Planktonic:

In-water Intervention Strategy
Limited Supporting Field Data

Benthic:

In-water Intervention Strategy
No Available Supporting Field Data

There is little available detail on the technologies for skimming or harvesting cyanobacteria from natural systems. A large surfactant, flotation, skimming, ozonation technology has been used in a pilot project in Florida (Page et al. 2020) that shows promise for removal of cyanobacteria and possible cyanotoxin destruction. A second project is a skimming application in Southampton, New York (Southampton Press 2019). Although harvesters for submerged aquatic plants are known and used occasionally for removal of invasive submerged grasses, such as *Hydrilla* spp. (McGehee 1979), data that support the removal of cyanobacteria biomass from concentrated blooms with these techniques are limited.

PLANKTONIC	**BENTHIC**
EFFECTIVENESS • Water body types: Pond, lake/reservoir, bay/estuary, systems allowing scum formation • Any surface area or depth • Water body uses: Any, except perhaps drinking water sources • Any trophic state • Any mixing regime • Reported (no data) treatment of 100 M gal/day	**EFFECTIVENESS** • No available studies
NATURE OF HCB • Scum-forming or floating HCBs • Singular or repeating HCBs • Toxic and nontoxic HCBs • Intervention strategy	**NATURE OF HCB** • No available studies on benthic cyanobacteria
ADVANTAGES • Biofuel production from harvested biomass is proposed • Low potential for adverse impacts • High volumes of surface scum biomass can be harvested	**ADVANTAGES** • No available studies on benthic cyanobacteria
LIMITATIONS • Limited data • Huge capital investment for reagents, air flotation technology, ozone, and operations and maintenance • May not be scalable • Hazardous waste designation for collected biomass possible • Indiscriminate removal • Scum is collected, so there may be surface water criteria concerns • Unknown costs • Need partners for post-collection commercial use	**LIMITATIONS** • No available studies on benthic cyanobacteria • Not selective to cyanobacteria • May spread benthic mats that reproduce by fragmentation • Disruptive of habitat • Generates high turbidity • Decay of disrupted macrophytes may negatively impact water quality

The sole estimate found for efficacy of harvesting and skimming is the 2019 Florida pilot project (Page et al. 2020). Unfortunately, much of the cyanobacteria present in this study were subsurface, and there was little cyanotoxin (microcystin) detected. Most results were for nutrient removal, but this method was quite effective in removing nitrogen and phosphorus, which are mostly found in the cyanobacteria biomass. There were two major limitations for the technology, however: huge capital and operations and management costs, as well as very high energy demand. Page et al. (2020) argued that these costs could be reduced if the harvested biomass could then be converted to biofuels and sold, but that technology is still in development.

As both skimming and flotation cannot remove an entire bloom, the remaining populations could re-seed and cause additional blooms. For skimmed cyanobacteria without biofuel conversion, the collected material could be considered hazardous waste with associated costs for its disposal. Subsequent disposal of harvested biomass may be limited depending on cyanotoxin content of the collected biomass.

COST ANALYSIS

Costs are relatively low for simple skimming and very high for surfactant-flotation-skimming-ozone treatment. Specific equipment for skimming or harvesting would be required, and some form of power would be needed. The relative costs below are for skimming only and surfactant-flotation-skimming-ozonation. If harvested biomass can be processed for commercial uses, net overall cost may be reduced. Whether funds recovered from the sale of the collected material are passed on to the lake manager to reduce their costs is unknown.

Relative cost per growing season: Skimming and harvesting

ITEM	**RELATIVE COST PER GROWING SEASON**
Material	$$–$$$
Personal Protective Equipment	$$
Equipment	$$–$$$
Machinery	$$–$$$
Tools	$–$$$
Labor	$$–$$$
O&M Costs	$–$$$
Delivery	$$$
OVERALL	**$$-$$$**

REGULATORY AND POLICY CONSIDERATIONS

Collected biomass may include intracellular cyanotoxins, so appropriate use of the harvested biomass will depend on the material's cyanotoxin concentration. If nontoxic, landfill application or use as wet fertilizer might be possible; composting would likely be allowed, but authorities would need to be contacted for local regulations. If processors can be found for use in the synthesis of commercial products such as foam rubber or biofuels, disposal permitting may not be necessary. If cyanotoxins are present, then permits for use of the collected biomass would be needed, and local and state officials should be contacted. For both toxic and nontoxic biomass, harvesting would remove cellular nitrogen and phosphorus, assisting in nutrient removal from impacted water bodies and therefore possible "credit" for TMDLs in a watershed.

CASE STUDY EXAMPLES

Lake Okeechobee and Newnans Lake, Florida, U.S.: Skimming alone or flotation followed by skimming are two strategies offered as intervention technologies for HCB removal in New York and Florida, respectively. In Florida (Page et al. 2020), a pilot study of the surfactant-flotation-skimming-ozone technology was conducted in Lake Okeechobee and Newnans Lake. Unfortunately for estimates of efficacy, little scum cyanobacteria were present; most biomass was at depth and at low cyanotoxin concentrations (<1 ppb). Results indicated that most of the nitrogen and phosphorus was found in the cells, and removal of nutrients was very high. The technology shows promise, particularly when surface cyanobacteria densities are elevated, but treatment costs are very high, estimated from $2M to $18M per year.

Southampton, New York, U.S.: Detail on the pilot program in New York can be found in the Southampton Press (2019).

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