Practical Methods for Control Of Algae and Water Weeds

By A. F. BARTSCH, Ph.D.

EVERY YEAR, increasing energy is being directed toward the control of excessive growths of algae and water weeds. Specific reasons for control vary, but in each case aquatic nuisance control is an attempt to protect or restore water uses that are considered valuable locally.

Algae and water weeds are not necessarily bad, not always a nuisance. They have an important place in the biological world in which we live. As normal year-round inhabitants of water, they help to determine its fertility, its ability to produce fish, support waterfowl and fur animals, and cleanse itself of pollution. From a historical viewpoint, algae and water weeds may signify a stage of developmental progress from lake to bog and finally to dry land.

But when algae are readily seen or smelled, when water weeds cover the bottom or float on the surface, or when either or both interfere with an important water use, demands for corrective action are made. Just as there is often a lack of agreement on the relative importance of various water uses, so also controversies may arise as to the need for control and the means by which it is to be accomplished (*1*).

Methodology varies with the nature of the problem, the geographic area, the existence of restrictive legislation, the equipment at hand, and the knowledge and experience of those doing the work. It is important to recognize that poorly conceived plans and haphazard execution may be more damaging than the aquatic growths they are designed to eliminate. Principally for this reason, and because no concise set of instructions is generally available, the following pages will describe various methods that have been used and important precautions that determine their safety and effectiveness.

All phases of algal and water weed control cannot be covered adequately in a single paper. Extensive literature already exists on control of algal tastes and odors in water supply (*2*). The "red tide," mussel poisoning, and the many commercial algicides used principally in swimming pools are outside the scope of this paper. Because methods and materials for controlling emergent and floating-leaf water plants are

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quite similar to those used on terrestrial plants, and because information on this subject is readily available (*2*), the section discussing methodology for water weed control is restricted to submerged plants only.

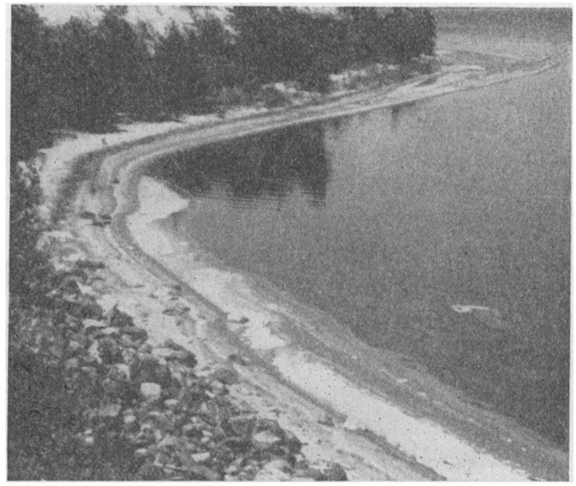
Characteristics of Algae

The word "algae" has not yet become popular in social conversation, but there is good reason to believe that algae will be much better known to future generations. They have two characteristics that hold promise of giving them great distinction. First, they can be grown intensively on a large scale to produce crops of potential high-protein food and raw materials for synthetic chemicals, fats, hormones, alcohol, and drugs (*3*). Second, sewage can be used as the culture medium, becoming stabilized in the process and contributing nutrients that heretofore have been dumped into surface waters and lost to productive use (*4–9*). Research already completed reveals the amazing possibility that over an area of less than a million acres enough algae could be grown to supply half the food protein needs of the present world population. Thus, this practice of algalculture may well contribute to the solution of two pressing problems—food supply and waste disposal.

In common with cultivated algae, those growing unattended in natural bodies of water have the same ability to convert inorganic materials into energy-bearing foods. For this reason they are important as the starting point of a food progression that ends with fishery products. Fish may feed directly upon these minute plants or may get them indirectly by eating minnows that ate insect larvae that ate waterfleas that ate algae. In either case, fishery products are principally algae, once or more removed.

Nearly all algal difficulties are caused by the ability of algae to grow rapidly and produce dense populations called blooms. Many of the details of how, why, and when algae take off on a growth rampage are not known. It is known, however, that they must have nutrients, ample light, and suitable temperature range.

