

APPENDIX D



ALGAL CONTROL

Algal Control

Currently, the District is able to take water into the WTP from either Lopez Lake (through a bypass pipeline which currently has not been authorized through a DHS waiver) or the Terminal Reservoir (approved source of supply). This appendix provides a discussion of additional steps the District could take if algal blooms continue to be a problem. More information is required to determine the probable cause(s) of the algal blooms in Lopez Lake and the Terminal Reservoir and to identify a method of algal control that would eliminate or reduce the severity of taste and odor events. A two-phased approach is recommended: (1) implementation of a data collection program, which will define the source(s) of the algal blooms, and (2) an evaluation of management strategies most appropriate for the District's situation. These two activities are discussed below.

Data Collection Program

A monitoring program could result in the collection of information that would help define the source(s) of the algal blooms. The program should include the collection of biological, chemical, and physical data from the Terminal Reservoir and Lake Lopez and its water sources. Biological data should include algal counts and species identification. Chemical parameters should include dissolved oxygen (in continuous profiles with depth) and nutrients (phosphorus and nitrogen). Physical characteristics should include temperature (in continuous profiles with depth) and pH. Water samples should be collected every two weeks from the sources of water to the Lake and at three locations in the Lake and Terminal Reservoir (at the surface and at depth). A detailed description of sampling and analytical methods could be developed in cooperation with the District if a monitoring program is to be initiated.

Potential Management Strategies

Many water utilities in the United States have applied copper sulfate on a regular basis for the control of phytoplankton populations in surface waters. Being a toxic substance, copper kills non-target organisms such as zooplankton and fish fry. Other disadvantages associated with its use include (1) possible blooms of copper-resistant algal species following treatment; (2) possible oxygen depletion caused by decay of significant amounts of bloom material; and (3) excessive copper accumulation in water plant sludges, which may reduce ultimate disposal options.

Casitas Municipal Water District (1987) surveyed water utilities to assess algal control strategies currently in use throughout the United States. Chemicals most often used included copper sulfate pentahydrate and chelated copper compounds. Chemicals used occasionally, but infrequently, included potassium permanganate and chlorine. Nutrient controls also are popular, as are physical controls such as

lake destratification and aeration. As might be expected, copper sulfate is the most commonly used chemical control method. The survey indicated that the most successful algal control programs are those that included both nutrient control measures and chemical treatments.

Alternatives to the application of copper compounds to lakes and reservoirs for algal control include phosphorus removal from the water column by chemical precipitation and inactivation, physical methods, and biological methods. These strategies are described below.

Chemical Precipitation

This technique, which is described by Cooke, et al. (1992, 1986), as a “lake-improvement” method, involves coagulation and flocculation of the source water, usually with alum but occasionally with sodium aluminate or ferric chloride. The objective of this procedure is to remove phosphorus from the water column. This procedure is especially useful in water supplies in which excess phosphorus from point sources, runoff, or internal cycling from the sediments exacerbates algal growth.

Physical Methods

Aeration is the most significant physical treatment method for controlling blue-green algal blooms in water supplies; it is appropriate only in impoundments. Other methods, such as light exclusion from the water column by addition of clay, activated carbon, etc., are impractical for use in large water supplies and are not discussed here. Cooke, et al. (1992) describe in detail several other nutrient-control methods that vary in terms of practicality, effectiveness, and difficulty of implementation.

The primary objective of aeration is to supply oxygen to an impoundment in order to prevent the development of anaerobic conditions in the impoundment and the subsequent release of phosphorus (i.e., internal loading) from the sediments, especially in the hypolimnion of eutrophic, thermally stratified lakes. Several techniques are described in the literature; the two most often discussed are artificial circulation and hypolimnetic aeration. Another technique for improving water quality is hypolimnetic withdrawal, which removes phosphorus-rich water from the bottom of an impoundment. Several benefits other than the elimination of phosphorus can accrue. Cooke, et al. (1992) describes this technique, as well as other aeration techniques, in detail.

Artificial Circulation. Artificial circulation has been employed since the 1950s to control algal biomass. It can be achieved by a variety of mechanical means such as pumps, jets, and air bubbles. Unlike hypolimnetic aeration, the goal of artificial circulation is continuous circulation of the lake from top to bottom. Stratification, therefore, is either prevented or destroyed in most instances, and no dramatic thermal gradient will exist. The technique is most successful in nutrient-

rich impoundments where nutrient sources cannot be eliminated and oxygen depletion at the bottom of the lake is common (Cooke, et al., 1992).

Hypolimnetic Aeration. Hypolimnetic aeration is a type of aeration used in impoundments with a clearly defined and stable thermal stratification during the warmer months of the year. The process results in aeration of the hypolimnion without destratification; thus, warming of the lake is avoided. If iron is available in reasonably high concentrations in the hypolimnion, phosphorus levels can be greatly reduced by precipitation.

