Planktonic:

In-water Intervention Strategy
Substantial Supporting Field Data

Benthic:

In-water Intervention Strategy
No Available Supporting Field Data

Substantial field evidence indicates that applying a stabilized peroxide pellet or a liquid peroxide mixture to a nonflowing water body can rapidly reduce HCBs and cyanotoxins (Mattheiss, Sellner, and Ferrier 2017, Matthijs et al. 2012). The pellet can be deployed in several hours to a day. Two pelletized types are now available: (1) one that sinks to the bottom for control of benthic cyanobacteria, as well as near-bottom or bottom populations, and (2) one that is a floating, slowly dissolving particle that moves with planktonic/surface blooms, responding to wind or other concentrating mechanisms. Field evidence from the Netherlands indicates that a lake-water-diluted peroxide solution can be effective in HCB control via dispersal at multiple depths (Matthijs et al. 2012). Effective peroxide concentrations appear to be 2.3 mg/L for *Planktothrix agardhii*, 3–4 mg/L for *Aphanizomenon* and *Anabaena/Dolichospermum*, and >5 mg/L for *Microcystis aeruginosa. M. aeruginosa* may require more than 5 mg/L, but zooplankton mortalities can occur much beyond 5 mg/L (Matthijs et al. 2016, Zhou et al. 2018). Impairment of overwintering benthic cyanobacteria at concentrations less than 1 mg/L has been shown to be temporary, while concentrations of 5 and 20 mg/L resulted in permanent damage to the benthic cyanobacteria community (Chen et al. 2016). Managers should consult the manufacturer's label for application guidelines.

PLANKTONIC	**BENTHIC**
EFFECTIVENESS • Water body types: Pond, lake/reservoir, any limited-flow freshwater system • Surface area: Small • Depth: Shallow • Any trophic state • Any mixing regime • Any water body use	**EFFECTIVENESS** • Water body types: Pond, lake/reservoir, any limited-flow freshwater system • Surface area: Small • Depth: Shallow • Any trophic state • Any mixing regime • Any water body use
NATURE OF HCB • All planktonic HCB types • Singular or repeating blooms • Toxic or nontoxic HCBs • Effective for most cyanobacteria • Intervention strategy	**NATURE OF HCB** • All benthic or near-bottom HCB types • Singular or repeating blooms • Toxic or nontoxic HCBs • Effective for most cyanobacteria • Intervention strategy
ADVANTAGES • Rapidly decomposes to O_2 and H_2O • Oxidizes cyanobacterial cells and cyanotoxins • Effective at <5 mg/L • Modest cost per acre, with dose dependent on cyanobacterial biomass • Field use common • NSF 60 certification for use in potable source water	**ADVANTAGES** • Rapidly decomposes to O_2 and H_2O • Oxidizes cyanobacterial cells and cyanotoxins • Pelletized H_2O_2 for benthic applications • Effective at 5–20 mg/L • Modest cost per acre, with dose dependent on cyanobacterial biomass • Field use common

LIMITATIONS • Requires access to surface area (for example, a boat) • Peroxide compounds need special handling and possible state-required training and application permit • Can release cyanotoxins from cells (but peroxides can quickly oxidize these compounds) • At H_2O_2 >5 mg/L, may impact zooplankton and fish • May be less effective in highly turbid systems	**LIMITATIONS** • Requires access to benthic area • Peroxide compounds need special handling and possible state-required training and application permit • Can release cyanotoxins from cells (but peroxides can quickly oxidize these compounds) • At H_2O_2 >5 mg/L, may impact zooplankton and fish • May be less effective in highly turbid systems

Figure 1. Granular and liquid peroxide application.
Source: J. Mattheiss, Hood CCWS, and Matthijs et al. (2012).

COST ANALYSIS

Costs for granule application are modest to moderate. Granules are used most often on ponds and small lakes, depending on the amount of the HCB and water body size. Liquid dosing is more expensive. Dosing and cost per acre are listed on each product; however, seeking <5 mg/L in-water H_2O_2 should be the goal. Granular peroxide compounds are not inexpensive, but cost is modest relative to mechanical strategies. However, one or two treatments per year or over several years may be required. Small boats with two people can disperse granular compounds, but special liquid-dispensing equipment (an additional cost) may be needed for multiple depth injections. Other cost estimates are presented in Appendix C.2 of HCB-1 (ITRC 2021).

