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Blue-Green Algae Control at Storm Lake

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Introduction

Heavy growths of blue-green algae are a major factor in limiting recreation at several of Iowa's lakes during the summer. The huge accumulations of these small primitive plants render lakes uninviting for swimming, angling or sight-seeing and when decomposition of the algae occurs putrid odors emanate therefrom creating intolerable situations. Occasionally certain species may become poisonous (Olson, 1951; McCleod and Bondar, 1952; Ingram and Prescott, 1952; Rose, 1953), thus creating the necessity for emergency measures to prevent loss of human life as well as loss of domestic animals and wildlife.

Storm Lake, in Buena Vista County, a 3,060 acre body of water is especially subject to heavy blooms of blue-green algae during summer and fall months which in recent years have caused much apprehension among local residents and conservationists. A bloom of toxic blue-green algae of tremendous magnitude developed here in 1951 causing death to several hundred migratory waterfowl, game birds, song birds, game and domestic mammals (Rose, *op. cit.*). In order to prevent a recurrence of this phenomenon, plans were made to control future blooms on this lake by treatments with copper sulphate. This paper includes the details of the work on this project during the summer and fall of 1953.

Inasmuch as the bloom in 1952 at Storm Lake was so extremely toxic and the situation deemed so exceptionally critical, the 1952 General Assembly appropriated $25,000.00 for the purchase of chemicals and equipment for treating the lake with algicides during the summers of the next biennium. Accordingly, a large supply of copper sulphate, the best known algicide, was purchased and a power spray barge constructed after a design similar to units in use on lakes near Madison, Wisconsin. This unit and the copper sulphate were not available until the middle of July, 1953, at which time treatments were started and continued until the middle of October. Except for a short period of time in August, the lake was kept fairly free of algal blooms and most of the local people were very pleased with the degree of control obtained.

Fortunately, no blooms of toxic algae developed during 1953. The predominant species present and identified as the cause of toxicity in 1952 was *Anabaena flos-aquae*. The huge bloom that developed in 1953 prior to treatment was composed almost entirely of *Aphanizomenon flos-aquae* and *Microcystis aeruginosa*, neither of which have been clinically proven as toxic in the Iowa lakes. Laboratory experiments with these species during the summer of 1953 proved them non-toxic at the time, and no mortality of domestic or wild animals occurred at the lake. Very small quantities of *Anabaena flos-aquae* and *A. spiroides* were found on two occasions in 1953; however, they were of no consequence. It is emphasized that both *Aphanizomenon* and *Microcystis* as well as other species of blue-green algae have been deemed poisonous in other states; consequently, to date we have been fortunate in this respect.

The physical and chemical features of Storm Lake favor large algal growths. It is shallow, with an average depth of six feet, is highly fertile and has alkalinities ranging from 175 to 250 parts per million. These factors, plus high summer temperatures, are usually associated in lakes that have heavy algal blooms. While the development of natural controls, such as altering the present status of any of these factors to reduce algal growths is highly desirable, it is not within the foreseeable future that such idealism can be achieved. Palliative measures such as copper sulfate treatments are therefore indicated until better methods are devised.

Equipment Used

The copper sulfate spraying equipment used at Storm Lake consisted of a wooden barge 16 feet in length and eight feet in width with a 100 gallon, baffled, solution tank amidships. A two h. p. gasoline engine operated a centrifugal pump to fill the tank and discharge the chemicals through two separately activated spray nozzles located at opposite ends of the transom. Each of these operated through a 90 degree arc, thus effectively covering a semi-circular area about 60 feet in diameter in the wake of the barge. The barge was propelled by a 25 h. p. outboard motor. A crew of two men plus a supply of six to eight 100 pound bags of copper sulfate and fuel created a slightly overloaded condition, especially during rough weather; however, the regular crew rarely failed to operate due to high winds. A 16 foot skiff with a 25 h. p. outboard was used as a tender and reconnaissance craft.

Methods

In order to make effective applications, the spray unit was carefully calibrated to treat algae concentrations at the proper dosage. The following calculations illustrate the method of calibration.

Average speed of barge—4 miles per hour
5,280 feet per mile x 4—21,120 feet per hour
21,120 x 60 feet (diameter spray area)—1,267,200 sq. ft. per hour.
1,267,200 x 3—3,801,600 cu. ft. per hour (upper 3 ft.).
3,801,600 x 7.5 (gal. cu. ft.)—28,512,000 gal. water in area.
28,512,000 x 8⅓ (lbs. per gal.)—237,600,000 lbs. water in area.

