H2Ohio Technology Assessment Program (TAP)

Final Report

Assessment of Nutrient Management Technology Submission

Algae Harvesting Hydronucleation Flotation Technology (HFT)

January 2022

TETRA TECH

EXECUTIVE SUMMARY

AECOM Technical Services, Inc. (AECOM) of Cleveland, Ohio has submitted a technology proposal Innovative Algae Harvesting Hydronucleation Flotation Technology (HFT) for Nutrient Removal, Recovery, and Harmful Algal Bloom (HAB) Mitigation to Ohio Environmental Protection Agency's (Ohio EPA) H2Ohio Technology Assessment Program (TAP) for the purpose of addressing the Lake Erie algal blooms and associated nutrient loading. HFT currently addresses two of the TAP objectives, while the three other objectives are being studied to address potential benefits from use of HFT.

HFT essentially consists of a treatment train for water high in total suspended solids (TSS). A small amount of chemical coagulant is added to, with the help of micro-bubbles, float the floc to the surface where it is gently skimmed and removed as a side stream. The bulk of the water is returned to the water body stripped of the TSS and the nutrients, toxins, and carbon embodied in them. The process works most notably with algae at the surface. The process is reported to be so gentle that no cyanotoxins are released in the process. HFT may be the only technology that physically removes HABs from the water body, although the process could also be used on agricultural runoff and manure lagoons addressing all five TAP objectives.

The boundary of AECOM's conceptual model ends at "beneficial reuse." These include biocrude, biogas, fertilizer, composts, biofoam, and waxes but none of these, except for biocrude described in the HABITATS Phase 1 Report (USACE, 2020), were fully developed in terms of costs, revenue, or any potential final waste streams requiring discharge to water bodies or landfills. Because of the numerous forms of beneficial reuse, these final wastes are considered minor.

No obvious fatal flaws were identified. A potential imitation could be the lack of capital and operation and maintenance (O&M) funding if potential beneficial reuse revenues are not included in the enterprise budget. Another key challenge is the embodied nutrients and toxins in the algal biomass. AECOM described conceptual ways to address these challenges but they were not fully evaluated. The transformation and fate of nutrients in the watershed is a common hurdle for any technology that seeks to reduce HABs. The fate and effects of the cyanotoxins can be mitigated through heating the waste stream biomass (part of the biocrude process); other methods could exist but were not described.

The technology has been demonstrated at least 10 times at various locations in Florida and New York. Removal efficacy of algae and associated nutrients and toxins are remarkably consistent throughout the range of scales (0.25 to 1 million gallons per day [MGD]), between 70% and 99%. Due to the high number of demonstrations, AECOM has a wealth of validated data and even third-party evaluations (e.g., the United States Army Corps of Engineers' [USACE] HABITATS program). Using AECOM and third-party data, removal rates were estimated to be approximately 21.0 pounds (lbs.) of Nitrogen (N) and 2.8 lbs. of Phosphorus (P) removed per MGD of process inflow. The expected capital cost of a 1 MGD treatment system amortized over a 10-year payment period is approximately $75,000. We estimate, using a discount rate of 3 percent, this represents a year 10 capital cost of $659,000. The "discount rate" is a financial term indicating the interest rate applied to the future value of a payment or revenue and is used in present value calculations. The operational costs associated with the system operation using Supervisory, Control and Data Acquisition (SCADA) telemetry were estimated at $250,000 per year. With economies of scale, the USACE HABITATS Phase 1 reported the cost of physical algae removal to be about \$0.30/lb. and for P removal about \$80/lb. with algae concentration of 100 milligrams per liter (mg/l) and a facility size of 100 MGD. Nitrogen removal costs are thought to be about 7.6 times less than for P because 7.6 times more nitrogen is removed than P (on a mass basis) per unit volume of water.

The HFT technology is highly modular, customizable, and scalable. A full-scale demonstration or permanent deployment would possess the ancillary land, energy, algae/TSS harvesting and beneficial reuses appropriate for a particular location. The core technology is the HFT process which is proven. What is not proven are the beneficial reuses and their market demand. These may reveal limitations on the deployment of the HFT process at scales larger than demonstration. Therefore, we recommend that a demonstration under the TAP program include one or more beneficial reuses using the output of the HFT system as feedstock or use the HFT system to intercept algae-laden intake for municipal water treatment plants.

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ACRONYMS/ABBREVIATIONS

Acronyms/Abbreviations	Definition
AECOM	AECOM Technical Services, Inc.
AOP	Advanced oxidation process
Chl-a	Chlorophyll-a
CLA	Chautauqua Lake Association
DAF	Dissolved air flotation
DCS	Design and consulting services
ERDC	Engineer Research Development Center
FDEP	Florida Department of Environmental Protection
HAB	Harmful Algal Bloom
HABITATS	Harmful algal boom interception, treatment, and transformation system
HASP	Health and safety plan
HFT	Hydronucleation flotation technology
HMI	Human-machine interface
HTL	Hydrothermal liquefaction
kWh/day	Kilowatt hour per day
lb.	pound
lbs.	pounds
MC	microcystin
mg/l	milligrams per liter
MGD	Million gallons per day
N	Nitrogen
NELAP	National Environmental Laboratory Accreditation Program
NPDES	National Pollutant Discharge Elimination System
NSF	National Science Foundation
O&M	Operation and maintenance
Ohio EPA	Ohio Environmental Protection Agency
P	Phosphorus
ppb	parts per billion
QAPP	Quality Assurance Project Plan

Acronyms/Abbreviations	Definition
RFT	Request for technologies
SCADA	Supervisory, control and data acquisition
TAP	Technology Assessment Program
Tetra Tech	Tetra Tech, Inc.
TKN	Total Kjeldahl nitrogen
TN	Total nitrogen
TP	Total phosphorus
TSS	Total suspended solids
U.S. EPA	United States Environmental Protection Agency
USACE	United States Army Corps of Engineers
WET	Whole effluent toxicity
WWTF	Wastewater treatment facility

1.0 INTRODUCTION AND BACKGROUND

H2Ohio (http://h2.ohio.gov) is Ohio Governor Mike DeWine's comprehensive, data-driven water quality plan to reduce Harmful Algal Blooms (HABs), improve wastewater infrastructure, and prevent lead contamination. Governor DeWine's H2Ohio plan is an investment in targeted solutions such as :

- Reducing phosphorus runoff through increased implementation of agricultural best management practices and the restoration of wetlands;
- Improving wastewater infrastructure;
- Replacing failing home septic systems; and
- Preventing lead contamination in high-risk daycare centers and schools.

HABs have been a concern in Lake Erie for decades, and the State of Ohio has a long history of developing solutions to address them. In support of these efforts, state agencies are often presented with new approaches for addressing HABs. These approaches often involve technologies and products that are typically innovative, can be proprietary, and span multiple scientific disciplines. To evaluate these proposals for their efficacy and feasibility, the Ohio Environmental Protection Agency (Ohio EPA) worked with the Ohio Lake Erie Commission to create a public advisory council—the Technology Assessment Program (TAP) Team. The H2Ohio TAP Team is comprised of representatives from the private sector, public sector, trade associations, and non-profit companies. The H2Ohio TAP team is conducting an evaluation of technologies designed to treat, control, and reduce HABs in the Lake Erie watershed. H2Ohio initiated the TAP to solicit and evaluate technologies that support one or more of the following five goals:

1. Reduction of nutrient loading to rivers, streams, and lakes;
2. Removal of nutrients from rivers, streams, and lakes;
3. Reduction of the intensity or toxicity of algal blooms;
4. Recovery of nutrients from animal waste; and
5. Improvement of nutrient removal in wastewater treatment systems.

The H2Ohio TAP Team worked to solicit and prioritize technology proposals for further review. A Request for Technologies (RFT) was developed and issued by Ohio EPA in November 2020 (H2Ohio TAP, 2020). The H2Ohio TAP conducted a thorough evaluation of the 40+ proposals received in response to the RFT and selected 10 technologies for further evaluation. The developers of these 10 technologies were given an opportunity to provide additional information and supporting data to allow an independent evaluation of their technology by a third party, Tetra Tech.

As a contractor to the Ohio EPA, Tetra Tech conducted an independent third-party evaluation of the 10 technologies selected by the H2Ohio TAP team. The goal of the evaluation was to provide a general assessment of the potential effectiveness, implementability, readiness, and cost of deploying each technology. Select technologies may eventually be demonstrated in the field under future H2Ohio programs.

2.0 PURPOSE

The primary purpose of the technology assessment and evaluations was to conduct a comprehensive scientific evaluation of the selected technologies to determine if and how they could be utilized to address HABs in Lake Erie.

Based on input from Ohio EPA and the H2Ohio TAP team, Tetra Tech established primary (P1 & P2) and secondary (S1 & S2) objectives for the third-party evaluation program. The primary objectives are critical to the technology evaluation and involve conclusions regarding technology performance that are based on quantitative and semi-quantitative data. The primary objectives for the evaluations of the participating technologies are as follows:

- P1: Effectively assess the performance, cost-effectiveness, and reliability data gathered from each vendor with regard to one or more of the 5 H2Ohio goals:
  - Reduce nutrient loading to rivers, streams, and lakes:
  - Remove nutrients from rivers, streams, and lakes:
  - Reduce the intensity or toxicity of algal blooms
  - Recover nutrients from animal waste:
  - Improve nutrient removal in wastewater treatment systems, specifically with small (e.g., lagoon) and decentralized systems
- P2: Ensure that the evaluations are completed by appropriate personnel using a documented, consistent approach and level of detail, to include:
  - Proof of concept review
  - Fatal flaw analysis
  - Review of previous implementation of the technology or similar technologies
  - Review of data quality objectives
  - Review of quality assurance/quality control procedures and reports
  - Evaluation of scalability
  - Information gap evaluation
  - Evaluation of cost; both total and by unit, such as nutrient reduced/removed
  - Feasibility review for a proposed demonstration project
  - Feasibility review for full scale implementation
  - Statement of probability of success

The secondary objectives pertain to Tetra Tech's approach to assessing and presenting the information and thus support the primary objectives.

The secondary objectives for Tetra Tech's evaluation are as follows:

- S1: Prepare Comprehensive Scientific Assessment and Recommendations Reports for each technology that will support potential users' ability to make sound judgements on the applicability of the technology to a specific site and to compare the technology to alternatives.

