Alum Treatment

Introduction

Many freshwater ponds and lakes in Massachusetts have poor water quality due to excess inputs of nutrients from businesses (e.g., cranberry bogs, golf courses) as well as residential properties (e.g., lawn fertilizers, septic systems). Runoff from pervious surfaces (e.g., roads, parking lots) can be a major nutrient source in suburban and urban watersheds. Nutrients can also enter from ground water or from nutrient rich lake sediments. Excess nutrients can augment plant growth and trigger algal blooms, which further degrade water quality by reducing water column dissolved oxygen (D.O.) concentrations as algal material degrades. Phosphorus is typically considered the limiting nutrient in freshwater systems (Sterner, 2008) and as a result considered the most important factor in controlling algal blooms. Alum treatment is increasingly being used as a tool to aid in reducing pond and lake phosphorus loads as a means of improving water quality and limiting algal blooms.

While alum treatments offer potential benefits to diadromous fishes in the form of improved water quality and D.O. concentrations, treatment can also potentially have unintended negative impacts to these species. Potential negative impacts to diadromous fishes from alum treatment to freshwater lakes and ponds include accidental extreme pH changes following alum treatment as well as smothering by floc material. Extreme pH shifts would impact all life stages and likely result in mass mortality. For example, one early alum treatment at Hamblin Pond on Cape Cod in the 1990s resulted in a significant fish kill (estimated ~ 16,000 fish) due to an improper ratio of alum to sodium aluminate being applied (Mattson et al., 2003). This caused pH to rise above 9 (Wagner *et al.*, 2017). However, methods appear to have been refined in recent decades as extreme pH shifts and associated fish kills have not been observed in Cape Cod alum treatments since the 1995 treatment of Hamblin Pond (Wagner *et al.*, 2017). Following this fish kill event and a similar pH alteration in a Connecticut lake in 2000, procedures were modified to maintain pH between 6 and 8 and Al concentrations < 5 mg/L (Wagner *et al.*, 2017). The deposition of floc material during fish spawning periods could potentially result in smothering and egg mortality, although studies on this interaction are lacking. Demonstrated short term impacts to benthic invertebrates could be due to smothering (Steinman & Ogdahl, 2012), so the potential risk to demersal eggs is supported through demonstrated impacts to other co-occurring, non-mobile organisms. Relatedly, it is unclear whether a floc layer would provide suitable substrate for egg development for eggs laid after the floc layer had been deposited. Finally, alum treatment and associated changes in water quality could change lake food webs and habitat characteristics (Lund *et al.*, 2009), which could potentially enhance or diminish the lake as foraging and nursery habitat for diadromous fishes. For example, associated improvement in water column D.O. may improve diadromous fish habitat while improved water clarity and other food web changes may increase predation risk. Further, impacts to favorable phytoplankton and zooplankton communities are largely unknown. This document reviews the literature and proposed best management practices to minimize potential impacts to diadromous fishes from alum use in Massachusetts freshwater ponds and lakes.

Description of Alum Treatments

Alum (aluminum sulfate) is a metal salt commonly added to freshwater systems to control excess phosphorus. Alum is typically added to the water column via a work boat that runs transects across the lake or pond. Aluminum ions combine with phosphate ions to form aluminum phosphate:

$$Al_2(SO_4)_3\ 14H_2O + 2PO_4^{3-} \rightarrow 2AlPO_4 + 3SO_4^{2-} + 14H_2O$$

As alum is added to the water column, it forms aluminum ions, which are hydrated and form an aluminum hydroxide, a solid precipitate. This resulting precipitate forms a flocculent material (floc), which binds phosphates to produce aluminum phosphate and settles on the sediment surface. This floc layer separates the sediment from the water column, further reducing release of internal phosphorus residing in sediments (Black & Veatch, 1971; NALMS, 2004).