Therefore, in order to obtain a dosage of 0.5 parts per million (referred to hereafter as p. p. m.) for a depth of six feet, or 1.0 p. p. m. for the upper three feet, 237 pounds of copper sulfate should be used for each hour's operation. Since there are roughly 237 million pounds of water in the treatment area of one hour's operation, 237 pounds of chemical produces the 1.0 p. p. m. by weight. Usually most of the algae are concentrated in this upper three feet of water, especially in relatively calm weather. Thus, it was not necessary to pre-calculate volumes or weights of copper sulfate for each area to be treated since the required amount was readily used by the sprayer.

In actual practice, the small skiff was used to make a rapid check of the lake each morning to locate algae concentration areas. The barge was then loaded with supplies and spraying started. Usually parallel paths over the patches of algae were sprayed, care being taken to avoid over-laps of previously treated paths. Buoy markers were used to delineate areas to be treated.

Counting Methods

To determine the effectiveness of treatments in controlling the algae and to indicate any important changes in the zoo-plankton, samples of the lake water were taken at regular intervals from established stations. The numbers of plankton organisms per liter were determined at the laboratory, following a modification of more or less standard methods.

Since the *Aphanizomenon* was the most abundant blue-green alga present all summer, a considerable amount of time was required to devise a system of counting that would be practical and rapid. *Aphanizomenon* is extremely fragile therefore the ordinary counting cannot be used satisfactorily. The individual flakes, or colonies, rapidly disintegrate into their component filaments when subjected to preservatives, centrifuging, or any of the usual methods of handling prior to counting.

In order to overcome this difficulty a direct count method was devised that proved satisfactory, rapid and meaningful. A large counting cell was made using an ordinary Petri dish with the central region delineated with a fine draftsman's pen into a square containing 25 square centimeters. The dish was then filled evenly to a depth of about 5 mm. with plastic clay. The clay in the region marked was removed thus completing the cell. In order to keep the ruled squares from wearing or washing off, the lid of the dish was placed on the back in a bedding of plastic clay.

The use of the cell involved no complex calculations or formulae such as are usually involved in plankton assays. Collections of lake water were made by a standard water sampling device and gently transferred to 2 quart jars. Upon reaching the laboratory, the sample was rotated gently to obtain an even distribution of all organisms, care being exercised to avoid disintegration of the *Aphanizomenon*. Immediately after mixing, a 10 ml. graduated cylinder was filled and transferred to the counting cell. Counts were then made with a binocular dissecting microscope. The low power was ample magnification for even very small flakes of *Aphanizomenon* and most other plankters. For very small organisms such as *Stephanodiscus* and *Melosira* (diatoms) or small rotifers, the high power was usually necessary. Ordinarily the entire number of organisms observed were recorded in the 10 ml. sample as they appeared in each 1 cm. square area. Where large numbers of the smaller items occurred, sample squares were counted and the necessary expansion of counts made to calculate the number in the 10 ml. sample. Three 10 ml. sample counts were recorded from each collection and the average numbers expanded to obtain the number of each plankter per liter. Where vast quantities of *Aphanizomenon* occurred dilutions of 1:10 or 1:20 were made to facilitate counts.

Results

As mentioned, only concentrations of algae were treated with the copper sulfate and since the lake had a huge accumulation in several areas prior to starting the control program, it was difficult to obtain a real over-all improvement in the lake. The heaviest concentrations were attacked first. Meanwhile reproduction occurred in other regions causing additional concentrations to develop and to reinfest the treated areas. Treatments were very effective as shown by actual before and after counts which revealed almost complete eradication of the blue-greens in the zones of treatment. However, a shift of wind often drove untreated accumulations into areas previously treated thus occasionally creating an impression of poor results. Copper sulfate is rapidly inactivated by uniting with the algae and that not so combined rapidly precipitates; consequently, the same areas often required treatment on successive days.

The following table indicates typical changes in the plankton counts prior to and 24 hours after treatment of a heavy concentration along the east shore of Storm Lake on July 22, 1953.

Table 1
Plankton counts prior to and 24 hours after treatment

Organism	Before Treatment , per liter	24 hours after treatment per liter
Aphanizomenon	16,000	330
Microcystis	300	30
Stephanodiscus	110,000	142,000
Melosira	31,360	25,360
Daphnia	37	20
Cyclops	15	11
Secchi disk reading	6 inches	36 inches

In this analysis only the major plankters are considered. Invariably an extensive list of species were found in each sample including, aside from the above blue-greens, diatoms and entomostraeans, many flagellates, protozoans and rotifers. It is apparent that the copper sulfate effectively reduced the blue-greens, had little effect on the diatoms and reduced the entomostracans considerably.

Action of the copper sulfate is rapid and the destruction of algae can readily be observed within a very short time after treatment. A sample taken from the Lakes Patrol dock on August 12, contained 3,250 *Aphanizomenon,* 2,200 *Microcystis* and 110 entomostracans per liter. Three hours after treatment another sample from the same location contained 600 *Aphanizomenon* and 150 *Microcystis* colonies. All of the *Daphnia* in this sample were dead; however, 45 *Cyclops* were still alive indicating more tolerance in this species.