- S2: Ensure that project deliverables follow consistent format and similar levels of detail. Each report will contain:
    - A summary of the technology and results of past uses of the technology;
    - Results of conceptual model review, fatal flaw analysis, and information gap evaluation;
    - A statement of probability of success and scalability of the project;
    - Verification of cost estimates at various implementation levels;
    - Results of the feasibility review for a potential demonstration project and full-scale implementation of the technology; and
    - Verification of claims made by applicants.

The technology evaluation consisted of the (1) collection; (2) evaluation; and (3) summarizing and reporting of data on the performance and cost of each technology. These data provided the basis for meeting the primary objectives.

Most data supporting these evaluations were provided by the technology developers and Tetra Tech attempted to verify it using independent sources, when available. Tetra Tech focused its verification efforts on key aspects of the technology (e.g., effectiveness, cost) as well as any claims that seemed questionable. Otherwise, Tetra Tech assumed information provided by the vendor to be accurate. Instances where Tetra Tech is unsure of a claim being made by the vendor are noted in the report. In some cases, information was also obtained from the peer-reviewed scientific literature. Tetra Tech worked with each developer to obtain the data necessary to meet the primary and secondary evaluation objectives.

Tetra Tech then completed an independent evaluation of the data provided by each developer and prepared separate reports for each technology evaluation, following a consistent report format. This report provides a summary of our review of AECOM's Algae Harvesting Hydronucleation Flotation Technology (HFT).

3.0 TECHNOLOGY OVERVIEW

According to AECOM, HFT is an "innovative, game-changing" algae harvesting technology for combatting HABs. HFT uses an advanced dissolved air floatation (DAF), liquid-solid separation technology developed by AECOM that physically removes algae, nutrients (phosphorus [P] and nitrogen [N]), carbon, and cyanotoxins that may be present from the water column. The HFT uses advanced DAF that has been adapted and optimized to operate at a high hydraulic loading rate while efficiently capturing algae and other suspended matter from water, along with cyanotoxins and nutrients that they contain. Key benefits of HFT as described by AECOM include:

- Physically removes nutrients from impacted waterbodies;
- Game-changing technology for management HABs;
- Provides long-term solution and reduces the threat of future HABs forming;
- Returns clean water to the impacted waterbody;
- Cost-effective, mobile, and scalable to various sizes;
- Proven effective in safely removing cyanotoxins; and
- Breakthrough technology for combatting climate change.

Information provided by AECOM demonstrates that HFT safety and performance have been successfully tested in multiple field-based pilot studies. AECOM describes that HFT has a compact modular and mobile design that provides versatility and scalability to address nutrient enrichment and HABs in a variety of aquatic systems ranging from small streams and ponds to large rivers and lakes. AECOM has indicated that the recovered algal biomass creates a valuable feedstock for green (carbon neutral) fuel, biofoam, fertilizer, and soil amendments.

HFT excels at removing near-surface, floating algae specifically but can also harvest other suspended solids from the water column. Because these solids may contain nutrients and toxins, HFT can be said to also remove nutrients and toxins. The technology meets the five TAP criteria in the following ways:

1. **Reduction of nutrient loading to rivers, streams, and lakes -** AECOM states that it is testing HFT in a farm setting in Florida. If the outcome of the test is favorable, further development of the technology to reduce nutrient loading *to* rivers, streams, and lakes may be promising. In this setting, algae are grown in ponds that capture high-nutrient agricultural runoff. The nutrient- and carbon-rich algal biomass is harvested using the HFT and is then beneficially reused as fertilizer and soil amendment on the farm. The clarified pond water can be used for irrigation on the source farm, or safely released to the watershed reducing nutrient loads to downstream water bodies.

2. **Removal of nutrients from rivers, streams, and lakes -** HFT directly removes nutrients *from* rivers, streams, and lakes by physically removing the algae containing the nutrients (and toxins).

3. **Reduction of the intensity or toxicity of algal blooms -** Skimmers and booms are employed to collect the algae from the water. Reduction in algal bloom intensity and toxicity in the water body is complete because algae is physically removed. Because cell walls are not broken, associated nutrients and toxins in the algae are also removed.

4. **Recovery of nutrients from animal waste -** While not yet tested, application of HFT to remove nutrient-rich solids from swine or dairy lagoon wastewater may be possible for the direct recovery of nutrients from animal waste. In the swine or dairy setting, lagoon wastewater may be able to be processed by HFT in a similar fashion as high-nutrient agricultural runoff but without the need to grow algae with it.

5. **Improvement of nutrient removal in wastewater treatment systems -** When considered as a clarifier technology, HFT can augment or supplant clarifier processes in typical activated sludge or biofilm wastewater treatment facilities while removing nutrients. If on-farm manure wastewater treatment lagoons are also regarded as a form wastewater treatment, HFT may also be promising as discussed above.

4.0 TECHNOLOGY EVALUATION

This section of the report addresses each of the criteria identified by Ohio EPA to be included in the independent evaluation process.

4.1 CONCEPTUAL MODEL REVIEW

HFT is an "innovative algae harvesting technology for mitigating and preventing HABs while simultaneously removing intra-cellular nutrients." AECOM's HFT system physically remove algae biomass and other suspended particles from waterbodies, thereby also removing the associated nutrients and toxins. The HFT systems utilizes advanced DAF technology which is an established process for liquid/solid separation. The DAF process has been adapted and optimized by AECOM for algae separation and to operate at high hydraulic loading rates.

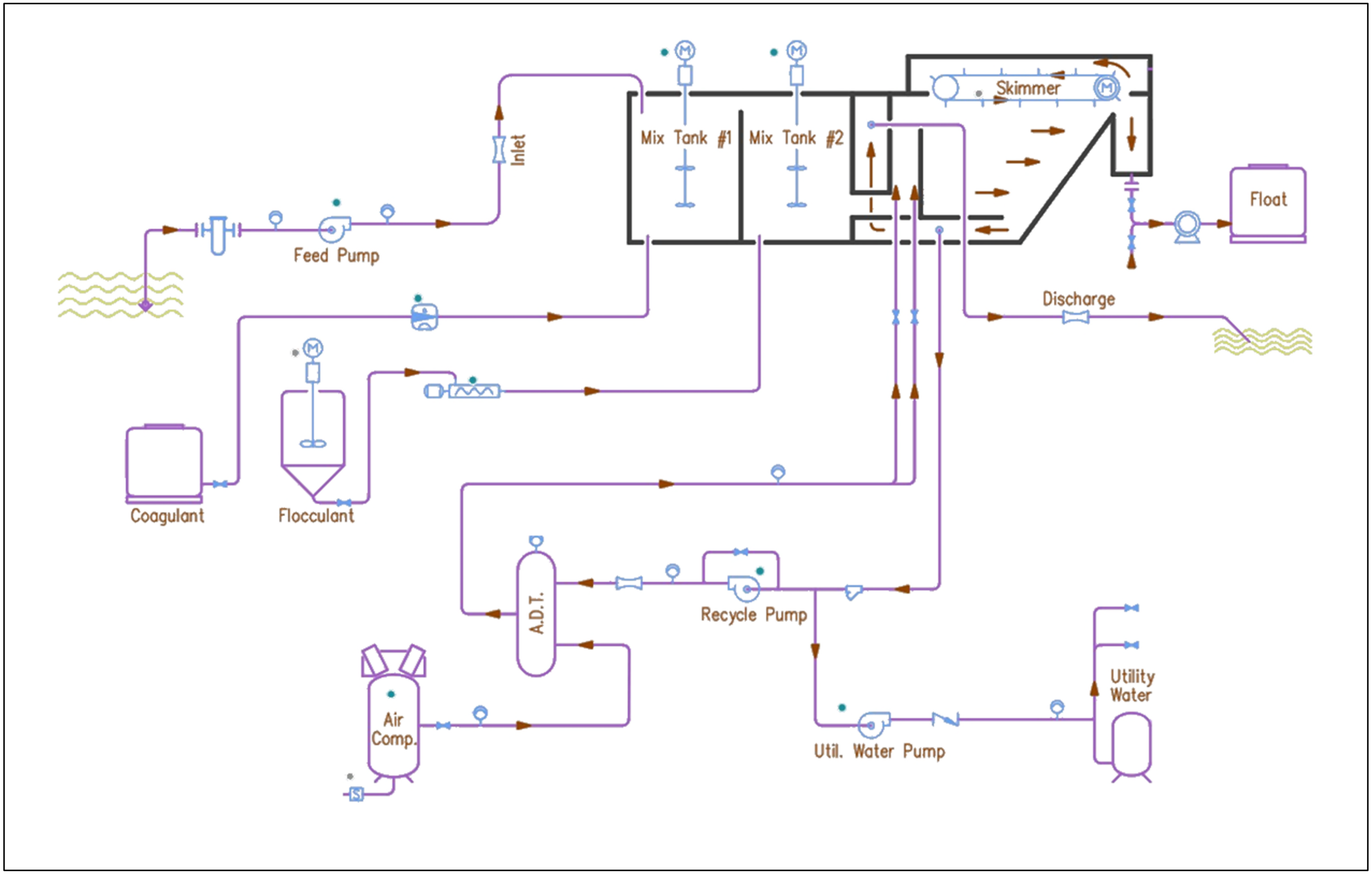
Surface water from an algae-laden waterbody is pumped into the HFT unit. To improve treatment performance, a low dose of coagulant(s) and/or flocculant(s) permitted for use in water purification and treatment may be added to the inflow. AECOM reports that a *de minimis* amount of commonly used coagulants/flocculants are used to facilitate a more efficient separation process of the algae cells from the water. This chemical addition is a side-stream process, so no chemical is added directly to the waterbody. Coagulant/flocculant concentrations are closely monitored and metered to optimize the algae/water separation process. The coagulants/flocculants are recovered with the algae biomass, and not released back to the waterbody.