Literature Review: efficacy and potential impacts of alum treatments

Reviews of alum treatment monitoring data have shown fairly consistent short-term water quality improvements in the form of total phosphorus reduction (Huser *et al.*, 2016; Wagner *et al.*, 2017). An assessment of the longevity of post alum treatment water quality improvements for 83 lakes in the U.S. and Europe found that benefits in the form of total phosphorus reduction averaged 11 years (Huser *et al.*, 2016). Longevity varied as a function of lake depth, with deeper, stratified lakes having greater longevity (15 years on average) relative to shallow, fully-mixed lakes (4.6 year average). Treatment longevity was also influenced by aluminum dose and watershed to lake area ratio, which, along with lake morphology, explained 82% of variation in treatment longevity (Huser *et al.*, 2016). A review of alum treatments on Cape Cod included data up to 10 years post-treatment and generally showed continued efficacy of phosphorus reduction over that time period (Wagner *et al.*, 2017). For a lake in Michigan, the efficacy of the alum treatment slightly declined five years post-treatment but still continued to retain phosphorus in sediments and keep water column phosphorus levels at reduced concentrations relative to pre-treatment (Steinman & Ogdahl, 2012). Nonetheless, the measured water column levels, while reduced, were still sufficiently high to support continued algal blooms, suggesting a need to also reduce phosphorus source inputs to improve long term water quality. Welch and Cook (1999) found that lakes with high inputs of phosphorus did not respond to alum treatment.

Overall, timing of treatment appeared to affect efficacy, with spring applications resulting in greater total phosphorus reductions than fall treatments in Cape Cod lakes (Wagner *et al.*, 2017). For other lakes the relationship of timing and efficacy was less clear. As an example, Mystic Lake, which received treatment in the fall, showed improvements and Lovell's Pond, treated in the spring, experienced lower clarity and continued cyanobacterial blooms post-treatment (Wagner *et al.*, 2017). Both of these outcomes suggest that the impact of treatment timing on efficacy is not fully understood.

Biological monitoring has revealed some short-term impacts of alum treatment on lake benthic communities. For a Michigan lake, overall benthic invertebrate density declined one year post-treatment (Steinman & Ogdahl, 2008), but densities were similar to pre-treatment levels five years post-treatment (Steinman & Ogdahl, 2012). The cause of the year one decline was not known, but could have been due to initial smothering by the alum floc (Steinman & Ogdahl, 2012). Smeltzer et al. (1999) also documented a short-term impact to benthic invertebrates, with species richness and density declining post-treatment in a Vermont lake but then rebounding within two years.

<u>Past Environmental Review:</u>

In the past 25 years, alum treatments have been documented in 10 Cape Cod lakes (Fig. 1; Wagner *et al.*, 2017). More recently, alum treatments haven been performed at two additional Cape ponds: Hinckleys Pond in Harwich and Mill Pond in Brewster. Alum treatments have only been included in two south coast permit applications in the past decade, but more applications are likely to appear in the future due to continued water quality problems in MA ponds and lakes as well as demonstrated efficacy of the alum treatment approach in Massachusetts (Wagner *et al.*, 2017).

Figure 1. Map of alum treatment sites on Cape Cod from 1995 to 2015. Image taken from Wagner *et al.* (2017).

Most Recently Reviewed Alum Treatment Projects:

1. *<u>White Island Pond Alliance (Plymouth/Wareham; DMF ID: 20122178)</u>*

To combat recurring algal blooms, the White Island Pond Alliance contracted Aquatic Control Technology to perform alum treatments. As part of our initial NOI review (2012), MA DMF recommended a TOY restriction on alum treatment from March 15 to September 15 to protect eels and river herring. Following a meeting with stakeholders attended by MA DMF diadromous and habitat project staff, MA DMF submitted a revised NOI letter (2013) that pushed the TOY start date back to April 1 to allow the contractor to have time in March to perform the alum treatment, the efficacy of which is both temperature and pH sensitive.

This revised TOY still protected the primary river herring spawning and larval development period. In 2014, following additional incursion requests from the applicant, MA DMF submitted a further revised letter to the conservation commissions supporting a slight incursion to April 5th for the East Basin component of the project and April 15th for the West Basin. This latter incursion was conditioned with a requirement for the West Basin to be separated with a seine barrier prior to April 5th to prevent adult river herring from entering the area of impact.

