***Planktonic:***

*In-water Intervention Strategy*
*Emerging Supporting Field Data*

***Benthic:***

*Strategy Not Applicable*

Hydrodynamic cavitation is a process to induce a phase change in water from a liquid to gas as microbubbles. There are a number of ways to produce these bubbles, including forcing water through a narrow constriction. As the bubbles collapse, a pressure (shock) wave is created that induces shear to disrupt colonies and aggregates. More importantly, Hydrodynamic cavitation is a process to induce a phase change in water from a liquid to gas as microbubbles. There are several ways to produce these bubbles, including forcing water through a narrow constriction. As the bubbles collapse, a pressure (shock) wave is created that induces shear to disrupt colonies and aggregates. More importantly, bubble collapse yields hydroxyl and oxygen radicals, strong oxidizing agents that inhibit or kill cyanobacteria due to the group's limited enzymatic capabilities to thwart strong oxidizing conditions. Like ozonation and the emerging nanobubble technology, hydrodynamic cavitation can control cyanobacteria by disrupting buoyancy control due to the collapse of intracellular gas vesicles (Li et al. 2015). The disintegration of the cell membrane is also possible through lipid peroxidation within the cell membrane (Li et al. 2015) but has not always been found (Jančula et al. 2014). Zhang et al. (2006) reported a loss of photosynthetic activity due to destruction of chlorophyll and phycocyanin, thereby preventing subsequent growth. Laboratory studies indicate gas vesicle collapse and settling of *Microcystis aeruginosa* (Jančula et al. 2014, Thomas et al. 2019), sometimes accompanied by cell lysis (Thomas et al. 2019). Similarly, microcystin degradation is documented in some treatments (Medina, Griggs, and Thomas 2016, Thomas et al. 2019) but not others (Li, Song, and Yu 2014).

| **PLANKTONIC** |
|---|
| **EFFECTIVENESS**<br>• Water body type: Pond<br>• Surface area: Small<br>• Depth: Shallow<br>• Any trophic state, but typically most effective in eutrophic systems<br>• Mixing regime: Meromictic, monomictic, or dimictic<br>• Any water body use |
| **NATURE OF HCB**<br>• Gas-vesicle-containing HCBs<br>• Toxic and nontoxic HCBs; effective for cyanotoxins<br>• Intervention strategy |
| **ADVANTAGES**<br>• Best at eliminating surface blooms and cyanotoxins<br>• Reported water quality and ecological benefits<br>• Effective on gas-vesicle-containing cyanobacteria with low impact on other phytoplankton |
| **LIMITATIONS**<br>• High costs<br>• Needs infrastructure (electricity, piping, boat ramp, etc.)<br>• With suboptimal treatment, cells may remain intact, fuel bottom biological oxygen demand (BOD), and not oxidize cyanotoxins<br>• Treats only surface blooms; useful in small ponds<br>• Repeated treatments may be required throughout the growing season |

Cavitation yields free hydroxyl radicals and reactive oxygen species, oxidizing agents also produced in several other cyanobacteria in-water prevention and intervention strategies, including barley and rice straw, the emerging nanobubbling technique, nanoparticles (for example, titanium dioxide), flocculation with clay and surfactant, and ultrasound treatments. Hydrodynamic cavitation, to date, has been used only in near-surface waters (a few feet) but has been suggested as a feasible approach for blooms that accumulate near the shore or in small lake embayments (Medina, Griggs, and Thomas

2016). Multiple cavitation cycles may be needed for maximum bloom loss: Jančula et al. (2014) reported that one cavitation cycle removed 66% of a natural surface *Microcystis* sp. bloom, followed by 73%, 83%, 94%, 97%, and 99% after two, four, six, 12, and 18 cycles, respectively. Li et al. (2015) also reported that hydrodynamic cavitation is superior to cavitation action caused by audio waves (ultrasound) in that 88% of *M. aeruginosa* was removed after 10 minutes, while only 39% was lost with ultrasound treatment.

**COST ANALYSIS**

Few field prototypes exist currently, but access to a bloom may require a boat. You may also need power for pumping lake water through the apparatus and special equipment for microbubble generation. If other additives are included (for example, hydrogen peroxide or a superoxide generator), these will be additional expenses.

**Relative cost per growing season: Hydrodynamic cavitation**

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

**REGULATORY AND POLICY CONSIDERATIONS**

Because hydrodynamic cavitation is a new strategy, state officials should be contacted about permitting and application. If other oxidizing compounds are included with cavitation, the use of and training for these additional compounds should be explored, including their potential effects on applicators and other lake biota.

**CASE STUDY EXAMPLES**

California, U.S.: Most recent work involves transferring natural blooms to mesocosms and subjecting these contained HCBs to hydrodynamic cavitation. Medina, Griggs, and Thomas (2016) worked on aliquots from natural blooms and noted 32% reductions in cell numbers using only hydrodynamic cavitation; however, with the addition of superoxide, 81% of initial cell numbers were removed vs. only 23% with just cavitation. In two lakes samples, microcystin concentrations declined 68% and 87% with hydrodynamic cavitation treatments, with only slightly higher declines (77% and 92%) when superoxide additions followed cavitation.

Lake Neatahwanta, New York, U.S.: In another pilot study with field blooms moved to the laboratory, Shaw (2020) reported a 50% reduction in cyanobacteria chlorophyll 72 hours after hydrodynamic cavitation treatment; if also treated with peroxide, the reduction was approximately 80%. Field trials of this approach are now underway.

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