The amount and type of coagulant/flocculant used depends on site-specific water quality characteristics and end-use of the recovered algal biomass. For example, the United States Army Corps of Engineers (USACE) Engineer Research and Development Center (ERDC) Harmful Algal Bloom Interception, Treatment, and Transformation System (HABITATS) pilot research study Phase 1 determined that the use of a coagulant was necessary to neutralize the algal cells in the waters tested, allowing them to interact and associate with the nanobubbles in the DAF process which creates the flotation of the dense floc. Without the coagulant addition, USACE ERDC found that most of the algal cells remained dispersed throughout the water. The coagulant used by USACE ERDC was aluminum chlorohydrate which was effective for treatment but was also concentrated in the algal biomass waste slurry (USACE, 2020). This concentration effect essentially diluted the algae in the concentrated biomass slurry taking up mass and volume with inorganic material which is not convertible to fuel. Instead, this inorganic material forms ash in the hydrothermal liquefaction (HTL) process. USACE ERDC concluded that an alternate organic coagulant should be considered for use in the future to increase compatibility with the HTL process. The use of a carbon-based coagulant would increase fuel yields and serve as an organic feedstock (USACE, 2020). According to their final technical report, organic coagulants have been successfully used for algae removal in DAF systems, however, dosing and further understanding of the chemistry would likely benefit from additional optimization studies. USACE ERDC initiated bench scale jar tests to optimize an organic, low-toxicity coagulation process for DAF and completed field-based pilot studies to optimize their usage in Year 2 of the program. The USACE ERDC HABITATS report for Year 2, however, was not publicly available at the time of this review but can now be accessed at https://erdc-library.erdc.dren.mil/jspui/handle/11681/42223.

The algae, coagulant/flocculant (if used), and other suspended particles form a floc as the water flows through a series of treatment and low-energy mixing tanks within the HFT unit. Nanobubbles, microscopic air bubbles with a diameter of approximately 10 nanometers, generated by the HFT process, attach to the floc and lift the floc to the surface of the water within the flotation tank. The floc forms a dense "skimmate" layer at the top of the flotation tank which is separated from the water by a skimmer and collected in a slurry holding tank. The clarified water is returned to the source waterbody. AECOM states that whole effluent toxicity (WET) bioassay testing (both chronic and acute) and chemical laboratory testing in HFT pilot projects have confirmed that the clarified water is not toxic to aquatic life. Secondary treatment methods such as chemical oxidation using ozone, hydrogen peroxide or both (Advanced Oxidation Process [AOP]) can be applied to the clarified HFT effluent water to destroy remaining algal toxins if more restrictive discharge standards need to be met specifically for algal toxins. Permits may be required to discharge the clarified water from the HFT back to the receiving waterbody and for disposal of the algae slurry. These permits could include the National Pollutant Discharge Elimination System (NPDES), Ohio EPA's Permit to Install Program, and the 401 Certification & Isolated Wetland Program. There do not appear to be any barriers to obtaining the required permits. As indicated by AECOM, the slurry or algae biomass waste can be further processed for beneficial use as a feedstock for bioplastics, biocrude liquid fuel, biofertilizer (liquid or solid), or as a soil amendment. Figure 1 shows an example process flow diagram for a HFT unit. Figure 2 shows a conceptual schematic as well as a photo of a HFT unit.

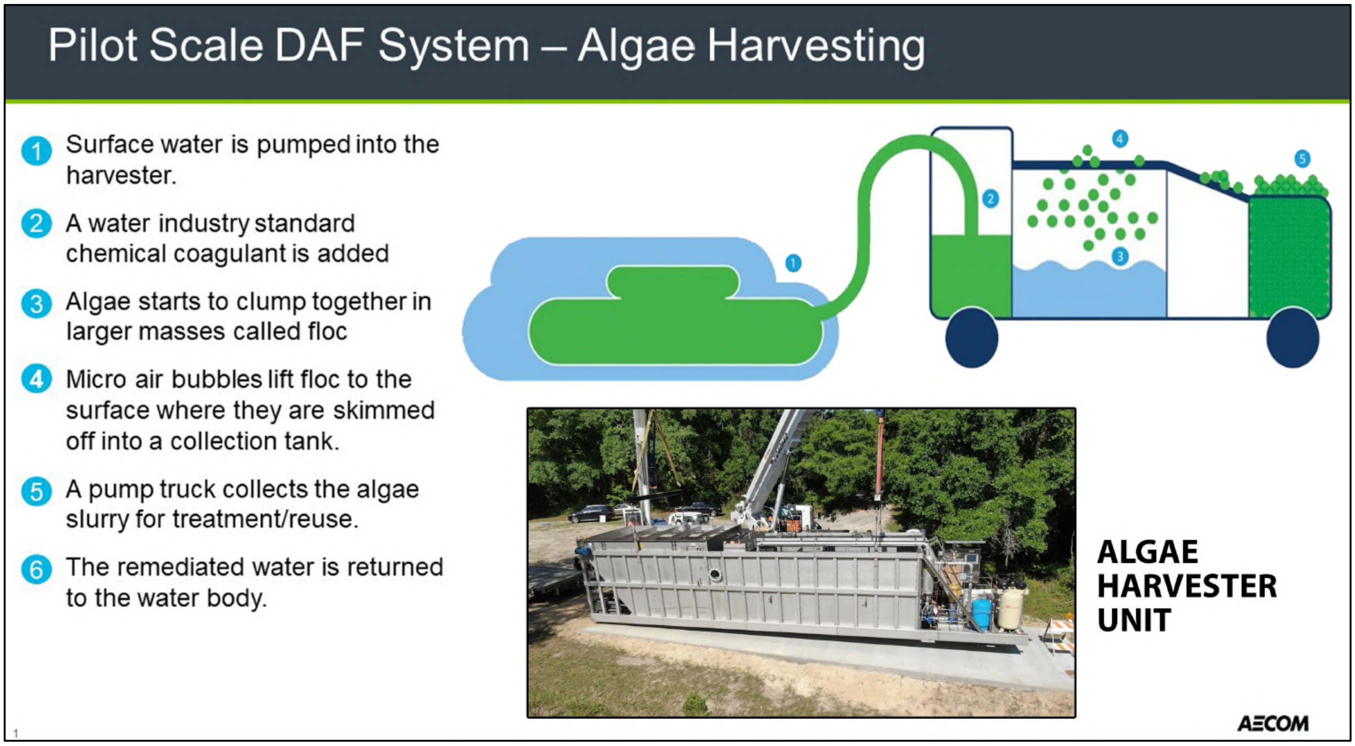
HFT removes key nutrients (phosphorus and nitrogen) that cause eutrophication of waterbodies through the removal of algae cells and other particulate matter holding the nutrients. The HFT process does not damage the algal cells and therefore the nutrients within the cells can be efficiently removed along with the algae biomass. Information provided by AECOM for samples collected during pilot testing confirmed high removal efficiencies for total nitrogen and total Kjeldahl nitrogen (TKN) (75 to 85%) and total P (85 to 95%). AECOM also provided information and data to indicate that the performance of HFT to removal algae, nutrients, and algal toxins from surface waters has been proven effective in multiple pilot scale studies at water bodies with a variety of water quality conditions in Florida and New York, including Lake Chautauqua in the Lake Erie basin. AECOM states that the performance of HFT (amount of algae, nutrients and toxins removed) is not affected by land use, soil conditions, or other geophysical characteristics of a watershed but is based on the concentrations in the surface water to be treated. The presence and abundance of algae and other particulate matter in the water column at the time of treatment is the driving factor that can affect the ability of HFT to meet the Ohio TAP objectives.

Figure 1 - Example Process Flow Diagram for Algae Harvester



Note : this figure was provided by AECOM (AECOM, 2021b) as part of information provided for this evaluation.

Figure 2 - Conceptual Schematic of a HFT System



Note : this figure was provided by AECOM (AECOM, 2021b) as part of information provided for this evaluation.

The HABITATS report (USACE, 2020) estimates that, at 100 mg/L algae and 100 MGD, the mass of algae removed each day would be almost 40 tons. It also reports removal rates of about 80 percent for both N and P (Figure 3-2 and Table 3-2, HABITATS report). Based on these assumptions and data, AECOM calculated (and Tetra Tech verified) the removal rate for a 100 MGD facility to be about 2,103 lbs. N per day and 277 lbs. P per day. This equates to about 21.0 lbs. N removed per MGD and 2.8 lbs. P removed per MGD.

HFT systems can be operated in configurations ranging from a mobile trailer or barge-mounted unit to larger design flow modular units that can be connected and run in parallel or placed at pre-determined, strategically selected locations near a waterbody. Due to its compact design and scalability AECOM states that the HFT system can be deployed to a wide range of surface waterbodies, from small ponds and streams to large rivers and lakes, including Lake Erie. AECOM provided several conceptual designs for various HFT treatment system configurations under a variety of potential operational scenarios, which are provided in the following Figures 3 – 8 (AECOM, 2021b). Each conceptual design includes the same basic harvester components and elements as described above.

AECOM reports that laboratory data show the HFT process does not cause significant algal cell rupture which results in the removal of intracellular algal toxins along with the algal biomass. These data were not available for review. Other algae control methods such as algaecides and ultrasound can rupture algae cells which may cause toxins to be released into the waterbody or ambient air. Oxidation can be applied to the clarified HFT effluent water as an additional treatment step to degrade algal toxins, however clarified effluent already has cyanotoxin concentrations. AECOM claims this oxidation step is safer than oxidation methods (e.g., hydrogen peroxide) applied directly to waterbodies to destroy algal toxins which have risks associated with harming of aquatic biota and triggering future algal blooms. Additional algal blooms can be triggered after these oxidation treatments because the phosphorus is not removed and remains in the waterbody available for uptake by algae.

Regarding cyanotoxins in retained biosolids, AECOM explains that these are degraded by heat in the HTL process. It is unclear if other processes downstream of HFT could be used to degrade cyanotoxins into harmless constituents, for example, exothermic composting. AECOM is collaborating with the Northwest Florida Water Management District and the University of Florida on a research project that includes the fate and degradation of cyanotoxins in biomass used for fertilizers and soil amendments.

At the various demonstrations already implemented, biosolids were discharged to the local municipal wastewater treatment facility (WWTF). It has been demonstrated in the research that the bacteria found in activated sludge are able to degrade cyanotoxins, especially microcystins (Barrington, 2013) but that cyanobacterial blooms are problematic for wastewater plants due to the effect of extracellular mucilage of cyanobacterial cells (Romanis, 2021). AECOM has indicated that disposal to a WWTF was for pilot scale research only and is not considered an option for full scale operations.