During the summer and fall, a total of 14 sampling trips were taken at Storm Lake and samples obtained from seven stations which were established as fairly representative of all regions of the lake.

Even though analyses made before and after treatments indicate excellent reduction in algae content, they are not typical of the lake as a whole since only localized treatments were made. Therefore, in order to present data that would be representative of the lake, all of the stations were sampled on each trip and the analyses were then averaged. Thus, any real improvement or decline in the algae count should be reflected in these over-all averages. Of course, treatments were made every day when possible; consequently no special effort was made to obtain data concerning individual treatments.

In addition to the analysis of plankton, Secchi disk readings were taken routinely at each station. Inasmuch as the major light limiting element in water was *Aphanizomenon,* the Secchi disk records are useful and practical as an index of its abundance. The increase in water clarity after treatment is apparent in the readings included in Table 1. When huge accumulations of algae formed on the surface, the disk disappeared immediately; however, other stations on the lake at the same time would have readings of from one to two feet when concentrations were of less density.

In Table 2 the dates of sampling trips, the average numbers of plankters per liter and the Secchi disk averages for the summer and fall of 1953 are outlined. Only the major organisms are included in the table for the same of brevity.

Table 2

Average quantitative analyses from 7 stations at Storm Lake

Date	*Aphanizomenon*	*Microcystis*	*Anabaena*	Entomostracans	Secchi Disk (feet)
7-23	16,000	450	0	127	0.5
7-27	3,640	285	0	75	1.0
8-4	2,309	964	0	57	1.0
8-12	9,992	3,783	0	166	0.5
8-13	3,400	1,800	0	150	1.0
8-26	16,967	1,620	0	92	0.5
9-10	3,000	420	0	180	1.0
9-14	922	407	0	395	2.5
9-15	230	0	0	90	3.5
9.24	2,735	50	0	339	1.5
9-28	2,700	1,330	71*—7**	117	1.0
10-15	820	135	0	108	2.5
10-30	80	0	0	76	4.5

**Anabaena flos-aquae*
***Anabaena spiroides*

Obviously, heavy concentrations of *Aphanizomenon* were present on July 23 and August 26. Some samples had counts of nearly 40,000 flakes per liter, while at the same time other stations were relatively much lower in their counts. The heavy concentrations were soon greatly reduced after treating. During the periods when counts declined to an average of 3,000 and less of *Aphanizomenon,* the lake was fairly clear and there were no offensive accumulations. It will be noted that the Secchi disk readings were correspondingly higher as the quantity of algae declined.

Prior to September 1, the spray equipment was operated by a crew that could not devote its entire time to the project. Thereafter, a local crew was employed to make more frequent and effectual treatments. As indicated in Table 2, the lake from then on was maintained in fairly good condition.

As noted previously, there were no blooms of *Anabaena flos-aquae* during 1953; whereas, the previous year had a terrifically heavy bloom of this toxic species. The appearance of the *Anabaena* in the samples of September 23 (Table 2) caused much apprehension since it usually is most abundant in the fall. Fortunately this slight development disappeared and was not encountered again. It was felt by some that perhaps the treatments may have been responsible for eliminating the *Anabaena;* however, this is an unlikely contention.

As indicated in Table 2, the quantity of entomostracans (*Daphnia, Cyclops* and *Diaptomus* principally) per liter showed no significant decline throughout the summer and fall. Some of the highest counts were taken in September at which time the lake was literally infested with windrows of *Daphnia* which had formed ephippia. Thus, it would appear that this important fish-food organism was not too adversely affected by the treatments.

Toxicity of Copper Sulphate

Copper sulfate is, of course, a poisonous substance. If consumed beyond certain limits by warm-blooded animals death will occur. Likewise, it is well known that fishes and other aquatic animals are very susceptible to over-dosages, especially in waters of low alkalinities. In the natural lakes of Iowa, alkalinities are high (150 to 250 p. p. m.) and treatments required to control algae are well below the lethal limits for mature fishes. The writer has conducted laboratory experiments in which mature green sunfish survived with no apparent injury in concentrations of 60 p. p. m. of copper sulfate. Little research has been conducted on the effect of the chemical on very young fish or their primary food items, the entomostracans; consequently, a preliminary experiment was conducted to determine some of these important considerations.