Three categories of hypolimnetic aeration have been described (Cooke, et al., 1992): *mechanical*, wherein hypolimnetic waters are actually removed, aerated, and returned; *injection of pure oxygen*, usually from liquid oxygen held in tanks onshore, and *injection of air*, accomplished either by air-lift or injection devices.

Layer Aeration. Layer aeration is a proprietary aeration system described as a process that "...redistributes heat and oxygen in a stratified lake or reservoir. It creates and aerates discrete layers, establishes several thermocline barriers to vertical diffusion, and reduces the volume and areal coverage of the hypolimnion" (Kortmann, et al., 1988). The authors report the elimination of blue-green algae from a lake that was aerated with layer aeration units.

Hypolimnetic Withdrawal. According to Cooke, et al. (1992), the principal purpose of hypolimnetic withdrawal is to remove poor-quality water from the bottom of the reservoir. The process has several additional benefits, among them a decrease in the hypolimnetic residence time and a reduction in the opportunity for the hypolimnion to become anaerobic.

Sediment Covers. Cooke (1980) discusses several techniques for covering bottom sediments. Several of the coverings (plastic sheeting or screens) were effective at controlling macrophyte growth. The use of fly ash to cover sediments and retard nutrient release was not recommended because of negative environmental impacts (toxicity, high pH, and heavy metals). Ferric sulfate was applied to three reservoirs in England to control phosphorus release and algal growth (Daldorph and Price, 1994). The application method was different in each of the reservoirs, and so was the treatment effectiveness. Ferric sulfate was most effective when it was applied to the main reservoir body, rather than a curbed-off section or tributary. Blue-green algae populations declined; however, macrophytes increased. Overall, water quality conditions in the reservoirs improved, and the reservoirs have been in continual operation since treatment started.

Biological Methods

Potential biological methods for the control of blue-green algae suggested by various researchers include (1) the application of viruses (cyanophages) that

specifically infect blue-green algae and certain other types of bacteria, called myxobacteria, and (2) biomanipulation procedures. The term “biomanipulation” was first suggested by Cheaper, et al. (1975), and Cheaper (1978) to “...include lake improvement procedures that alter the food web to favor grazing on algae by zooplankton, or that eliminate fish species that recycle nutrients” (Cooke, et al., 1986).

Use of Cyanophages and Myxobacteria. The effectiveness of cyanophages and myxobacteria against blue-green algae has been demonstrated only in the laboratory, and these organisms are not generally available for field use. Carmichael (1992) notes that microbiological control of cyanobacteria has been advocated for some time and cites studies by Safferman and Morris (1964, 1991) and Burnham and Fraleigh (1983) that highlighted difficulties in maintaining sufficient supplies of virus and myxobacterial cultures in the laboratory for use in treating water supplies. The host-specific nature of this method of control also makes it less practical.

Biomanipulation. Biomanipulation involves changing the ratios of the various components of an aquatic ecosystem, notably the phytoplankton, herbivores, primary predators, and top predators. Carpenter and Kitchell (1988) and Kitchell, et al. (1993), experimented with the fish communities in oligotrophic kettle lakes that were rather isolated from outside disturbances. Carpenter and Kitchell (1988) state that large manipulations of fish community structure can produce order-of-magnitude changes in water quality characteristics such as algal biomass. Carpenter, et al. (1992) note that the addition of another trophic level (piscivores) in one lake resulted in decreased phosphorus turnover rates because phosphorus was incorporated in the fish. Although fish excrete considerable amounts of phosphorus, food webs that are dominated by piscivores tend to have smaller algal components and are less sensitive to phosphorus inputs

Source Water Control Summary

These alternatives are summarized in Table 1, which indicates the problems addressed by the alternative, its effectiveness, potential negative impacts, and relative costs (when they could be estimated). A detailed evaluation of control strategies should be conducted when sufficient data have been collected to identify the source(s) of the algal blooms. The evaluation should also consider other management strategies, such as wetlands, in-line chemical treatment, detention basins, and a comprehensive watershed management plan.

Table 1: In-Lake Alternative Management Strategies

Strategy	Problems Addressed	Effectiveness	Negative Impacts	Relative Costs
Copper sulfate	Algae	Moderate, short term	Toxicity, Cu build-up in sediments	---
Chemical precipitation	Phosphorus	Control internal source	Temporary	---
Artificial circulation	Phosphorus, sulfide, possibly algae	High for sulfide	Could increase algae and turbidity; noise	Low
Hypolimnetic aeration	Phosphorus, sulfide	High	Reservoir depth	---
Layer aeration	Algae	Moderate	Proprietary	High
Hypolimnetic withdrawal	Nutrients	Moderate to low	---	---
Sediment covers	Algae, phosphorus	---	---	---
Cyanophages	Algae	---	Impractical	---
Bio-manipulation	Algae	Variable	---	---