Water everywhere is a potential culture medium for at least some kinds of algae. Surface waters naturally contain all the kinds of nutrient elements needed for growth, some of which are used only in trace quantities. Waters having more nutrients grow bigger crops of algae, just as fertile farmland grows more grain per acre than less fertile land (*10*, *11*). Of the various elements necessary to growth, nitrogen and phosphorus have attracted most attention because algal blooms are most frequent and objectionable in hard-water lakes containing abundant supplies of these two elements. In addition, there is reason to believe that exhaustion of phosphorus through growth uptake may function in limiting further algal growth (*12*).



A midwestern lake during an algal bloom with windrows of algae along the shoreline.

Variations in light intensity, temperature, availability of nutrients, and other changes that come with changing seasons somehow interact to stimulate algae into seasonal spurts of growth. The springtime appearance of diatoms, the summer and fall appearance of blue-green algae, and the reappearance of diatoms in fall and winter are well known to many water works operators.

Excessive algae cause damage in a number of different ways. The seasonal havoc they cause in water works by interfering with filtration is only too well known. Rapid filters which might ordinarily operate for 75 to 100 hours between washes sometimes have filter runs reduced to 2 hours or less. Diatoms such as *Synedra*, *Asterionella*, and *Melosira* are chiefly responsible. Disagreeable tastes and odors frequently accompany excessive algae, apparently as a result of compounds released directly from the algal cells or produced by actinomycetes associated with them (*13, 14*).

Water works operators have devised many ingenious methods for combating their particular algal problems and removing tastes and odors. This phase of the algal control problem is covered thoroughly in the literature (*2, 15*).

In many fertile lakes, blooms of algae, especially blue-greens, become so profuse that the water takes on a pea-soup consistency and color. Odors, which at first may be grassy, haylike, and not particularly unpleasant, become especially objectionable when the algae decay. Floating windrows of algae sometimes are compacted into a scum so solid that turtles and birds can walk on it. Lakes in this condition have no utility for bathing, boating, fishing, or any other form of recreation. Before this point has been reached, property owners and resort patrons already have left for more pleasant surroundings.

Algal decay in summer sometimes depletes dissolved oxygen resources so that fish die of suffocation (*16*). In frozen, snow-covered lakes, respiratory utilization of oxygen by algae themselves may bring about the same end result which is commonly known as "winterkill." Some kinds of algae can kill fish and other animals directly through production of poisons. Since 1878, reports of animal poisoning by toxic algae have come from every continent in the world. The victims include domestic animals: cattle, sheep, horses, turkeys, geese, and dogs; and wild birds, mammals, and fish (*2*). The "red tide" off Florida, caused by pigmented free-swimming algalike organisms, and mussel poisoning along the Pacific coast are related phenomena.

These damages demonstrate clearly that algal control is necessary and justifiable under certain conditions. Algae may be controlled either by limiting their unrestricted growth or by killing existing algae. Local circumstances determine which procedure is more desirable.

Control by Growth Limitation

When feasible, nuisance growths of algae can be limited or prevented by limiting the area of shallow water in reservoirs, by maintaining high water levels, and by limiting incoming nutrients from soil erosion, irrigation return flows, sewage and treatment plant effluents, certain industries, and other sources. This type of approach is sometimes called biological or ecological control.

It has been pointed out that the lakes at Madison, Wis., are notorious for several reasons (*12*): because Longfellow once wrote a complimentary poem about them; because of the extremely objectionable algal blooms which have infested the lower lakes of the chain; and because of the large-scale use of copper sulfate to control blooms in three of the lakes having a total area of 13.5 square miles. To these should be added now a fourth distinction: the current attempt to alleviate the algal difficulties by diversion of effluents from a secondary sewage treatment plant around the lakes to the Yahara River below. This activity, costing several million dollars, is motivated by State legislation of which the validity has been upheld by the Wisconsin State Supreme Court.

Concurrently, research has developed methods for stripping effluents of nitrogen and, more particularly, phosphorus. Plant scale tests of phosphorus removal with lime have been made in Minnesota and Wisconsin (*17–19*); other phosphorus removal tests are under way in Connecticut. Effort continues in learning to understand better the various complex factors that determine how lakes respond when fertilized by effluents (*20*). As growing population contributes greater quantities of phosphorus to water and as the use of phosphorus-bearing detergents increases, it can be expected that phosphorus removal will be considered more widely as an algal control procedure.

