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Algae Control Problems and Practices Workshop

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Abstract

This workshop provided an opportunity for discussion between people with algae problems, persons involved with controlling the problems, and individuals who are familiar with the regulatory processes for treating and dealing with algae problems. The goal of this workshop was to establish a closer interaction between people working with various aspects of algae growth problems in the Pacific Northwest.

Introduction

Western water resources are continuously facing increased demand from industry and the public. Consequently, many of these resources are required to perform multiple tasks as they cycle through the ecosystem. Many plants and animals depend upon these resources for growth. Algae are one group of plants associated with nutrient and energy cycles in many aquatic ecosystems. Although most freshwater algae are microscopic in size, they are capable of dominating and proliferating to the extent that the value of the water resource for both industrial and domestic needs is compromised. There is a great diversity of aquatic environments and systems in which algae may be found, and there are many varieties of treatment and control techniques available to reduce the impacts of excessive growth. This workshop was organized to exchange information about these control problems and practices.

The general discussion was initiated by describing specific algae control problems within a hydrogeneration system, the rationale used to develop a treatment process for this problem, and the development of a decision matrix to compare and judge alternative techniques. A presentation of the various types of control practices, including chemical, biological, and mechanical techniques followed. Some specific control practices were also discussed during the presentation including a biological technique using barley straw, a chemical technique using an herbicide, and the mechanical practice of hydro-blasting.

Discussion

There is a considerable body of information available, based upon technical and professional experience, for controlling the growth of algae (Evans and Hoagland 1986, Pieterse and Murphy 1990). However, rarely is a complete description available correlating various problems, treatment applications, and lessons learned (Janik, et.al. 1980). We, the authors, thought we had

a fairly good handle on the subject, but several areas of uncertainty quickly appeared as a control program was developed. Therefore, the principle goal of this report is to suggest a means to organize information pertinent to a particular algae problem and then use this data to develop a pathway for comparing and judging available treatment technologies. To illustrate this process, we used the example of a nuisance algae growth problem that exists on the Tiger Creek Canal, one of Pacific Gas & Electric's (PG&E) hydropower water conveyance systems.

Problem Description

The Tiger Creek Canal originates from an impounded water resource in the Sierra-Nevada Mountains, in the Mokelumne River Basin. The drainage is granitic bedrock with low human impact i.e., little development, low recreation use, minimal forestry activity. The water is very soft, slightly acidic, and low in nutrients. Flow in the hydrogeneration canal is maintained at 550 cfs for maximum power generation. The canal is approximately 17 miles long and is made up of concrete box sections, 20 feet long by 14 feet wide. The water depth is about 6 feet, with 1 foot of freeboard. The flow velocity is approximately 7 ft/sec. In addition to the canals, there are two reservoirs associated with the general flow of the canal. The first, called the Regulator Reservoir, has a surface area of approximately 7 acres. This reservoir receives water from the upper 15 miles of theTiger Creek Canal, as well as from Tiger Creek proper, and serves as a main reserve for the feed flow into the second reservoir, the Tiger Creek Powerhouse Forebay. This reservoir has an approximate surface area of one acre and feeds directly into the powerhouse generator penstock.

The Tiger Creek Canal system was built for power generation in the early 1930's. Algae problems are not new to the system and have been handled by a variety of methods (Creek 1992, Creek 1994). The control methods selected and used over the years have changed primarily as a result of PG&E management decisions based upon environmental and economic considerations. Currently, the basic form of treatment is a mechanical procedure using high pressure water blasting. This strategy requires taking the canal out-of-service and draining it to expose the sides and bottom. A truck equipped with high pressure water jets is then driven through the canal, dislodging and washing out the algae.

While this procedure is effective in removing the algae from the canal, there is considerable cost associated with this operation. First, there is the lost generation capacity while the system is down. Typically, it requires two days to clean the entire canal, and then an additional two days of outage is taken to dry the canal. (It has been determined that the extra days of drying will significantly delay the regrowth of the algae). Unfortunately this treatment method needs to be repeated several times during the active algae growing season, normally beginning in early May and continuing through October. Therefore, alternative methods for algae control have been sought over the last several years.