2. *Town of Brewster Mill Pond Complex (Brewster; DMF ID: 20162034)*

Alum treatment was proposed in Upper Mill Pond as part of a phosphorus control program. In a 2017 NOI comment letter, MA DMF recommended a TOY restriction of March 15 to June 30 and September 1 to November 15 to protect eels and river herring. MA DMF also recommended a pilot water testing treatment program to determine the appropriate alum/aluminate ratio to ensure it would not cause an excessive change in pH (i.e., outside a 6.0-7.5 range). MA DMF also recommended that alum treatment occur in the fall (after November 15 TOY) and be applied to the deepest areas of the pond away from the shoreline. A pre-, during, and post-application monitoring program and fish kill monitoring program were also recommended, with treatment being suspended if any fish kills were detected.

3. *Town of Harwich Hinckley's Pond*

The Town of Harwich treated the 174-acre Hinckleys Pond in 2019 with a target of a 2:1 ratio of alum to sodium aluminate applied at a dose of 108 g/m^2 over the target area of 90 acres where the depth is 12 ft or greater. The treatment occurred in the fall with 77,000 g of alum and 40,000 of sodium aluminate applied at a cost of $400,000 - $500,000, including ongoing monitoring costs. Under the project Order of Conditions from the Town of Harwich Conservation Commission, post-application monitoring is ongoing. Unlike the While Island Pond and Mill Pond projects, MA DMF did not receive an NOI to review or comment upon for this project.

4. *Ashumet Pond, Mashpee*

The 216-acre pond was treated in 2001 to reduce internal phosphorous loading from anoxic sediments. A total of 28 acres was treated in September using a 2:1 ratio of alum and aluminate at a concentration of 7.2 to 28.7 mg/L applied to the hypolimnion at depths ranging from 1.5 to 6 m (total dose of 43 g/m^2) . No toxicity effects were detected in a comprehensive monitoring program (Mattson et al. 2003). The total cost for this project, including equipment, permitting, project management, monitoring and lab analysis was $377,000 (Mattson et al. 2003). Unlike the While Island Pond and Mill Pond projects, MA DMF did not receive an NOI to review or comment upon for this project.

Summary of key components to review letters involving alum treatment in systems containing diadromous species:

1. **Time of Year Restrictions**: Time of year (TOY) restrictions on alum treatment should be recommended for the months when diadromous fishes are most vulnerable and abundant. The most conservative TOY, beginning with the earliest spring date for the

species present in a given system and extending until the latest fall date, should be recommended as a starting point if the permit application does not provide information on why such a restriction would not be feasible. The spring TOY is the most critical since floc could potentially smother eggs. No alum treatment should be supported during the peak of river herring spawning and larvae emergence from mid-April through June. Decisions on April activity may have site-specific, or regional considerations. Avoidance of summer and early fall months is also ideal as it provides an additional protection against potential pH effects. The primary species under DMF jurisdiction that will receive TOY review for alum treatment will be river herring, with some case-by-case consideration for white perch and American eel.

2. **Monitoring Plans:** Adequate monitoring is critical to assess the efficacy of the alum treatment as a phosphorus reduction technique and to detect any potential negative environmental impacts (e.g., fish kills, extreme pH shift). Monitoring should be established prior to alum treatment, continue during treatment, and ideally be continued for multiple years post-treatment. See Table 1 below for common monitoring specifications.
3. **pH Stability Assurance:** The permit application should contain information demonstrating how pH will be stabilized during alum treatment. If lacking, this information should be requested in comment letters in addition to associated pH monitoring.
4. **Commitment to Nutrient Source Reduction:** While not necessarily something that can be included in permit conditions, DMF comments should continue to highlight the need to have a broader watershed-level plan to reduce nutrient inputs as a long-term solution to water quality improvement. Alum treatments should be used as a complement to, not a replacement for, source reduction strategies such as fertilizer application BMPs, low impact development storm water management designs, reduction in impervious surfaces, wetland restoration and maintaining vegetated buffers. While phosphorus is often the limiting nutrient in freshwater systems, nutrient dynamics vary among systems, which further warrants a more holistic approach to nutrient management that also includes controls on nitrogen (Maberly *et al.*, 2020).