Complete exclusion of light to prevent algal growth is exemplified in the covering of water storage tanks and basins. Partial exclusion of light by induced turbidity has had limited application and this only in the water works field intermittently since 1933. For this purpose, activated carbon is applied to open coagulation and settling basins by bag-dragging, injecting, or pumping to produce a so-called carbon "black-out." Dosage rates of 1 or 2 parts per million once or twice daily on sunny days have proved satisfactory.

Control by Algicides

Although new commercial algicides continue to appear on the market, practically all large-scale projects in recreational waters involve use of copper sulfate. Experience with this compound dates from 1890 in Europe and from 1904 in America, and its merits and shortcomings are fairly well known. In spite of this, such important factors as the mechanism by which it kills algae, determination of exact necessary dosages, long-term effects upon lake ecology, and inducement of algal tolerance are either unknown or controversial.

Temperature, light, and alkalinity determine the amount of copper sulfate that must be added to water to produce a killing concentration that will persist for a sufficient contact period. Alkalinity is particularly important because of the completeness and rapidity with which soluble copper can be precipitated as a copper carbonate. Undoubtedly, this reaction accounts for much of the variability of success when published dosages for different species are followed. Three developments represent attempts to fit the dosage more accurately to the chemical nature of the water.

One of these is the use of the citrate salt to avoid rapid copper precipitation (*21*). A mechanical mixture of sodium citrate and copper sulfate, now on the market, is used chiefly in industrial plants. It is reported to be successful.

A second approach is the development of a "copper sulfate demand test" to indicate the optimum dosage for the algae in a given water (*22*, *23*). The test has been used successfully by some but not all persons. There appears at present to be no reasonable chemical explanation for the test reaction.

The third approach is utilization of simple arbitrary dosage rates related to alkalinity. The following have been used successfully in various midwestern lakes for 15 years:

Methyl orange alkalinity $<$50 p.p.m.=0.3 p.p.m. $CuSO_4.5H_2O$ in total volume of water (0.9 pound per acre-foot).

Methyl orange alkalinity $>$50 p.p.m.=a rate equal to 2 p.p.m. $CuSO_4.5H_2O$ in surface foot of water only (5.4 pounds per acre).

Material cost at these dosage rates is approximately $.80 per acre.

Courtesy of K. M. Mackenthun, Wisconsin Committee on Water Pollution.

A fish kill caused by blue-green algae.

Regardless of the equipment used, the principal requirement in treatment is rapid and uniform distribution of the algicide. This is an important requirement, whether the body of water is treated in its surface entirety or only along a marginal zone. Copper sulfate has been applied in many different ways—by bag-dragging, power blowers, aircraft, dry feeders, solution boxes, drippers, sprayers, and by placing crystals on ice (*2*). Spray equipment has been widely used because it meets the rapid distribution requirement quite satisfactorily and usually can be assembled from equipment at hand.

Water supply for the spray unit (see diagram) is pumped from the lake through intake I, and the main volume of flow goes out through the spray nozzle, which is hand-operated. By manipulating valve V_2, water can be directed onto crystals at C. If sufficient material is maintained in the bag M, a saturated solution will be obtained. This solution is introduced into the system through line S, and the quantity regulated with plug valve V_1. Mixing occurs in the pump.

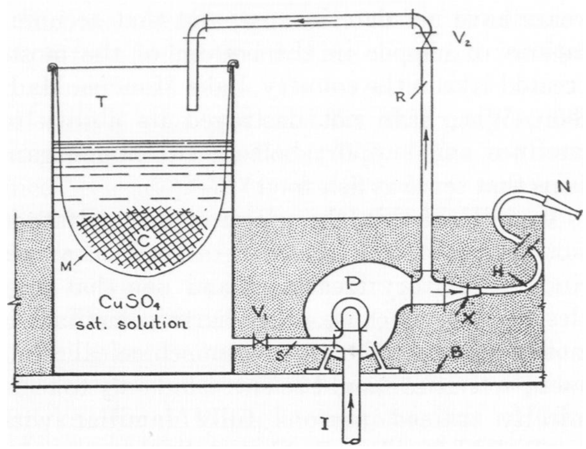
In operation, saturated copper sulfate solution is bled into the pumping system at a rate determined by width of spray lane, speed of boat, and temperature of the water. The table shows the gallons per minute that will yield 1 p.p.m. of copper sulfate for 1-foot depth under the conditions specified.