In order to effectively develop a control strategy to meet the immediate needs, and to develop a long-term control plan, it is necessary to assemble and organize the proper information. The following discussion presents the format used to develop the algae control strategy for the Tiger Creek Canal system. The first part outlines a means of organizing baseline information describing what is known about the current situation. The second section describes the development of a decision matrix. This matrix addresses management concerns more closely aligned with environmental, safety, and economic responsibilities.

Assessment of the Problem

The initial assessment provides a description of baseline conditions (water quality data, algal species identification, and other physical and chemical parameters) associated with the immediate problem. This information will be needed in developing the control strategy and determining whether the control is working properly. The general outline developed to organize baseline information in the Tiger Creek Canal system is presented below.

Type of Impact

The type of impact considers whether the algae problem affects the environment, productivity, public health, or aesthetic values. Productivity is related to any industrial process which is impacted when the development of algae reduces the efficiency of the system to deliver the required water to the process. The algal growth problem at Tiger Creek affects productivity by reducing the ability to generate electrical power. The development of filamentous algae in the canal alters the flow characteristics of the water. This change causes the water level to increase in the canal, decreasing the freeboard along the canal sides. In order to maintain the lost freeboard, the flow into the canal system is reduced, and subsequently the power generation is reduced.

Environmental impacts are generally associated with the balance of the ecosystem, and may be divided into direct or indirect impacts on human populations or activities. These effects include the invasion of new species, the presence of potential health problems, or the development of taste, odor, and visual aesthetic problems which prevent, or reduce, the use of these resources (Biggs 1996). Public health concerns are usually associated with domestic water supplies, recreational contact areas, and the health of livestock and wildlife. For example, many people are familiar with "red tides" and their effect on fish, shell-fish and other animals in the food chain that may ingest these algae. The development of large blooms of blue-green algae in freshwater reservoirs may also possess toxic characteristics that endanger animal or human health (Prows and McIlhenny 1974).

Sensitivity

Sensitivity is largely a subjective perception of the problem, resulting in a ranking into various categories receiving high, medium, or low attention. There is often a high level of attention associated with algal blooms that result in direct impacts to water used for public consumption and/or industrial application, since these conditions may cause immediate threat to public health or halt on-line production. These problems seem to be handled rapidly with little attention to the cause leading to the problem. Ironically, after the problem is under control, the level of attention rapidly decreases. The decision processes and results are poorly recorded and, little if any attention, is paid to developing a control strategy to prevent reoccurrence of the problem. Because medium and low sensitivity problems tend to occur over a longer time frame, they are better documented, and long term control strategies are more often developed for these levels of problems.

History

History deals with the general considerations that include the relative frequency of occurrence, the area of potential impact, reasons for the problem's existence, and the record of field information describing conditions associated with the problem.

The area of impact may be limited to the specific site or encompass a much broader area, requiring the development of basin management criteria. In the case of the algae problem in the Tiger Creek Canal, the potential area of impact for a treatment plan is much larger than the immediate watershed, since the Mokelumne River is a primary source of drinking water to the East Bay area of San Francisco. Therefore, any control strategies considered need to address potential concerns downstream from the immediate area of application.

Before launching a lengthy investigative effort, it is often beneficial to perform a logical evaluation of the existing problem. It may be possible to identify obvious reasons for the existence of nuisance algae growth. Recent changes may have occurred within the area such as an increase in nutrient loading, removal of shading, or the introduction of new uses and activities. This process is often overlooked, but may save considerable time, money and effort.

