

# THE ALGOLOGIST AND WATER SANITATION<sup>1</sup>

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A potable water is a necessary adjunct to the development and well being of a community. Each member expects, as a part of his communal rights, a palatable and pure water supply. If the water becomes distasteful because of sediment, peculiar flavors and odors, or if drinking it results in illness, then, and only then, will he give any consideration or thought as to the source, contaminating factors or the chemical and physical treatment which contribute to the purity of the supply.

The highly technical engineering principles and problems connected with the location, construction and operation of reservoirs and purification plants are beyond the scope of this paper. Only those that pertain to the elimination of aquatic organisms which may interfere with the delivery of potable water to the consumer will be considered. Likewise, bacteriological examination is a separate study and will be ignored except in a few instances where the intimate relations between bacteria and plankton involve the algologist.

To the causal observer, the work of the algologist in connection with water supplies is something new in the application of microbiology. Instead, it is a science which has been developing for nearly a century, and if I may predict, will become more and more important as the centralization of populations and industrialization increases in this or any other country.

The industrialization of an area with a subsequent increase in population demands a substantial increase in the water supply. This demand is met by utilizing surface water available in lakes or rivers. Unlike the inadequate, but relatively pure well water, these surface supplies create a major problem in which algae specifically, and microorganisms in general must be combatted.

Although the study of microorganisms began with the invention of the compound microscope near the beginning of the seventeenth century, it was not until about 1850 that their importance in water supplies was recognized. After Hassall in England and Cohn on the continent first directed attention to the importance of microorganisms, the next fifty years saw important and far-reaching investigations carried on by numerous workers in this country as well as in Europe. While these investigations were of basic importance for future work, none of them resulted in a systematic examination of any particular water supply until the Massachusetts State Board of Health in 1887, established and has since maintained such a survey. Numerous cities soon followed its example. However, satisfactory methods to control microorganisms were not known until 1905 when Moore and Kellerman proposed the use of copper sulfate for the elimination of algae. This was the beginning of the modern period of algal control in water supplies.

All natural water sources such as lakes, rivers, streams and ponds, and in some cases, artificial wells which are maintained by underground streams, contain plankton. The name "plankton" is applied in water supply work to all microscopic or near-microscopic organisms, both plant and animal, which maintain a free-floating existence in bodies of open water. Although plant and animal plankton are involved in water sanitation, the microscopic plants or algae, are of

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primary importance because they alone can manufacture and contribute to the food supply of the animal plankton. Elimination of the algae is therefore the first step in the control of the animals.

The identification and the determination of the number of algae present is the initial problem in the treatment of any reservoir. The investigator must be able to identify all common plankton algae, to the species if possible, under relatively low magnification. This is imperative because the counting chambers used do not permit the use of high magnifications. Only trained algologists who are thoroughly familiar with range in forms and structures of the various species encountered can satisfactorily undertake this part of the work.

A great many species of algae may be present in a reservoir but more than likely a few species will be found in sufficient abundance to affect the water supply. Usually there are great variations in the number of individuals in these species. As all species are not equally obnoxious, quantitative rather than qualitative studies are necessary. It is not the intention here to enumerate all the plankton algae which may be encountered. Such information, if desired, may be readily secured from standard manuals of the algae. The following list does however, present a few of the important flavor and odor producing genera, or which, because of shape and structure may prevent proper filtration and necessitate frequent cleaning or "backwashing" of the filter beds.

BLUE GREEN ALGAE	GREEN ALGAE	YELLOW GREEN ALGAE AND DINOFLLAGELLATES	DIATOMS
<i>Anabaena</i>	<i>Pandorina</i>	<i>Synura</i>	<i>Asterionella</i>
<i>Microcystis</i>	<i>Volvox</i>	<i>Uroglena</i>	<i>Synedra</i>
<i>Aphanizomenon</i>	<i>Tetraspora</i>	<i>Dinobryon</i>	<i>Fragillaria</i>
<i>Rivularia</i>	<i>Spirogyra</i>	<i>Ceratium</i>	<i>Tabellaria</i>