A meter to measure flow in line S would be desirable. Less accurate but similar results can be obtained by calibrating valve V_2 and then adjusting valve V_1 to maintain a constant level in the solution tank.

During treatment, it is advantageous to spray along successive parallel lanes working from the shoreline outward. In lakes with appreciable alkalinity, rapid formation of copper carbonate gives the treated water a slight milky appearance. This can be used as a guide to avoid additional spraying in areas already covered. Sighting points on shore can be used when treating less alkaline lakes in which a similar color change does not occur.

To persons experienced in algal control, development of a peculiar and characteristic odor indicates that algae have been affected by treatment. Origin of the odor is not definitely known, but it perhaps is caused by aromatic substances released from cells in the presence of copper. Simultaneously, the algae become faded, and mats of filamentous algae become frothy from trapped gas bubbles. These changes occur within 10 to 20 minutes. Within a day or two the algae largely disappear, and the water is usable again. Duration of relief depends upon a number of factors, varies with different bodies of water, and cannot be predicted exactly. When small lakes are treated in their entirety, one treatment per season usually suffices. If shoreline zones only are treated, several applications usually are required.

Diagrammatic sketch of copper sulfate applicator.



KEY: I—Water intake line. S—Copper sulfate solution line. P—Pump. H—Applicator hose line. N—Spray nozzle. X—Location of injector, if used, line S being directly connected at this point, in that event. R—Recirculation line. T—Copper sulfate solution tank. C—Copper sulfate crystals. M—Mesh or burlap bag. V_1 and V_2—Plug valves. B—Boat hull.

Copper sulfate has properties that make it much less than an ideal algicide. Among them are the following: (*a*) Like other heavy metals, copper in sufficient concentration has the ability to poison fish and other aquatic life; (*b*) when precipitated, it can accumulate in lakes; and (*c*) it is corrosive to equipment and paint. Because of these properties a number of important precautions should be noted. Avoid spraying on or near minnow traps or live boxes because the momentary high concentration may be sufficient to cause fatalities. The screened intake to the pump should be kept clean to avoid pumping excessive volumes from the solution tank. In the event a weed-clogged propeller, sheared pin, engine failure, or other difficulty stops the boat, close valve V_1 immediately to prevent overdosing. Avoid spraying on painted buildings, boats, and piers that will be stained by the chemical. Finally, if the pump and piping are not fabricated of copper-resistant materials, flush thoroughly by pumping lake water through them before stopping operations, even for a temporary period.

Field and laboratory studies have shown that fish are not killed by copper at concentrations normally used for algal control, that the fishing and fish yields of lakes treated as long as 26 years have not deteriorated, and that accumulations of copper in the bottom of the most-treated lake in the country, Lake Monona, Madison, Wis., have not destroyed its ability to produce and support bottom-dwelling organisms that serve as fish food (*24–28*).

In spite of this, the use of copper sulfate is not foolproof, and the margin between a safe and satisfactory treatment and one that may destroy fish or cause other harm sometimes is not very great. For this reason, chemical treatment activities should be entrusted only to technically trained persons fully familiar with potential hazards and able to take the necessary precautions. Consideration of these points has led either to specific legislation or to State supervision of chemical treatment in such States as Wisconsin, Minnesota, and Michigan.

The deficiencies of copper sulfate have also stimulated a systematic search for a more desirable algicide. Preliminary tests with one compound (2,3-dichloronaphthoquinone) show that it holds promise as a more selective algicide for blue-green algae, which most commonly cause nuisance blooms in lakes (*29*). It apparently has no immediate toxicity to other organisms and does not accumulate. It has not yet been used on a large scale. The algicidal properties of certain antibiotics are under study also (*30*).

Gallons of saturated solution of $CuSO_4$ required per minute to give 1 p.p.m. $CuSO_4$ (for depth of 1 foot)

Speed of boat (miles per hour)	60-foot width of spray		
	15° C.	20° C.	25° C.
1	0. 21	0. 19	0. 17
2	. 42	. 38	. 35
3	. 62	. 57	. 52
4	. 83	. 76	. 70
6	1. 03	. 95	. 87
5	1. 24	1. 14	1. 04
	80-foot width of spray		
1	0. 28	0. 25	0. 23
2	. 56	. 51	. 47
3	. 83	. 76	. 69
4	1. 11	1. 01	. 93
5	1. 37	1. 27	1. 16
6	1. 65	1. 52	1. 39

Characteristics of Water Weeds

Like algae, water weeds have many values when the crop is not excessive. In addition to contributing to the natural appearance of bodies of water, vegetation serves as food for many animals from insect larvae to muskrats, beaver, deer, moose, and waterfowl; as cover and breeding places for fish; as a stimulator of natural purification; and potentially as mulch and food for farm animals.

