems globally.

Authorized customers and observers can check their units from anywhere as well. AECOM doesn't want anyone to think the harvester is a black box. Dan believes it's much better for interested people—for example, local officials and residents near a lake that's being treated—to see the data, the process, and the results.

"People need to understand how it works and what it does," he says.

To date, the technology has won several prestigious awards:

- Three Environmental Business Journal awards
- An Impact Award from the Federal Laboratory Consortium of 1

Accepting the FLC Impact Award, March 29, 2023 Left to right: Bill Colona, David Pinelli, Tammy Karst-Riddoch, Marissa Campobasso (USACE), Martin Page (USACE), Linda Burger (FLC Chair), Dan Levy

- An Innovation of the Year award from the U.S. Army Corps of Engineers, Engineer Research Development Center

WHAT'S NEXT?

By harnessing the power of algae to consume nutrients and atmospheric carbon, it's now possible to remove the key nutrients that fuel HABs by harvesting algae.

The solution AECOM's algae harvesters provide is a win-win-win. They restore waterways, help decarbonize the planet, and produce a biomass rich in carbon and nutrients that can be converted to clean energy, fertilizer, and other products. This process not only provides clear, safe water but produces minimal to zero waste. And in March 2022, AECOM entered a new partnership with Genifuel to produce aviation fuel from the biomass.[1]

As more harvesters are put in place, Guy plans to add cloud-based data processing, onsite video, and other elements using the *groov* EPIC control system.

To date the algae harvesters have been designed for fresh water, but as Florida's experience since 2016 illustrates, harmful algal blooms are also a severe problem in salty water. This summer, Dan Levy reports, AECOM and the team will start looking into similar treatments for brackish water.

1. https://aecom.com/press-releases/aecom-enters-strategic-partnership-with-genifuel-to-transform-algae-and-wastewater-biosolids-into-sustainable-aviation-fuel/

About AECOM

AECOM is the world's trusted infrastructure consulting firm, delivering professional services throughout the project lifecycle—from planning, design, and engineering to program and construction management. On projects spanning transportation, buildings, water, new energy, and the environment, our public- and private-sector clients trust us to solve their most complex challenges. Our teams are driven by a common purpose to deliver a better world through our unrivaled technical expertise and innovation, a culture of equity, diversity and inclusion, and a commitment to environmental, social and governance priorities. AECOM is a Fortune 500 firm and its Professional Services business had revenue of $13.3 billion in fiscal year 2021.

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Website: https://aecom.com/

About Ecosa

Ecosa Process Technologies is a platform for applying decades of diverse process experience in the areas of industrial wastewater treatment, product recovery, and water reuse. Ecosa provides Process Optimization, System

A closer look at the harvester on the barge

Case Study: Clearing Harmful Algal Blooms

Upgrading, and Process Consulting Services and innovative, high-rate flotation clarification technology.

Contact: David Pinelli
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Website: www.ecosa.net

About ENGraphted

Guy Chetrit, as the Principal and Licensed Professional Engineer (PE) at ENGraphted Inc., provides cross-discipline engineering design and consultation. With 30+ years of experience in the process industry, we provide unique solutions stemming from experience, integrity, and ingenuity. From worksite visits, to phone consultation, to complete fabrication, to project management and startups, all with vast operational experience in the industry, we welcome your challenging projects.

Contact: Guy Chetrit, P.E.
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ABOUT OPTO 22

Opto 22 was started in 1974 by a co-inventor of the solid-state relay (SSR), who discovered a way to make SSRs more reliable.

Opto 22 has consistently built products on open standards rather than on proprietary technologies. The company developed the red-white-yellow-black color-coding system for input/output (I/O) modules and the open Optomux® protocol, and pioneered Ethernet-based I/O.

Famous worldwide for its reliable industrial I/O, the company in 2018 introduced *groov* EPIC® (edge programmable industrial controller). EPIC has an open-source Linux® OS and provides security features, connectivity to PLCs, software, and online services, plus

data handling and visualization, in addition to real-time control.

groov RIO Ethernet-based edge I/O modules, introduced in 2020, include I/O and IIoT software in a compact industrial package that goes anywhere.

All Opto 22 products are manufactured and supported in the U.S.A. Most solid-state SSRs and I/O modules are guaranteed for life.

The company is especially trusted for its continuing policy of providing free product support, free online training, and free pre-sales engineering assistance.

For more information, visit opto22.com or contact **Opto 22 Pre-Sales Engineering**:

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