It is critical to assemble field data describing the physical, chemical and biological characteristics of the area in which the problem is occurring, and also, in areas impacted by any treatment technology. This information provides assistance in developing a control strategy and a means for detecting significant changes in the application area as a treatment is applied. Control strategies may be directly influenced by potential changes in the natural conditions such as temperature fluctuations, water hardness, solution pH, dissolved oxygen, or dissolved and suspended solids. It is also important to characterize the biological components of the system, since different species of algae have varying degrees of tolerance to the methods used to control them (Palmer 1977). In the Tiger Creek Canal system, nutrient loading was originally thought to be assisting the filamentous algae growth. However, water quality measurements made during this last season indicate that the nutrient concentrations were low. Presently, light and water temperature appear to be the primary triggers for the dominant algae.

Social aspects of the problem, and the affected area, are important to consider since geopolitical sensitivities are often subtle and may be overlooked. For instance, most people are not concerned with implementing a control program that kills algae. However, if the control program contributes to the death of other animals, such as game fish; or causes a significant change in the overall water quality, public attention will be much higher, forcing the discontinuation of the treatment program.

In the case of PG&E's algae problem, the impact to power production and system operations must be included in the development of a control strategy. These considerations led to the construction of a decision matrix where the costs of labor, materials, and other resources could be assembled and compared.

Development of Decision Matrix

PG&E developed the matrix formulation (Table 1, Lindquist 1995) to compare and evaluate various techniques using common criteria. By applying certain weighted values to each criteria, it is possible to rank the control technologies and determine which control technique should be considered for implementation. The categories in the Table were selected and ranked in importance based upon previous algae control experience at PG&E.

Table 1. Control Technology

Consideration	Chemical	Biological	Mechanical	Combination
Implementation Costs	($$)			
Operational Costs	($$)			
Feasibility	*			
Availability	*			
Timing	*			
Monitoring Needs	*			
Environmental Risks	*			
Operational Impacts	*			
Regulatory Risks	*			
Safety	*			
Short/Long Term Solution	*			
R&D Opportunity	*			
Champion	Name			

(**NOTE**: *Criteria that do not have direct costs associations are numerically weighted using 1, 2, 3 to indicate high, medium, or low characteristics, Lindquist, D. 1995.)

Criteria Definition

Implementation Costs take into account the costs of installing and initiating the proposed algal control technology, and include costs related to the labor and materials required for implementation.

Operational Costs deal with the costs associated with maintaining the operational status of the control practice, after the technology is installed. While monitoring needs are addressed elsewhere, the costs associated with any monitoring requirements are also calculated under this heading.

Feasibility determines the ability to apply the technology within the existing conditions of the site. Under this consideration, it is important to identify any uncertainties and determine whether additional studies or pre-testing will be required before full implementation is possible.

Availability determines if the technology is an off-the-shelf item or requires additional development before installation. Also, it includes the identification of a commercial vendor of the practice.

Timing deals with developing a schedule for implementation of the control practice. For instance, in PG&E's problem, algal growth does not usually begin until the first of May. The control technologies were then judged upon how much time was required to have them in place, and whether they could meet the target date.

Monitoring Needs address the collection of data to verify algae control and to support any environmental and regulatory measurements required for implementing a control strategy.

Environmental Risks are considered to be synonymous with regulatory risks; however, regulations may change over time, and materials not presently considered to be harmful may be considered hazardous as new risk factors are discovered.

Operational Impacts deal with the implementation of the algae control strategy within the framework of ongoing process activities, and address the impacts on existing operations during the implementation of the control technique.

Regulatory Risks address the sensitivity of the algae control technique within the current regulatory framework and include the manpower and other resources required to fulfill these requirements.

Safety refers to the safety of employees, personnel implementing and operating the control program, and the general public.

Short/Long Term Solution describes whether the control strategy can be used for several years or provides a temporary, stop-gap measure that can be used until a long-term solution to the algae problem can be developed.

R&D Opportunity addresses whether it is necessary to conduct some tests to optimize the salient features of a control technology to the existing conditions for a particular algae growth problem. R&D issues may be used to identify potential financial resources to assist in the development of a control program, since it may be possible to obtain State or Federal assistance to support the research.