Figure 3 - HFT Conceptual Design for Nutrient Removal from Agricultural Runoff

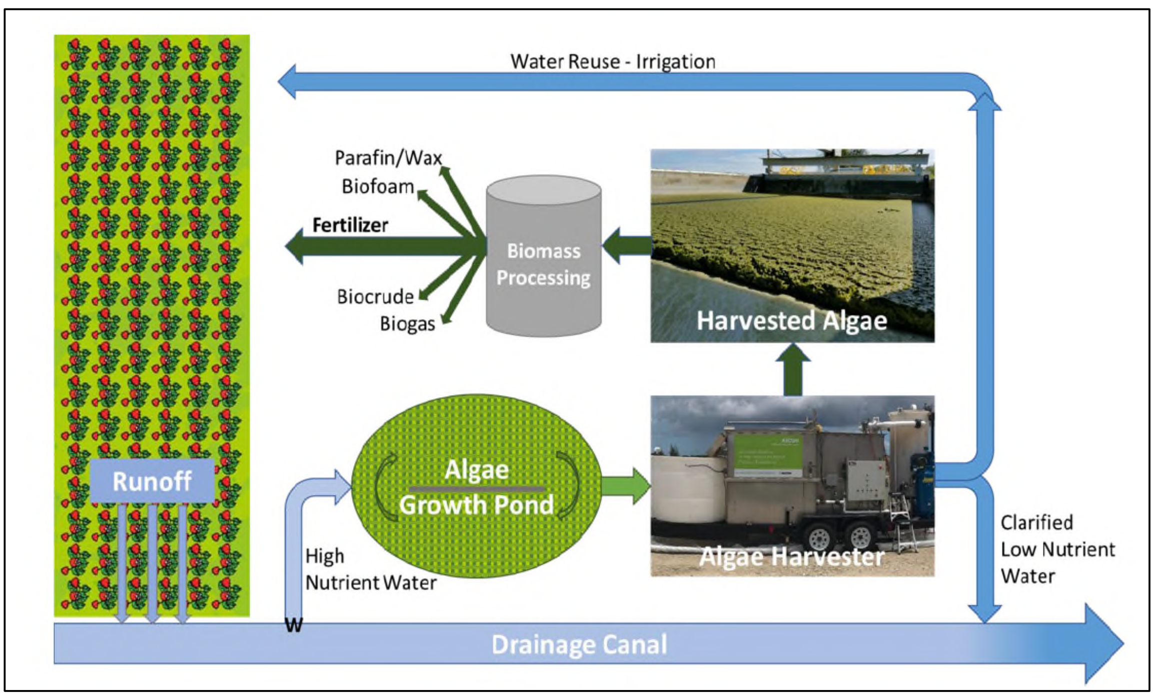


Figure 4 - HFT Conceptual Design for Land Based Nutrient Interception in Rivers

Figure 5 - HFT Conceptual Design for Lakeside Interception and Capture

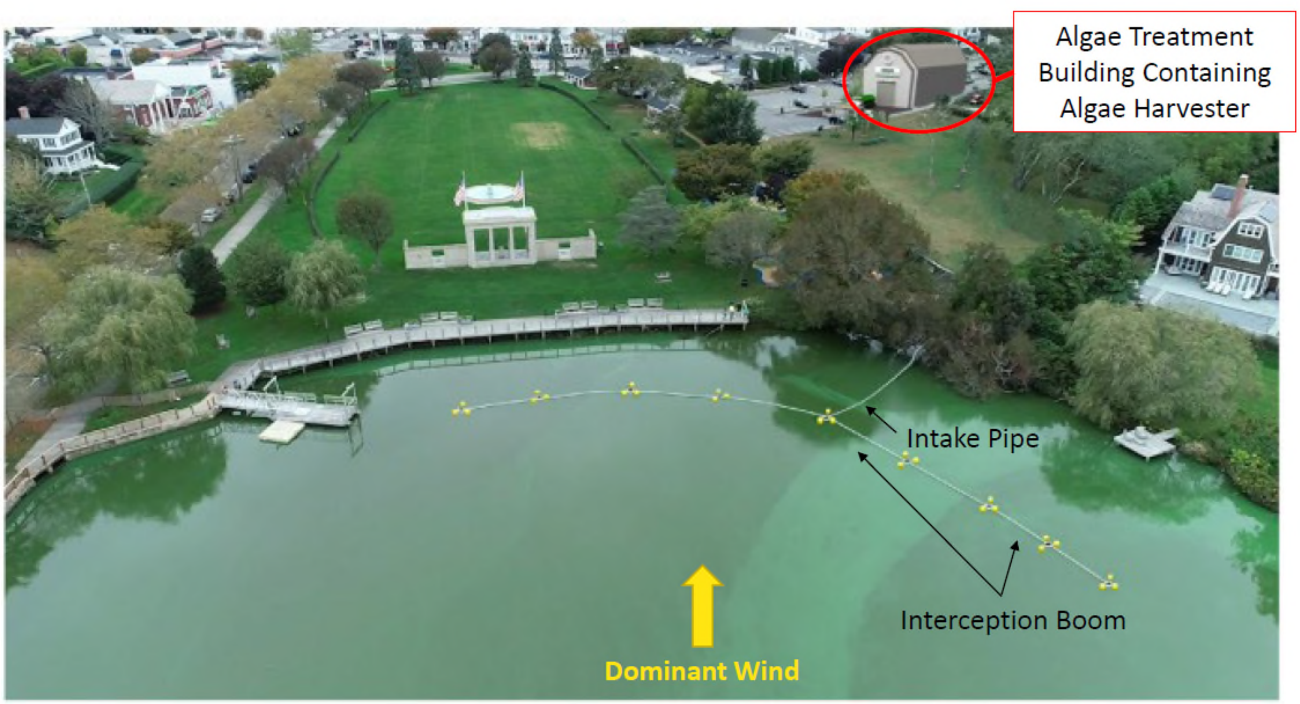


Figure 6 - HFT Conceptual Design for Large Scale Algae Harvesting Treatment Plants

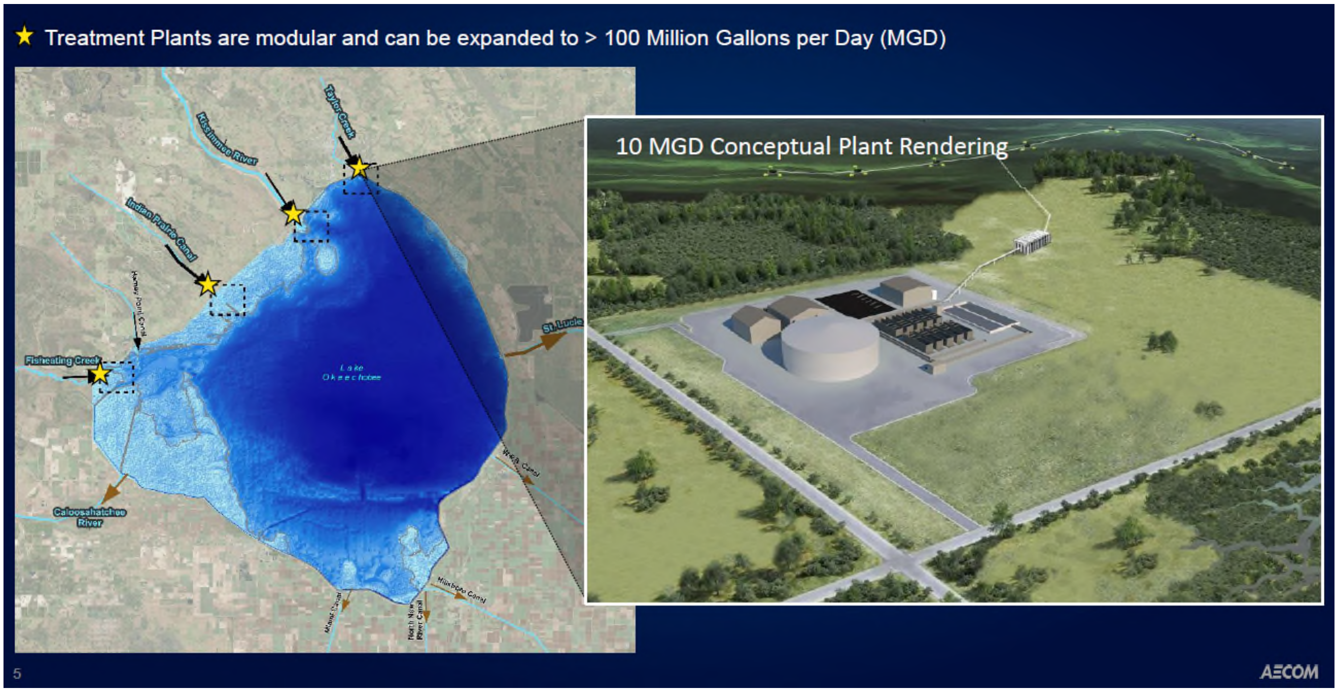


Figure 7 - HFT Conceptual Design for a 1 MGD Algae Harvester Unit (Lake Munson 2021)

Figure 8 - HFT Conceptual Design for Barge Mounted Units

AECOM reports that maintenance of the HFT systems is minimal. According to AECOM, HFT does not have many moving parts and requires only routine maintenance, such as lubrication and oil changes for electric motor driven components. HFT individual components including pumps, air compressors, mixers, gear motor, etc. are commercially and readily available and require minimal maintenance.

HFT appears to be a highly automated process that AECOM indicates can operate under a Supervisory, Control and Data Acquisition (SCADA) system. HFT operating conditions and water quality parameters can be continuously monitored and recorded. AECOM indicates that a HFT system is equipped with an on-board touch-screen human-machine interface (HMI) and can also be operated remotely through a secure weblink or cellular signal. Daily chemical preparation and dosing do require limited operator attention. Automation is expandable to include other system components such as ozonation, slurry dewatering, and recovered biomass transformation processes.

Information provided by AECOM reports that the life span of a HFT unit should be 50 or more years. The core of the HFT is constructed of stainless steel and with the mechanical components properly maintained the system should meet this expected life span. AECOM states that the individual components (electric motor driven) of the system have a typical replacement period of 5 to 30 plus years.

AECOM states that the carbon and nutrients in the captured slurry or algal biomass can be beneficially reused as potentially several valorized products, which provides multiple environmental benefits and can potentially offset treatment costs. AECOM describes four potential uses for the algae biomass waste slurry. These include the following:

1. Algal biomass from the waste slurry can be used as a biofertilizer and as a soil amendment. AECOM states that the use of the waste algal biomass in this way would be a more cost-effective and eco-

friendlier alternative to synthetic products. The waste algal biomass can be used directly or further processed following HFT to optimize its value for agricultural use. This potential use appears to have no further waste stream.