On the other hand, excessive vegetation interferes with bathing and other recreation, fishing and fishery management, pleasure boating, and commercial navigation. It limits the flow in irrigation canals and drains, depreciates waterfront property, contributes to winterkill of fish, and supports mosquito breeding. These are the reasons why waterfront property owners and improvement associations seek methods that will give relief.

Growth of water weeds is influenced by light penetration, availability of nutrients, and temperature, in much the same ways as is algal growth. In addition, some plants are dependent on suitable bottom material and depth of water. Although most plants propagate by means of seeds, many have accessory propagation abilities by rootstocks, tubers, winter buds, and plant fragments. These facts suggest physical control methods that may be used and explain some of the difficulties that arise.

Physical Control of Water Weeds

Physical control of water weeds includes both mechanical and nonmechanical methods. Many mechanical methods and equipment, such as hand raking, dragging chains, pulling cables, underwater saws, power mowers, a puller and baler, and a cutter and baler, have been used with variable success. Notable disadvantages of some of these methods are oxygen depletion from decaying weeds, development of stockier weed growths, and rooting of cut fragments. These methods do, however, offer the advantage of quick action and are suitable for opening isolated channels.

Two newly developed machines (one developed by a private individual at Hartland, Wis., and one developed by the University of Wisconsin) that automatically remove the plant mass after either pulling or cutting have several important advantages. They eliminate many of the disadvantages of simple cutting, such as oxygen depletion and attendant fish kills, odors of decay, and the nuisance of wind-driven windrows of rotting weeds concentrated along shorelines. They also remove nutrients in the form of cut weeds which eventually may limit both nutrients and weed growth.

Of the many nonmechanical methods that have been used, two are sufficiently novel to be of interest. Both represent attempts to produce environmental conditions that limit photosynthesis. In one case, the water is converted into weak ink by adding a black dye called nigrosine (*31*). The method thus far has been only partially successful. The dye is nontoxic to fish but has the disadvantage of making the water unattractive until natural forces cause the dye to fade. In the other case, light penetration is decreased by heavy blooms of algae that are stimulated by intentional addition of fertilizer (*32*). Although the method has been used with some success, the stimulated blooms of algae may themselves be equally objectionable. When used in impoundments which can be at least partially drawn down, the added nutrients can be drained away eventually.

Chemical Control of Water Weeds

During recent years, a large variety of chemicals have been used for control of submerged aquatic plants. Among them are hydrocarbons such as orthodichlorobenzene, trichlorbenzol, dichlorbenzol, and naphtha; hormone weed killers such as 2,4-D and 2,4,5-T; and other compounds such as sodium chlorate, ammonium sulfamate, copper sulfate, and sodium arsenite (*33*). None can be considered an ideal aquatic herbicide for general use.

The chlorinated hydrocarbons and naphtha, while effective under proper conditions, are so highly toxic that they will kill fish and their food before controlling vegetation. Ammonium sulfamate and the 2,4-D's are too expensive for use on submerged plants. Sodium chlorate is suitable for muskgrass but will kill fish and fish food at weed-killing dosages.

Sodium arsenite remains as one of the cheapest, safest, and most effective chemicals for use in recreational areas. So far as published records go, it was first used for this purpose 30 years ago in the Madison, Wis., lakes and has since been adopted for use in fishery management. It is now widely used, especially in the midwest. Because of its toxicity, proposals to use it in water supply reservoirs should be considered with extreme care.

Mainly on the basis of field experience, effective dosages under various conditions are quite well known. Although concentrations as low as 1 p.p.m. (white arsenic equivalent) will affect plants after a sufficiently long exposure period, application rates in practice must compensate for arsenic losses by diffusion, wave action, and absorption by vegetation and bottom mud. The following rates are commonly used (*34*):

(*a*) Ponds and lakes treated in entirety=5 p.p.m. (as As_2O_3); (*b*) Shoreline areas:

1. Minimum dimensions of area suitable for treatment = 200 ft. x 200 ft. unless a slough or bay, with minimum area of 4,000 sq. ft.
2. Protected bays and protected shoreline areas, maximum average depth 8 ft.=7.5 p.p.m.
3. Unprotected areas, maximum average depth 8 ft.=10 p.p.m.
4. Treatment of areas outside these limits as well as isolated patches—difficult, unduly costly, and not dependable.