During the operation of the walleye hatchery at Spirit Lake, Iowa, in the spring of 1953, 10 aquaria containing lake water (M. O. alkalinity 224 p. p. m.) were set up. Three walleye fry (approximately 1 week old) and approximately 10 *Daphnia, Cyclops* and *Diaptomus* were added to each. The concentrations of copper sulfate in the aquaria ranged from 0.5 to 8.0 p. p. m. respectively in nine of the aquaria. The 10th aquarium was retained as a control with no copper sulfate. The walleye fry survived normally in the concentrations of 0.5 and 1.0 p. p. m. for the duration of the experiment (64 hours). In all concentrations above 1.0 p. p. m. the fry were dead after four hours. The entomostracans *Cyclops* and *Diaptomus* were very resistant, surviving 5.0 p. p. m. throughout the experiment; however, the *Daphnia* were dead after 20 hours exposure in the 0.5 p. p. m. and three hours in the 1.0 p. p. m. solutions.

This indicates that very young fish may be killed by a slight over-dosage and that *Daphnia* in requisite concentrations will be killed. In practice, however, it is seldom that treatments would be necessary during the early spring when young-of-the-year fishes are so delicate. No apparent losses of fish of any size or species occurred at Storm Lake during 1953. Since only small portions of the lake were treated at any one time the effects on the *Daphnia* fauna was probably not particularly significant.

Quantitative sampling of the insect larvae on the lake bottom prior to treatments was made to determine what damaging effects, if any, would result from the precipitated copper. Unfortunately, it is believed that an insufficient amount of sampling was done to indicate definite conclusions on this. Mackenthun and Cooley (1952) conducted extensive research in lakes near Madison, Wisconsin, on this subject and while their data indicate a considerable reduction in numbers of organisms per unit in lakes that have been treated than in the untreated lakes, they attribute the variance to ecological factors rather than to the copper. Likewise Moyle (1949) found no variance in the production of rough-fish between lakes treated for many years and nearby untreated lakes. This indicates that bottom organisms may not have been adversely affected by the treatments.

Ekman dredge samples were taken from seven stations on Storm Lake on July 21, 1953. The bottom mud was screened and the organisms identified, counted and volumes computed. On February 8, 1954, another series of samples were taken from approximately the same stations to determine any variance that might be attributable to the treatments. In Table 3 a comparison of numbers and volumes of bottom organisms is outlined.

Table 3

Number and volume of organisms per Ekman dredge sample before and after treatments.[1]

	July, 1953		February, 1954	
Station	Number	Volume (ml.)	Number	Volume (ml.)
1	24	0.3	19	0.1
2	40	0.4	22	0.1
3	30	0.1	21	0.1
4	22	0.1	19	0.1
5	19	0.2	12	0.3
6	19	0.1	17	0.1
7	21	0.4	51	0.5
Totals	175	1.6 (ml.)	161	1.3 (ml.)

[1]Ekman dredge samples 36 square inches of bottom.

Obviously there is little variance in the numbers of organisms or volumes in this comparison. However, it is widely recognized that winter populations of bottom organisms, particularly insect larvae, are greater than in summer; consequently, the reduction may be more significant than is indicated. The bottom organisms collected were the usual lake mud dwelling forms including primarily the midge larvae Tendipes and Tanypus, Cerattopogonid larvae and the oligochaete, Tubifex.

Copper Sulphate Used

A total of 40,700 pounds of copper sulfate was used from July 17 to October 15 in combating the algal blooms at Storm Lake in 1953. This amount is equal to 13.3 pounds per acre for the entire lake. Actually, of course, the treatments would be much higher than this on a per acre basis if calculated on the regions treated. The main body of the lake did not receive or require treatment except on a few occasions when large masses of algae drifted out from shore.

Summary

The copper sulfate treatment of Storm Lake during the summer of 1953 for the control of blue-green algae was planned

originally to mitigate the danger of toxic algae which had prevailed during several previous seasons. Fortunately the toxic species, *Anabaena flós-aquae* did not develop this year; however, treatments were made to control heavy blooms of *Aphanizomenon* which, though not usually toxic, are potentially dangerous. Treatments were made by a specially designed power spray vessel and were confined to localized areas of heavy concentrations of algae. The effectiveness of the control program was assayed by counts of plankton organisms from seven representative stations on the lake. A special counting cell was devised that proved to be satisfactory in determining the abundance of plankton per unit volume. Bottom fauna and most entomostracans, potential fish-food organisms, were apparently not adversely affected by the treatments. Some controlled experimental data were obtained that indicated danger to small fish in concentrations of copper sulfate slightly higher than are necessary to control algae. Also, the important fish-food crustacean, *Daphnia,* could not withstand the minimal dosage of 0.5 p. p. m.

From the standpoint of most of the local people and organizations interested in the program it was felt that the treatments were very successful. The beaches were kept open all smmer and there were no losses of livestock or game animals during the year. It is believed that the program will be more effective in 1954 when treatments will be started as soon as algae appear, thus possibly preventing unsightly or dangerous accumulations.

Much recent research has been done and is continuing on the development of specific algicides that will eliminate some of the objectionable features of the copper sulfate. Some of these studies have been successful and doubtless experimental work will be done in Iowa during the next year testing the new chemicals for algae control.

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