2. Anaerobic digestion of the waste algal biomass can generate energy as biogas (methane). This also has the benefit of producing a concentrated nutrient-rich residual which can also be used as a biofertilizer or soil amendment, according to AECOM. This potential use appears to have no further waste stream.

3. The algal biomass waste can be used in bioplastics production which contributes to carbon sequestration. AECOM states that bioplastic resins have been developed that comprise up to 40% renewable, algae-derived carbon which results in readily biodegradable or durable thermoplastics. This potential use may have its own waste stream.

4. According to AECOM, HTL, which is a process currently under development by the United States Department of Energy, converts organic matter into biocrude that can be blended with crude petroleum to provide a drop-in-place algae biofuel for direct consumption. As part of the federally funded program, HABITATS, USACE ERDC conducted pilot tests in 2019 and 2020, with support from AECOM, that demonstrated that HABs can be effectively harvested and transformed into biocrude using HFT units. This potential use has its own waste stream high in nitrogen, but the USACE opined that further resource recovery opportunities of HTL waste streams are numerous and not onerous (USACE, 2020).

4.2 FATAL FLAW ANALYSIS

Fatal flaws of HFT are not apparent. The effectiveness of HFT in the removal of algae, nutrients, and algal toxins from a waterbody appears to be based on the concentrations of each at the time of treatment. HFT systems appear to be scalable and adaptable based on the compact design of individual units. Based on the information provided by AECOM HFT systems have been constructed and configured in a variety of ways including, mobile trailer units, barge-mounted units, and larger design flow, modular units can be connected and run in parallel or constructed as fixed land-based plants. This versatility allows the technology to potentially be deployed at a wide range of waterbodies, from small ponds and streams to large rivers and lakes. AECOM indicated that the HFT and supporting technology is comprised of robust machinery which was designed for continuous operation. The technology is highly automated (through a SCADA system), and its operation can be monitored and controlled remotely. If mechanical components of a HFT system fail, they can be repaired and/or replaced.

Perceived limitations of HFT appear to be limited to funding availability for purchase or lease of the system equipment, space availability for staging of the equipment, power availability, and coagulant/flocculant supply, if required. AECOM provides mitigation measures for these perceived limitations and they are not considered to be fatal flaws of the technology.

The algal biomass waste stream for the HFT demonstration projects has been sent to local wastewater treatment plants for ultimate treatment and disposal. According to AECOM this was done to expedite the research due to the short time of treatment for the demonstration projects. AECOM anticipates that for full scale operations the beneficial use of the waste stream, as biofoam, biofuel, or biofertilizer production will be incorporated into the project to reduce operational costs and eliminate waste disposal costs. The reuse or disposal of the algal biomass waste stream should be carefully considered if HFT is implemented within the Lake Erie basin. We would expect to see further demonstrations avoid discharge to a local WWTF altogether; WWTP could relocate nutrients and possibly cyanotoxins within the watershed. If algal biomass was incorporated into composts, it is likely the embedded nutrients would be more bioavailable and less mobile when applied over time on farmland. However, reuse of algal biomass waste streams has been proven effective for the transformation of biomass into biofuel (HABITATS Year 1 and Year 2). AECOM reports that the reuse of algal waste streams has and continues to be investigated by AECOM and partners. The HABITATS report (USACE, 2020) provides estimates of costs and energy requirements of HFT when coupled with deployments of biofuel production.

As described above, the persistence and fate of cyanotoxins in algal biomass can be eliminated in HTL for conversion to fuel, thus transforming a health risk to a sustainable, carbon-neutral biofuel. Research is ongoing to valorize the biomass as a biofertilizer that will consider algae toxin reductions (U.S. EPA Farmer to Farmer Grant). This project is intended to reduce dependency on commercial fertilizers in support of circular economy.

4.3 REVIEW OF PREVIOUS IMPLEMENTATION OF HFT

AECOM provided summaries of significant demonstrations at various scales and noted that its largest scale operation yet is underway in Lake Munson (far right column in the table below). The most detailed information available is found in the HABITATS (USACE, 2020) report for the Lake Okeechobee demonstration. It is important to note that AECOM anticipates that the energy source to be conventional power grid for full-scale implementation, with perhaps incrementally more land requirements, permits, and legal agreements required.

In Table 1 (*HFT Pilot Study Performance Summary for Total Phosphorus (TP), Total Nitrogen (TN), Microcystin (MC), and chlorophyll-a (Chl-a) Removal Efficiency*) AECOM's presented a performance summary for six demonstration projects, included below (AECOM, 2021b). Further results are anticipated in the HABITATS Year 2 report, expected in October. Algae (chlorophyll) concentrations in this table are in a similar range or slightly higher than Lake Erie (i.e., 100 to 200 parts per billion [ppb] = 0.1 to 0.2 mg/l).

Table 1 - HFT Pilot Study Performance Summary for Removal Efficiency

Projects	Influent average concentrations (ppb)				Effluent average concentrations (ppb)				Removal Efficiency			
	TP	TN	MC	Chl-a	TP	TN	MC	Chl-a	TP	TN	MC	Chl-a
Lake Bonnet, FL	200	2900	-	81	41*	718	-	12	80%*	75%	-	85%
Bivens Arm, FL	210	2970	0	185	16	883	0.15*	14	92%	72%	21%*	92%
Lake Okeechobee, FL	410	3050	0	-	20	700	0	-	95%	77%	NA	-
Lake Agawam, NY[1]	220	3460	46	197	10*	620	2	1	94%*	82%	93%	>99%
Saddle Creek, FL	500	3050	1	195	48	-	-	17	90%	-	-	91%
Lake Chautauqua, NY	107	2625	4	169	21	703	0	20	81%	73%	89%	88%

[1]Microcystin results are prior to ozonation. With ozone treatment, microcystin concentrations were reduced in the final effluent to below the laboratory detection limit (<0.3 µg/L)
*Effluent concentration below laboratory detection limit
NA – not applicable

AECOM was requested to provide other operational data on its demonstrations such as energy source, consumption, disposition of waste stream, labor requirements, land requirements, and any legal agreements or permits required. The following table summarizes these data for four demonstrations (AECOM, 2021b).

Table 2 - HFT Demonstration Specifications

Specification	Lake Agawam	Lake Chautauqua	Lake Okeechobee	Lake Munson
Energy Source	Generator	Generator	Generator	Generator
Energy Consumption	Minimal	Minimal	Minimal	Minimal
Operation Type	Demonstration	Demonstration	Demonstration	Demonstration
Duration of Operation	10 days	5 days	5 days	10 months (ongoing)
Waste Stream	Local Wastewater Treatment Plant	Local Wastewater Treatment Plant	Local Wastewater Treatment Plant	Local Wastewater Treatment Plant
Labor Requirements	1 Operator, 1 Research Assistant	1 Operator, 1 Research Assistant	1 Operator, 1 Research Assistant	1 Operator, 1 Research Assistant
Land Requirements	1/8 acre	1/8 acre	1/8 acre	1/4 acre
Legal Agreements and Permits	No legal agreements; State and Local Permits obtained	No legal agreements; State and Local Permits obtained	No legal agreements; State and Local Permits obtained	No legal agreements; State and Local Permits obtained

These demonstrations, similar to a full-scale implementation, are placed at locations of recurring algal blooms in inlets, bays, harbors, or with open water harvesting by barge with a fixed base onshore. The demonstration projects have, so far, used an HFT with a hydraulic capacity of 130 to 150 gallons per minute. A larger, 1 million MGD unit was designed and built by AECOM in 2021. Field testing of this larger unit is underway in a research project funded by the Florida Department of the Environment (FDEP) by an HAB Innovative Technology grant awarded to the Northwest Florida Water Management District. This unit was installed and operated at Lake Munson in July 2021, and the project is being expanded to remediate a 10-acre HAB-impaired lake at the Apalachee Regional Park, Tallahassee, Florida. This research is scheduled to be completed in 2022. At this time, energy consumption is being measured in real time at two ongoing field studies in Florida to accurately determine energy usage for each system. Regarding the waste stream, AECOM anticipates eliminating wastewater treatment plant discharges in favor of beneficial use of the waste such as biofoam, biofuel, and biofertilizer. AECOM will be demonstrating the transformation of algae biomass to fuel using a mobile HTL unit in January 2022 and will be starting an 18-month US EPA “Farmer to Famer” pilot test in December 2021 on the use of biomass as biofertilizer/soil amendment. Information on energy consumption and removal efficacies for the Lake Okeechobee demonstration are found in the HABITATS report (USACE, 2020) in relation to scaling up the treatment capacity. These data are discussed in Section 4.8 Feasibility for Full-Scale Implementation.

4.4 COST EVALUATION

The two core design criteria of the HFT system according to AECOM include mobility and high removal efficiency while the system is either operated by staff or in the autonomous mode. AECOM has finalized two initial classes of treatment units with design capacities of 0.25 MGD and 1 MGD. Each of these HFT systems are stated to require a relatively small footprint (0.1 acres and 0.25 acre, respectively) and offers high recovery rates, typically >90% solids removal. Specific costs of a HFT system would depend on the system design. AECOM provided estimated costs associated with both capital and operation costs of a HFT system. At the time of this evaluation there is no unit cost (e.g., dollars per pound algae removed) information available for HFT. Because this is a novel technology, AECOM anticipates the costs to be reduced over time as more HFT units are built and deployed. AECOM also anticipates a cost reduction for large scale systems.

The expected capital cost of a 1 MGD treatment system amortized over a 10-year period is approximately $75,000 per year based on high-level estimates provided by AECOM. This does not include valorization of the algae biomass. The operational costs associated with the system operation using SCADA telemetry were estimated at $250,000 per year. AECOM indicated that the cost of materials (coagulants/flocculants) would be minor since a *de minimis* amount of product would be required. AECOM also indicated that support equipment costs would be minimal and could include equipment required for mobilization and demobilization of the system and staging area equipment (security fencing, work trailer, biomass storage tanks, etc.). Labor costs would be limited to a single operator with an occasional assistant due to the highly automated nature of the HFT system which minimizes labor requirements.

AECOM stated that the provided cost estimates could be used for budgetary planning purposes and were based on the following assumptions:

1. A land-based site is selected that is suitable for operations and is in proximity (e.g., several hundred feet) to a distressed water body.