Commercial sodium arsenite is available in three forms—a dry powder, a solution containing 4 lb. of As_2O_3 per gallon, and another containing 9.6 lb. per gallon. The 4-lb. preparation is used most commonly. Material requirements can be determined easily from the fact that 2.7 lb. per acre-foot=1 p.p.m.=0.67 gallon of 4-lb. solution. Material costs range from about $2 to $4 per acre-foot. (An "acre-foot" of water is the quantity of water in an acre of water 1 foot in depth, or the equivalent of 43,560 cubic feet of water.)

For small areas, the chemical can be applied underwater by gravity feed lines draining a solution tank. Spraying equipment similar to that used for algal control is suitable for large-scale operations. The total areas to be treated should be delineated into subareas of such size that they require a quantity of material equal to one-half the capacity of the solution tank. This permits initial dilution to a 2-lb. solution and allows more accurate distribution. Treatment should be from the shoreline outward, first along lanes of travel parallel to the shore, and then at right angles to it so as to crisscross the area in two directions. Attempt should be made to regulate dosage relative to depth.

Generally, 5 to 10 days are required for death and collapse of plants. Seeds are not appreciably affected. Dead plants turn brown, generally sink to the bottom and decompose, but with rough water some may be torn loose and float to the surface. Such floating vegetation should be removed from the water to avoid development of nuisance conditions. The duration of relief following treatment is determined by a number of factors. Notable are the relative size of the treated area to the total area of weed growth and, within it, the effectiveness of kill. In most cases, treatment must be made during two or three successive seasons to obtain relief of several years' duration.

The toxicity of arsenic and causticity of the solution make necessary a number of important precautions. Cattle and other grazing animals should be excluded from the treated area for at least 3 days following treatment. Care should be exercised to avoid spilling or spraying the solution on flowers, shrubbery, trees, or other vegetation—especially where grazing may later occur. Water should not be used for bathing or stock water for at least 3 days. Rubber gloves and protective cream or a face mask should be worn by the operator, and direction of boat travel should be such as to avoid wind-blown spray that will cause skin burns.

Field and laboratory tests show that there is a fairly wide margin of safety for fish and fish foods when using arsenic. In laboratory aquariums, critical concentrations for various kinds of fish over a 10-day period range upward from about 10 p.p.m. As_2O_3. Fish food animals vary widely in tolerance; mortality rates for chironomids, mayfly nymphs, and freshwater shrimp may be high at 2.5 to 4.0 p.p.m., whereas damselfly and dragonfly nymphs, sow bugs, and water mites survive concentrations of 10.5 to 21.0 p.p.m. (*34*).

Hazards to aquatic organisms during and after treatment are less serious than the laboratory data suggest. Most fish and some fish food animals are repelled by the chemical and move into untreated water. Diffusion, wave action, and absorption by the vegetation and bottom mud progressively reduce the concentration. Hazards are greatest when large masses of decaying vegetation deplete dissolved oxygen. This can be avoided by initiating treatment when the plants are young and growing vigorously or by temporarily leaving areas untreated if control procedures are not initiated before the vegetation becomes dense.

The history of water weed and algal control, although not well recorded, is marked occasionally by instances of fish destruction. In practically every case they resulted from excessive enthusiasm among untrained operators who apparently felt that if 1 p.p.m. will control algae, 10 p.p.m. should do it 10 times as well. Such unfortunate occurrences reemphasize the importance of limiting control activities to trained technicians only.

Control of aquatic plants is becoming a recognized management tool in the field of water conservation. Frequently it is necessary, if acceptable potable water is to reach the consumer. In other waters, continued recreation, fishery management, navigation, and other water uses that provide pleasure and profit are dependent on it.

Presently available algicides and aquatic herbicides leave much to be desired. Ideal preparations for these purposes should be safe, selective, and economical. The search for them continues, and there is real promise that cleaner lakes can be a reality.

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