Table 1. Proposed water quality monitoring for alum treatment projects

Parameter	Recommendation
Number of Monitoring Stations	• Minimum of 3 (ponds ≤ 50 acres) to 5 (lakes > 50 acres)
Monitoring Station Locations	• Minimum of 1 near inlet, outlet, and middle of pond
Station Depths	• Surface, bottom (within 0.5 m) and at 1 m intervals throughout water column
Water Quality Parameters	• Temperature, pH, D.O., specific conductivity, alkalinity (all depths) • Secchi disc depth, total nitrogen (TN), total phosphorus (TP), dissolved aluminum (Al) (surface) • TN, TP, dissolved Al (mid-water)
Sampling Schedule	• Pre-treatment: 2 weeks and 1 day prior

	• Post-treatment: 1 day, 7 days, 14 days, then monthly post-treatment April-November of sampling year + ≥ 2 years post-treatment* *Sampling frequency can be reduced for TN, TP, and dissolved Al measurements if a suitable threshold is met
Additional Water Quality Parameters for Consideration	• Turbidity (NTU) • Chlorophyll *a* • Groundwater nutrient monitoring • Phosphorous (P) (total orthophosphate, total P, dissolved P, insoluble P)

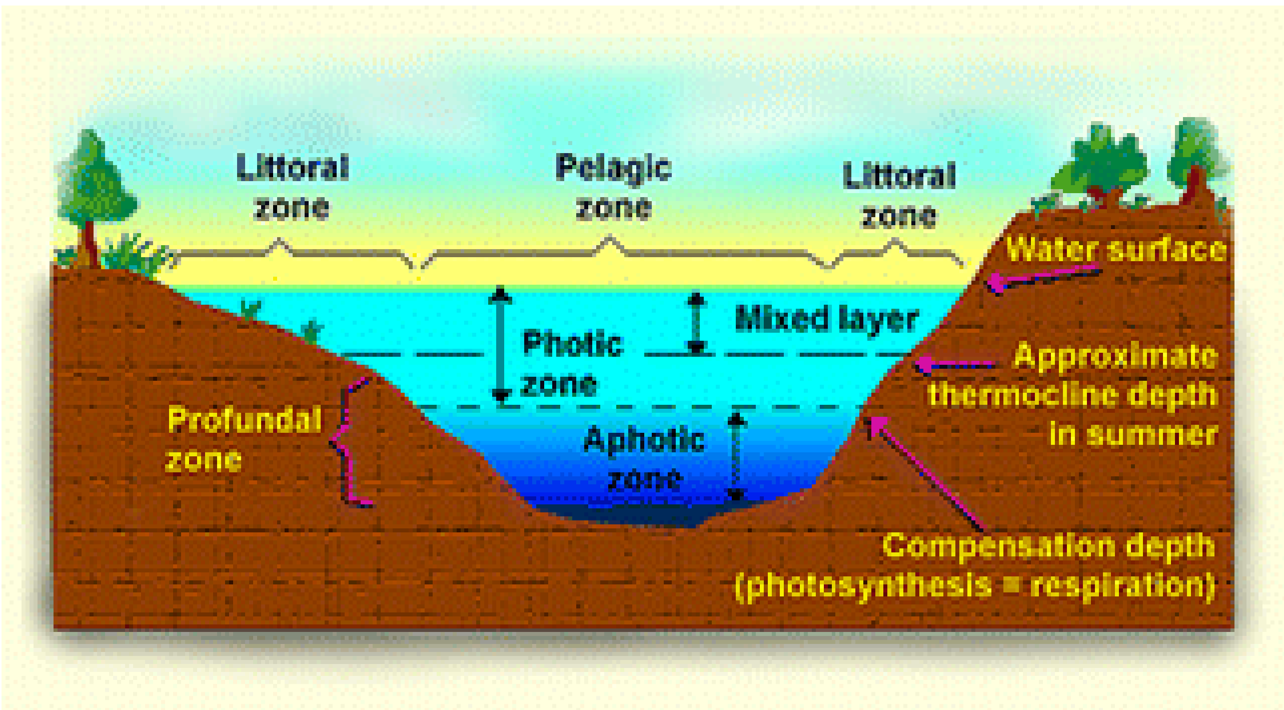

Figure 2. Diagram of lake habitats showing distinct zones that should be included in monitoring programs. Monitoring stations should include both littoral and pelagic zones and include depth-stratified sampling from surface to near bottom in both regions. Image taken from: http://www.aquatic.uoguelph.ca/lakes/page21.htm

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