2. The system will have a design capacity of 1 MGD and be operated 24 hours/day for eight months of the year and dormant for four months. This operating scheme considers the cooler winter months in Ohio when algae growth is comparatively low.

3. Local staff will operate the system. One operator would be on-site/on-call 8 hours/day 5 days/week to monitor and have the capability to have basic control function over the HFT system via telemetry when not on-site.

4. Required permitting would be managed as a separate activity.

5. Valorization of the recovered algae biosolids includes use as a "feedstock" for beneficial reuse in bioplastics, energy reclamation (biogas or liquid biocrude), liquid or pelletized fertilizer, etc., with the sales revenue (i.e., profit) of the biomass used to defer a portion of the overall operational cost.

6. Recognizing a broad range of site-specific variability, the cost for mobilization, site preparation, shakedown, demobilization, and site restoration are not included.

As part of the HABITATS Year 1 demonstration at Lake Okeechobee, USACE developed some unit costs based on collected data. At the demonstration scale (about 1 MGD), the HFT process costs about $2 million per year. These costs were developed including capital costs, O&M over a period of 30 years and revenue offsets from biofuel energy use and sales. A single 1-MGD facility could generate about 120 gallons per day of biocrude. Other unit costs are presented in the following Figures 9, 10, and 11 (USACE, 2020). Significant technological advancements and updated, more efficient energy consumption and costing estimates are expected in the HABITATS Year 2 program report.

Figure 9 - Cost per pound of algae removal at varying ambient algae concentrations

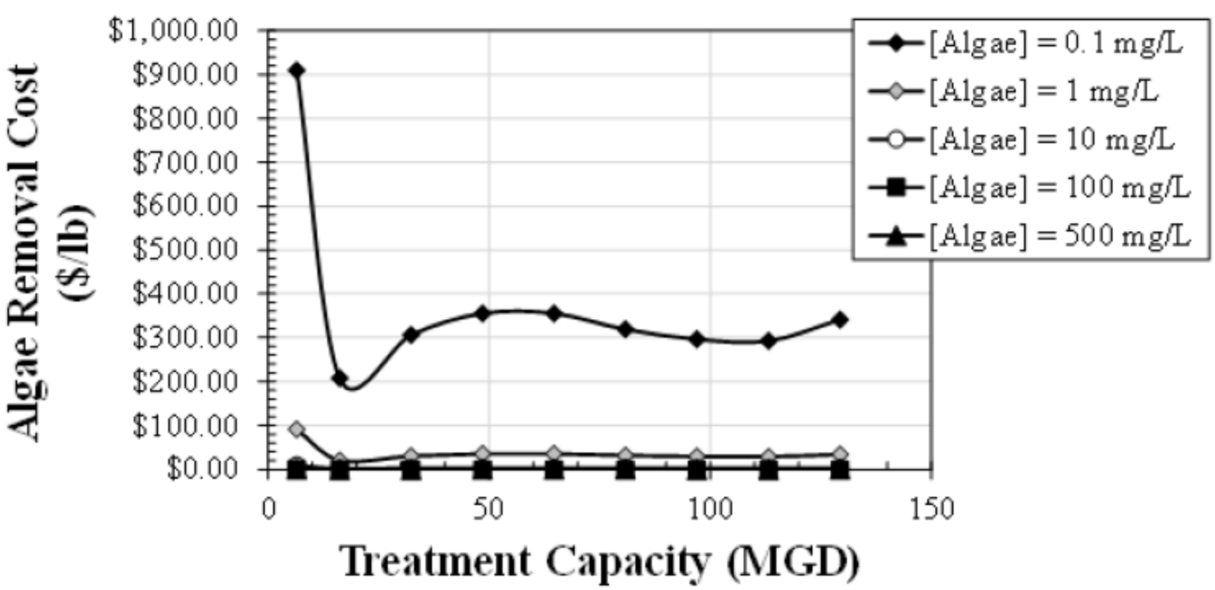


Figure 10 - Cost per pound of algae removal at high ambient algae concentrations

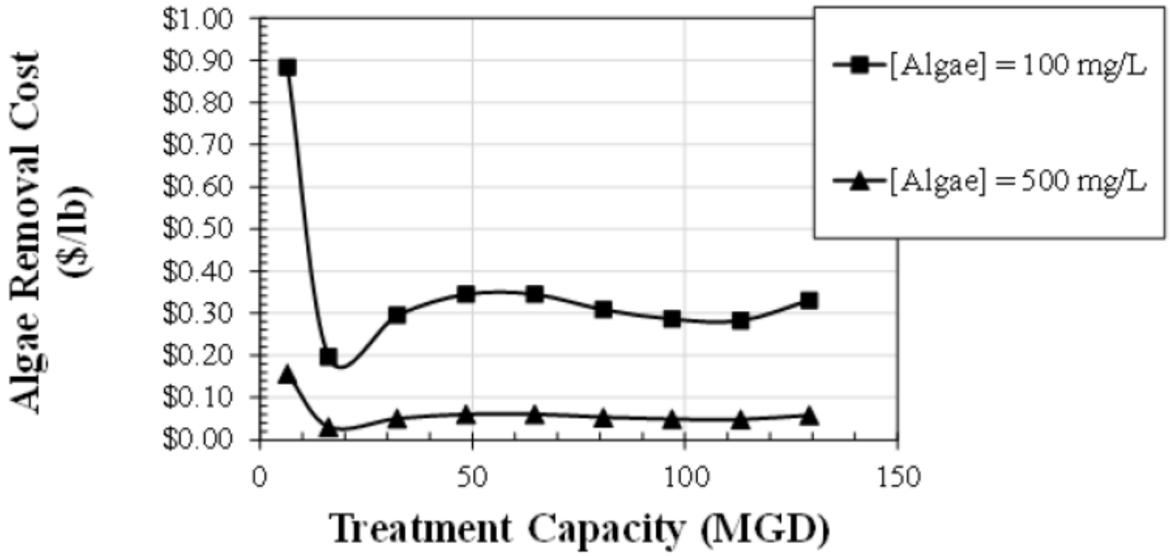
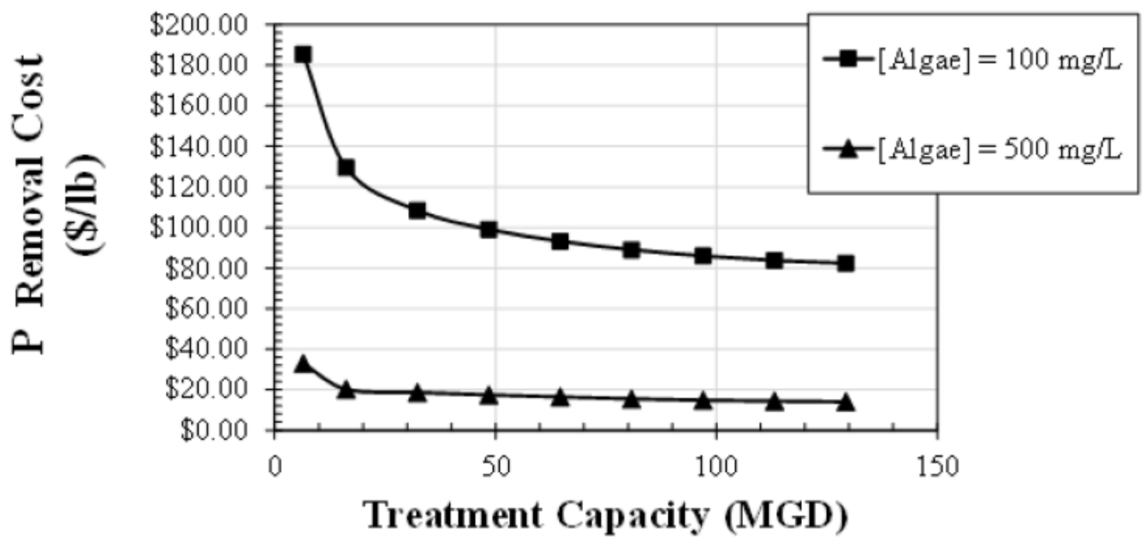


Figure 11 - Cost estimates per pound of phosphorous removal at high algae concentrations



4.5 SCALABILITY EVALUATION

The HFT technology is highly modular with flow rates as low as 0.25 MGD and as high as 100 MGD, or more. The main prerequisites for expansion are:

a) land-related, such as space, easements, leases, etc.,
b) power supply, and
c) waste stream management.

At various scales and locations, these prerequisites may take different forms and larger facilities may be more difficult to site. Figures 12 and 13 (AECOM, 2021b) show an actual 1-MGD demonstration facility and a rendering of a 10 MGD facility, both land-based but drawing from near shore skimmers, booms, and pipelines.

Figure 12 – One MGD Algae Harvester Module Design Concept (from Lake Munson, 2021)

Figure 13 – Ten MGD Conceptual Plant Rendering

AECOM states that removal efficiencies are consistent at any scale but vary based on concentrations of influent TSS, nutrients, and algae, as flocculants act on suspended solids. Each deployment must be customized to site-specific water quality and nutrient reduction objectives.

In order to evaluate the efficacy of scaled-up technology deployment on overall nutrient loading to and in Lake Erie, a hotspot analysis may be helpful. For example, if HFT plants were installed at all locations of known and recurring HABs, how many would be required to not only remove the algae but also to remove significant quantities of N and P from Lake Erie?

4.6 INFORMATION GAP EVALUATION

AECOM provided large amounts of relevant data and few data gaps exist. Remaining data gaps are apparent as one expands the operational boundary beyond the “fence line” as depicted on Figure 12. These gaps are discussed below.

- **Energy demand** – AECOM’s current demonstrations are collecting more data on energy use. This will be useful to estimate the infrastructure needed to scale up and the type and capacity of any onsite power generation using production of biocrude as a feedstock. While capital costs are relatively known, periodic operation costs such as energy demand or revenue from energy sales will greatly influence the 10-, 20-, or 30-year present value.

- **Waste stream processing** – Scenarios for utilizing the waste stream were presented conceptually but no estimates were provided showing the ultimate disposition of algal biomass. Several beneficial reuses were identified such as biocrude, biogas, fertilizer, composts, biofoam, and waxes but none of these, except for biocrude described in the HABITATS report (USACE, 2020), were fully developed in terms of costs, revenue, or any final waste streams requiring discharge to water bodies or landfill. The USACE HABITATS Phase 2 demonstration completed research that supports the assertion that algal biomass can be recovered and reused using HTL. The technical report for this project was not available at the time of review but has since been publicly released.