Relative cost per growing season: Peroxide application

ITEM	RELATIVE COST PER GROWING SEASON
Material	$–$$
Personal Protective Equipment	$
Equipment	$–$$$

Labor	$–$$
OVERALL	**$$**

REGULATORY AND POLICY CONSIDERATIONS

Applicator training and permits for application may be required in many states. Check individual state regulations.

CASE STUDY EXAMPLES

Lake Anita Louise, Frederick County, Maryland, U.S.: Mattheiss, Sellner, and Ferrier (2017) reported that 350 pounds of peroxide crystals were dispersed over ~4.5 acres in a 10–12-foot-deep system from a small boat in approximately 3 hours. Peroxide concentrations approximated 3 mg/L and rapidly declined to background levels in 3 days. Densities of a *P. agardhii* surface bloom were dramatically reduced and remain low 4 years after treatment.

Various locations: Liquid application with peroxide levels at ~3 mg/L have also proved effective in Lake Koetshuis, Netherlands (Matthijs et al. 2012); Ouwerkerkse Kreek, Netherlands (Burson et al. 2014); and an Alabama aquaculture pond (Yang et al. 2018).

REFERENCES

Burson, A., H. C. Matthijs, W. de Bruijne, R. Talens, R. Hoogenboom, A. Gerssen, P. M. Visser, M. Stomp, K. Steur, Y. van Scheppingen, and J. Huisman. 2014. "Termination of a toxic Alexandrium bloom with hydrogen peroxide." *Harmful Algae* 31:125-135. doi: https://doi.org/10.1016/j.hal.2013.10.017.

Chen, Chao, Zhen Yang, Fanxiang Kong, Min Zhang, Yang Yu, and Xiaoli Shi. 2016. "Growth, physiochemical and antioxidant responses of overwintering benthic cyanobacteria to hydrogen peroxide." *Environmental Pollution* 219:649-655. doi: https://doi.org/10.1016/j.envpol.2016.06.043.

ITRC. 2021. "Strategies for Preventing and Managing Harmful Cyanobacterial Blooms (HCBs)." Washington, D.C.: Interstate Technology and Regulatory Council. Strategies for Preventing and Managing Harmful Cyanobacterial Blooms Team. https://hcb-1.itrcweb.org/.

Mattheiss, J, K. G. Sellner, and D. Ferrier. 2017. "Lake Anita Louise Peroxide Treatment Summary December 2016." https://www.lakelinganore.org/wp-content/uploads/2017/01/Peroxide-Application-Summary-Report-Final.pdf.

Matthijs, H. C., P. M. Visser, B. Reeze, J. Meeuse, P. C. Slot, G. Wijn, R. Talens, and J. Huisman. 2012. "Selective suppression of harmful cyanobacteria in an entire lake with hydrogen peroxide." *Water Research* 46 (5):1460-72. doi: https://doi.org/10.1016/j.watres.2011.11.016.

Matthijs, Hans C. P., Daniel Jančula, Petra M. Visser, and Blahoslav Maršálek. 2016. "Existing and emerging cyanocidal compounds: new perspectives for cyanobacterial bloom mitigation." *Aquatic Ecology* 50 (3):443-460. doi: https://doi.org/10.1007/s10452-016-9577-0.

Yang, Zhen, Riley P. Buley, Edna G. Fernandez-Figueroa, Mario U. G. Barros, Soorya Rajendran, and Alan E. Wilson. 2018. "Hydrogen peroxide treatment promotes chlorophytes over toxic cyanobacteria in a hyper-eutrophic aquaculture pond." *Environmental Pollution* 240:590-598. doi: https://doi.org/10.1016/j.envpol.2018.05.012.

Zhou, Q., L. Li, L. Huang, L. Guo, and L. Song. 2018. "Combining hydrogen peroxide addition with sunlight regulation to control algal blooms." *Environmental Science and Pollution Research International* 25 (3):2239-2247. doi: https://doi.org/10.1007/s11356-017-0659-x.