A Champion is the person who has the responsibility for assembling the basic information on the control strategy, finding answers to review committee questions, and developing the basic classification of the technique for review purposes. Without such a person, the information base on the control practice will likely be fragmented, resulting in the inability to adequately evaluate a technique.

This decision process works well when people, with different professional experience and backgrounds, rate the various categories according to their knowledge and biases. It is also helpful to have consultants or vendors present descriptions of algae control techniques to the reviewers. Where appropriate, dollar amounts can be used to complete the matrix. Other categories are ranked and given a weighted value based upon the perceived level of difficulty.

After calculating a value for each category, the champions present the results. If questions are raised, the champion has the responsibility for finding answers and presenting the information at a later round of discussions. In the case of the Tiger Creek problem, several different control practices were considered for implementation this year. Three review periods were used to present information on control alternatives, answer questions about techniques, and develop the ranking. After these reviews, PG&E had sufficient information to select the algae control strategy for implementation.

Specific Control Strategies

Chemical Control

Chemical methods are often selected since they are easy to apply on an "as needed" basis. The most widely used is the application of copper or copper compounds for the control of algae. In order to properly use any chemical treatment procedure, it is imperative that basic water chemistry is known so that an effective dose concentration can be calculated. Chemical agents may be sensitive to water hardness, acidity, and particulate loads in the application area. Also, the general persistence and form of the chemical should be considered. Some materials interact with other components in the system, increasing their potential toxicity. Some of the newer herbicides are designed for specific, short duration control. This type of treatment often requires repeated application but has the advantage of lowering the long term environmental liability.

The application of Hydrothol, an aquatic herbicide, is under consideration by PG&E. This herbicide is specifically designed for use in aquatic systems with algae as the primary target. A presentation was given during the workshop addressing the chemical properties, application requirements, and registration efforts underway to permit broader application of this product with fewer regulatory restraints (Solga 1996).

Biological Control

A biological control agent is based upon the activity of a living organism or a pathogen. The "activity" may be a direct or indirect action. For instance, the use of algae-eating fish, snails, macroinvertebrates or other animals is considered a direct action (Janik et.al. 1980). Similarly, bacteria, fungi and viruses may infect or parasitize algae, resulting in their death. The indirect activities of some organisms may also control or eliminate algae. For example, some fish create an increase in the suspended solids in the water column, reducing light penetration to the bottom sediments; and thereby, decrease the ability of attached algae to grow. Other micro-organisms may produce proteins, enzymes, or compounds which reduce the ability of the algae to grow.

General stream flow conditions in the Tiger Creek Canal system prevent the use of conventional biological control agents such as fish or macroinvertebrates. The production of algae control agents, during the fermentative degradation of barley straw (Welch et.al. 1990), was considered for testing this year. (Barley straw, during decomposition, produces certain chemicals that are effective in controlling algae growth.) A presentation was given during the workshop describing the biological basis of the treatment and features of a system for test implementation at Tiger Creek Canal (Frank 1996).

Mechanical Control

Mechanical control methods involve the physical scraping, dislodging, raking and removing of biomass. Many configurations of mechanical techniques have been developed to eradicate algae within various water conveyances systems. Mechanical methods have advantage in controlling growth in isolated regions and environmentally sensitive habitats. In the Tiger Creek Canal, water blasting has been used as the predominant means of removing and controlling algae.

Combined Algae Control

The combined use of algal control techniques has not received much attention, but appears to have great potential (Pieterse and Murphy 1990). Previous research at PG&E with chlorine, hydrogen peroxide and other chemicals, in combination with water blasting and desiccation, have resulted in algae control for longer periods than application of single control procedures (Creek 1994).

Conclusions

The Decision Matrix formulation developed by PG&E provides a means to compare and evaluate different algae control techniques using similar criteria. The process can be used by individuals of varying experience and background to select the appropriate control technique for a given application or site.

Interactions between personnel with interests in algae control problems are valuable in gaining new insights into control strategies. Activities, such as this workshop, should continue on a regular basis to foster these interactions.

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