- **Harvesting methods** – Relatively few data were presented on the areal capacity and utility of the barge method of harvesting algae compared to other methods. It is unclear what the capture rates are on open water versus boom collection, the time and energy required to collect a unit mass of algae, and how wind and water currents effect the time available to collect the algae.

4.7 FEASIBILITY FOR LARGE-SCALE TECHNOLOGY DEMONSTRATION

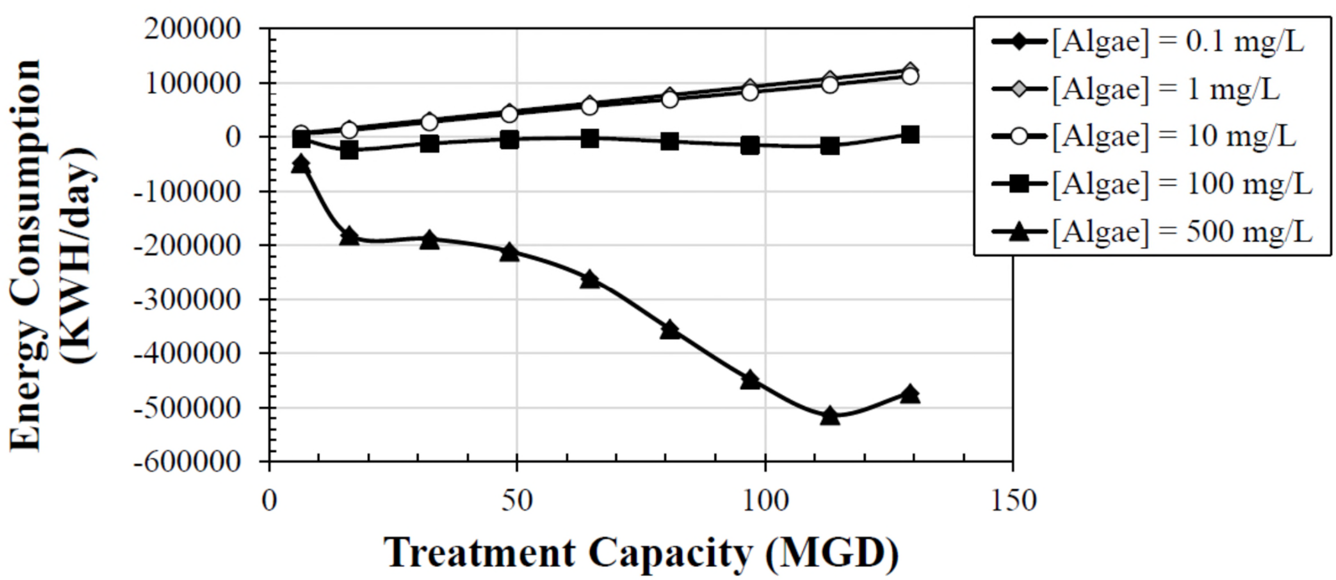
The largest HFT unit (1 MGD) demonstration to-date is the Lake Munson project, funded by FDEP Blue-Green Algae Task Force. The Lake Munson project was awarded a portion of $10 million in grants. The demonstration is ongoing and successful to-date. A reasonable assumption would be that a similar demonstration be conducted in Lake Erie or in its watershed. However, with multiple past demonstrations in Florida and New York, both barge-based and land-based, further demonstrations should be differentiated by incorporating more downstream components to prove the feasibility of biomass beneficial reuse. For example, further demonstrations should not use a local municipal sanitary sewer to discharge the algal biomass. With these yet-undemonstrated reuse components it may be appropriate to use a 0.25-MGD HFT facility with associated reuses at the appropriate scale as a demonstration. Estimated capital and periodic costs for these beneficial reuse components were not provided but should not be significant hurdles.

4.8 FEASIBILITY FOR FULL-SCALE IMPLEMENTATION

The HFT system is highly modular. The definition of “full-scale” could be simple arithmetic – 100 0.25-MGD facilities distributed in the watershed or a single 25 MGD facility in a hotspot with large amounts of algae available. As AECOM noted, these facilities may be owned and operated by private landowners, public, or quasi-public entities. Each facility likely would have its own mix of system inputs and outputs including power source, land, permits, contracts, algae harvesting, discharges, and beneficial reuse. The information AECOM provided indicates that the treatment system is indeed adaptable to a number of settings. Other settings equally potentially feasible include those currently being demonstrated, namely, agricultural runoff and manure lagoons.

Perhaps most helpful is to define full-scale in terms of a holistic view of the watershed and end users of the raw or processed algal biomass. It would be reasonable to assume that economies of scale exist to be experienced at certain size of biomass production, biocrude, power facility, etc. At a certain scale, enterprise costs may indeed become revenues (e.g., sale of energy) or monetized benefits (e.g., carbon capture). The following figure from HABITATS Phase 1 (USACE, 2020) report is perhaps the best indicator of this potential at scale is the energy consumption in kilowatt hours per day (kWh/day) as a function of the treatment system capacity in MGD.

Figure 14 - Effect of ambient algae concentration on the energy consumption



The calculations for the figure developed with revenue offsets from biofuel energy use and sales for a single 1-MGD facility generating about 120 gallons per day of biocrude. While not converted to energy sales, these data would have a significant impact on the overall enterprise costs of any scale of facility. Refer to Figures 9-11 for more cost information from the HABITATS Year 1 report. Updated and potentially more favorable data will be available in the HABITATS Year 2 report.

4.9 PROBABILITY OF SUCCESS

Success has been proven in numerous demonstrations to-date. Success has typically been defined as removal efficiencies and low concentrations of toxins, N, P in clarified water returned to the water body. When TAP objectives are used as metrics of success the evaluation is more nuanced.

While not specifically a TAP objective, the HFT technology literally removes algae cells from the water body. Along with the algae, a collateral amount of water, microscopic organisms, dissolved solids, and particulates are also removed. In acute HABS, the effect is complete and immediate. Comparable, conventional “removal” by using algicides can have a similar effect, although embodied nutrients and toxins remain in the water.

TAP objectives are mostly defined in terms of nutrient removal from water bodies or inputs to water bodies. On this topic, the HABITATS report (USACE, 2020) estimates that, at 100 mg/L algae and 100 MGD, the mass of algae removed each day would be almost 40 tons. It also reports removal rates of about 80 percent for both N and P (Figure 3-2 and Table 3-2, HABITATS report). Based on these assumptions and data, we calculate the removal rate for a 100 MGD facility to be about 2,103 lbs. N per day and 277 lbs. P per day. This equates to about 21.0 lbs. N removed per MGD and 2.8 lbs. P removed per MGD.

4.10 FINANCIAL VIABILITY

According to information provided by AECOM, the firm is a large, long-established international consulting firm with extensive financial resources to support production, sale, and implementation of HFT over the long term. AECOM is a Fortune 500 firm, listed at #163 as one of America’s largest companies. Their Professional Services business had a revenue of approximately $13.6 billion in fiscal year 2019 and approximately $13.2 billion in fiscal year 2020. AECOM has over 56,000 employees worldwide and over 600 employees based in Ohio. AECOM became an independent company formed by the merger of five entities. Their official founding was in 1990 but many of their predecessor firms had distinguished histories dating back more than 120 years. More than 50 companies have joined AECOM and in 2007 they became a publicly traded company on the New York Stock Exchange. As stated by AECOM, the structure of the company strongly positions them to design, build, finance, and operate infrastructure assets for their clients around the world and organizes the operations of AECOM into four principal groups: Design and Consulting Services (DCS), Construction Services, AECOM Capital and Management Services, and Enterprise Growth Solutions.

Therefore it is Tetra Tech’s opinion that AECOM is financially viable to support large scale and long term implementation of this technology.

4.11 QAPP

AECOM provided two example quality assurance project plans (QAPP) developed for their Lake Agawam, New York and Lake Munson, Florida demonstration projects. These QAPPs were state approved documents and meet the respective state requirements for quality assurance plans. The QAPPs include detailed information regarding data quality objectives, sampling process design and procedures, laboratory and field quality control procedures, and data review, verification, and validation procedures. AECOM indicated in additional materials provided to Tetra Tech that their HFT demonstration projects operate under state-approved QAPPs. Based on this statement and the review of the example QAPPs provided, the assumption can be made that the data provided by AECOM associated with their demonstration projects is reliable and suitable for the purposes of this assessment.

Additionally, Tetra Tech assumes the data provided by AECOM from the HABITATS Year 1 study conducted by USACE ERDC is also reliable and suitable for the purposes of this assessment. The HABITATS Year 1 Final Technical Report (USACE, 2020) includes detailed information regarding the pilot project overview, selection of the demonstration site, water quality sample collection and testing methods, treatment testing and HTL testing methods. The assumption was made that the data contained with the HABITATS Year 1 final report are reliable and suitable for use in this assessment, but it is recognized that the HABITATS Year 2 final report will contain updated information with significant improvements in fuel production estimates and significantly lower costs. The HABITATS Year 2 report has not been reviewed by Tetra Tech.

4.12 DATA VALIDATION

AECOM states that the data used to evaluate the performance metrics of HFT at demonstration sites were collected following procedures outlined in the QAPP for each site. Influent, effluent, and algae biomass slurry samples collected by AECOM were analyzed for various parameters according to QAPP requirements at National Environmental Laboratory Accreditation Program (NELAP) certified laboratories. Pending approval from USACE, AECOM can provide laboratory certificates of analysis for the HABITATS Year 2 project at Lake Chautauqua and Saddle Creek. USACE ERDC conducted independent analysis of data collected for the HABITATS Year 1 and Year 2 projects. The independent analysis for the HABITATS Year 1 project is included in the final technical report (USACE, 2020). The independent analysis for the HABITATS Year 2 project is provided in the final report for that project, which was not publicly released until October 19, 2021, after completion of this report.

4.13 SUPPLY CHAIN

The HFT process typically uses commodity potable water treatment chemicals (coagulants/flocculants), but these are not likely to be supply chain dependent. AECOM stated that they have experienced no supply chain issues with their demonstration projects and they believe any supply chain issues are unlikely to occur for full scale application given that the chemicals are widely available from numerous chemical suppliers. There are also several alternative products and formulations that could be used if there was a supply shortage. Supply issues with the basic mechanical and structural components of the HFT system are unlikely. HFT does not have a lot of moving parts and individual components (pumps, air compressors, mixers, gear motor) can be repaired and are commercially and readily available if they need to be replaced.

According to AECOM, the lead time needed for fabrication of a new HFT unit is approximately four months. This time includes the necessary time for implementation design and planning specific to the applications needs and treatment site. It also includes time required to secure the required permits and time to construct the unit(s) if existing units are not readily available.

4.14 ENVIRONMENTAL RISKS

AECOM claims that HFT is a “no harm” solution for HAB and nutrient management in surface waterbodies. According to their AECOM, there is no risk to the environment or health and safety from use of the technology. AECOM stated that the two potential concerns with regards to environmental risk, the use of chemical coagulants/flocculants and exposure to algal toxins, were identified early in the development of HFT and have been mitigated through system design, operations, and monitoring. The following paragraphs summarize information related to the use of chemical coagulants/flocculants, and Section 4.14.1 addresses the risks to algal toxin exposure.

The inorganic chemical coagulants and flocculants that may be used in the HFT process are approved by the National Sanitation Foundation (NSF) International and are commonly used for purification in potable water and wastewater treatment. The chemical constituents of many of the coagulants/flocculants (i.e., aluminum and iron) are found naturally in surface waters but can be toxic to aquatic organisms at high concentrations or long exposures. Aluminum sulfate (alum) is an inorganic flocculant that is also often applied to lakes and ponds to remove phosphorus from the water column and prevent internal loading of phosphorus from the sediments. Aluminum-based products can cause a lowering of the pH of the treated water; however, it is not anticipated that the low dose used in the HFT process would decrease the pH of the water drastically. No significant change in pH occurred in any of the pilot demonstration projects completed to date.

The risks associated with the use of a chemical coagulant/flocculant in the HFT process can be effectively mitigated through careful consideration and selection of the product, dosing, and monitoring. AECOM states that jar tests and bench-scale flotation tests are performed prior to HFT operation to select the most effective product and dosing regimen to optimize algal separation and minimize risk. AECOM states that the jar and bench scale tests are conducted at regular intervals during the treatment period to verify effectiveness and adjust the dosing regimen if necessary.

AECOM stated that laboratory testing during several field studies confirmed that low doses of coagulant/flocculants used in the HFT process are bound up in the dense floc that is created and removed from the water column, and therefore they are not present in the clarified water in any significant amount. Bioassay testing was conducted in conformance with USEPA criteria during the pilot test in November 2017 on Lake Bonnet, Polk County, Florida as well as the Phase I HABITATS in Moore Haven, Florida (Lake Okeechobee) in July 2019. This testing confirmed that there were no adverse effects on vertebrate or invertebrate test organisms for either chronic or acute toxicity in the clarified water that was returned to the waterbody (Test America – ASL,(2017) (USACE, 2020).

AECOM provided the NELAP-certified laboratory certificate of analysis for toxicity testing of the sample from the Lake Bonnet pilot demonstration. Both acute and chronic testing showed no significant difference between the control and a sample concentration of 100% for water flea and fathead minnow survival and water flea growth (Test America – ASL, 2017). Results of the toxicity testing for the HABITATS project were published in the USACE

Year 1 report. AECOM also provided several safety data sheets for commonly used coagulants and flocculants, including inorganic and organic chemical, which Tetra Tech reviewed.

4.14.1 Health & Safety

According to additional information provided by AECOM, there are no significant health and safety risks associated with the implementation of HFT. Operational risks were evaluated and mitigated through detailed risk assessments in Health and Safety Plans (HASP) developed by AECOM for their demonstration projects to date. AECOM provided an example HASP for their Agawam Lake Algae Harvesting Pilot Demonstration project which included a pre-job hazard assessment listing potential safety/health hazards and the control measures to be taken to mitigate risk.

There is a health risk associated with handling water containing algal toxins, especially if the toxins are released into the water through cell breakage or if the toxins or aerosolized. According to AECOM, the HFT process does not rupture the algae cells and therefore intracellular toxins are removed along with the algal biomass slurry. The toxins are not released back into the waterbody. AECOM claims that pumping of the algae-laden water to the HFT for treatment as well as the discharge of treated water back to the waterbody does not cause excessive turbulence that could aerosolize toxins. The components of the HFT unit which include mixing are enclosed preventing the release of toxins into the air surrounding the unit during the treatment process.

AECOM stated that extensive monitoring of toxins was performed during pilot studies and the data supported the claim that HFT does not pose a risk due to the release of toxins to water or air during operations. AECOM also states that HFT consistently and significantly reduced MCs and nodularin in treated water to below the USEPA recreational use guideline of 8 µg/L. MC and nodularin concentrations in the air around the HFT units were consistently below the detection limit.

4.15 COMMUNITY PERCEPTION & DISPROPORTIONATE IMPACT

According to AECOM, community response to their HFT demonstration projects has been overwhelmingly positive. AECOM has not formally evaluated or documented potential impacts to surrounding communities where HFT is being implemented but they anticipate that the technology would receive much community support where algae blooms affect the safety of drinking water supplies and recreational or industrial use. AECOM believes that by removing toxic algae and nutrients, valorizing the algae biomass waste slurry, and sequestering carbon, lake communities will see first-hand how HFT can make an impact on restoring nutrient enriched and HAB impacted waterbodies.

It is typical for communities impacted by HABs to be frustrated by the lack of significant progress to address the issue, especially if HABs have been a long term, common issue. AECOM stated that during their past demonstration projects communities have most often expressed concerns related to the environmental safety of HAB mitigation techniques. AECOM goes on to further state that once communities understood the HFT process and were able to observe the systems in operation, most of their concerns were alleviated.

AECOM further explained that stakeholders, regulatory agencies, community leaders, politicians, and the public in Florida and New York have had the opportunity to see the HFT in operation and have been extremely supportive of the technology. The Chautauqua Lake Association (CLA) posted a 5-minute video of the HFT pilot test conducted in August 2020 on their website to further promote the use of HFT on Chautauqua Lake (Chautauqua Lake Association, AECOM – Chautauqua Lake Association, 2020). The CLA executive director Douglas Conroe commented that “This pilot study offers realistic hope for producing an environmentally friendly, no chemical option for remove localized HABs along with removing phosphorus and nitrogen nutrients from our over-abundant nutrient-laden lake.” (Chautauqua Lake Association, AECOM – Chautauqua Lake Association, 2020).

AECOM anticipates that public outreach and engagement prior to the installation of an HFT unit would be the preferred method to mitigate negative public perception of this technology. They also anticipate that the local, state, and federal permitting process would also work to mitigate negative impacts by requiring discharge limits and public participation and stakeholder outreach. AECOM states that HFT pilot tests have been implemented in several states and various settings and has been modified to account for public feedback. Adaptation of HFT systems based on community feedback is expected to be part of any future implementation projects.

AECOM believes that because HFT siting options and configurations are highly adaptable to many conditions, environmental justice considerations are able to be factored into location feasibility to ensure this technology does not have a disproportionate impact on minority or lower income communities.

4.16 WASTE/BY-PRODUCT MANAGEMENT REQUIREMENTS

AECOM states that the low dosages of coagulants/flocculants used in the HFT process are bound up in the dense floc that is produced and removed from the water column and the process water is safe to return to the water body. The coagulants are retained in the algal biomass as are toxins and nutrients, and this is supported by monitoring data for chemical constituents in the source water and HFT clarified water. Tetra Tech views the algal biomass is consistently regarded by AECOM, appropriately, as a resource for beneficial reuse. This is in contrast to a typical viewpoint – a “waste by-product” whose ultimate disposition could be a landfill or discharge to water bodies. However, during every demonstration thus far, AECOM has utilized local municipal wastewater treatment plant to discharge algal biomass. AECOM has stated that the demonstration projects were short- term and the biomass was disposed at a WWTF for the purposes of the demonstration only. Valorization of the biomass for reuse has been confirmed to be feasible for biofuel (HABITATS Year 1 and Year 2 studies) and AECOM has indicated that research is set to begin that will optimize the algae biomass for use as fertilizer.

Minor waste would be expected for consumables whose lifespan is 0-5 years, such as booms or equipment spares, however these were not quantified. Finally, even though the HABITATS Year 1 report had estimates of kilowatt-hours, no emissions calculations were conducted based on the energy mixes in the power grid at a proposed full-scale deployment location. Also, no fuel usage or emission were included for barge harvesting. Detailed energy consumption for the HFT is expected in the HABITATS Year 2 report.

5.0 FINDINGS AND OPINIONS

AECOM provided ample data to support their assertions with only a few minor omissions and data gaps. Filling these data gaps would allow for a more holistic evaluation with a larger operational boundary. The HABITATS Year 2 report is expected to fill many of the data gaps by providing updated information on costing, energy consumption and one waste stream reuse scenario (biofuel transformation). Unfortunately, this report was not available in time for this review. AECOM admits some key information is still being developed in a few ongoing and planned demonstration projects that will further fill information gaps.

The technology appears robust, scalable, and relatively simple. It may have high energy intensity, but this could be mitigated through onsite biocrude production.

AECOM listed the only potential limitation for widespread use of the HFT as funding availability for the purchase or lease and operation the system. Other requirements include ⅛ to ¼ acre land for staging the equipment, power availability, and chemical supply. If the operational boundary were expanded to include the potential revenue from beneficial reuse of the algae biomass, this could improve cost efficiency.

The technology's effectiveness increases with greater TSS. This is true of algae on the surface, in the water column, in agricultural runoff (growing algae from the runoff is necessary), and manure lagoons. Treatment of surface algae has been thoroughly demonstrated, but other less-concentrated sources have not. Though not specifically a TAP objective, it is the only technology that physically removes algae, nutrients, and cyanotoxins from the water column. It excels at removal of TSS and therefore the nutrients and toxins held in them and is a valuable tool for acute HAB aesthetic, recreation, and health threats, fulfilling many TAP objectives. It appears to be less developed for nutrient capture or nutrient mobility upstream in the watershed or on farmland.

On one hand, the technology has already been demonstrated successfully in Florida and New York numerous times. On the other, the value of another demonstration specifically in Ohio could be justified if it included actual demonstrations of beneficial reuse of the waste stream. Another demonstration could include interception of algae in municipal water treatment intakes with the HFT system as a pretreatment method. To facilitate agency comparisons of technologies, refined 10-, 20-, and 30-year present value cost estimates would also be helpful.

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