The diatom genera *Synedra*, *Fragillaria*, and *Asterionella* cause much of the filtration trouble, although mats of *Spirogyra* or other filamentous algae settling on the filters may result in similar difficulties. These, as well as a number of other genera including those listed above may cause unpleasant odors or flavors. Some algae, for example the species of *Synura* which has the odor of cucumbers, may be identified on the basis of odor alone. Other odors or flavors produced by algae may be described as fishy, grassy, moldy, pig pen, and aromatic such as geranium, violet, or nasturtium. Other than *Synura* which is extremely disagreeable, the blue green algae probably account for a large proportion of bad tasting water because of their wide occurrence and the great rapidity with which they grow and multiply. In all instances the odor is presumably due to oils produced within the cells of the alga and liberated into the water upon their death and decomposition. This explains the sharp increase in the odor intensity of water for a few days following the application of an algicide. Results of bacteriological studies during this period show a great increase in the number of bacteria which is inversely correlated with the decrease of the algae. The intensity of the odors are stated in terms of "The Threshold Odor Number," a figure which represents the dilution of the sample that is required to reduce the odor to a point where it is just detectable. An odor free water is used to dilute the sample. With the realization that *Synura* oil can be recognized in concentrations as low as one part in twenty million parts of water it becomes apparent that the algae must be eliminated at the source rather than at the pumping station.

The value of the data obtained will depend largely upon the careful selection of stations at which periodic collections are made. These stations should include

areas of greatest plankton concentration as well as those that will yield data concerning the effect of tributary streams entering the reservoir. The extent to which sewage or industrial contamination, algal growth, and commercial or pleasure navigation may be highly important.

Samples may be obtained by one or more of several methods. If a complete tabulation of all organisms is desired, a known quantity of the water may be centrifuged. Another excellent procedure is that known as the Sedgwick-Rafter Method. By this method the organisms are removed from the sample by means of a layer of fine sand supported on bolting silk, then washed from the sand by a measured quantity of distilled water. The objections to this method are the amount of equipment necessary, the time necessary for filtration, and a possible loss of organisms which stick to the sand. If the results justify the means, and extreme accuracy may be sacrificed, then the net method may be used. In this procedure a known amount of water is passed through a net of silk bolting cloth. These nets come in various size mesh but the No. 20 mesh is relatively satisfactory. Although part or all of the small plankton may pass through the net, most of the objectionable species of algae are retained. If the net is handled in the same manner each time a collection is made, and the same amount of water is passed through at each collection, the final result is a figure that represents the relative abundance of the important species of algae present. The writer has used this method with satisfactory results during the past several summers in plankton surveys for the Columbus City Division of Water, Columbus, Ohio.

The resultant filtrate from the net may be made up to any desired volume for easy and rapid computing. In the Columbus survey, 25 gallons of river water are filtered through the net and the resultant sample made up to 50 cc. with a standard preservative. At this concentration, one cc. of sample is equal to one-half gallon of river water. Preservation of the sample is necessary if they are to be kept for even a few hours. If not preserved, decomposition and the use of the algae as food by the zooplankton will render the sample useless. A word of caution here is advisable. Colonies of *Synura*, *Uroglenopsis* and *Aphanizomenon* disintegrate upon preservation. Samples containing these genera should be worked while still living, or immediately after fixation. The latter is better with motile algae as it is almost impossible to count the living organisms. The population is determined by transferring one cc. of the sample to a standard counting chamber holding one cc. and which is one mm. deep. By using a Whipple disc which has been calibrated to give a field of one sq. mm., the number of each species in one cu. mm. of sample is determined. At least ten such "counts" should be made, and for greater accuracy up to twenty-five should be made. The average of these counts multiplied by one thousand will give the average number of each organism in one cc. of the sample. If this one cc. of sample represents one-half gallon of water then the average number of each organism per gallon of water in the reservoir is easily computed by doubling the number in the sample. If it is desirable to have the final results expressed in terms of the metric system one may work with liters instead of gallons. However, if the work is part of an organized program of a City Water Filtration Department, it is well to keep results in the terms ordinarily used by other workers at the station.

Counts should be made at intervals of not more than one week. If the results show a rapid increase of one or more objectionable species, steps toward their elimination should be taken immediately. If development is allowed to continue, the resultant "Water bloom" will be so intense that treatment will result in extremely disagreeable odors. If the bloom is checked early in its development, it will be less difficult to control, and the after effects are far less evident to the consumer. Control should also be initiated if there is a general and steady increase

of all species because the enormous volume of decomposing organic material will produce some disagreeable odors or flavors.

The most satisfactory method for the control of algae in reservoirs, lakes ponds or pools is that proposed by Moore and Kellerman in 1905. The control, as previously stated in this paper, is accomplished through the use of copper sulfate. This compound as an algicide is cheap, effective, easily applied, and harmless to human beings in the concentrations found effective. Any objections to its use in drinking water are unfounded. Copper is normally present in the human body and many of our foods contain greater quantities of the metal than is found in the water following treatment. When  $\text{CuSO}_4$  is applied to the water in a reservoir much of it changes to insoluble compounds so that the water which reaches the consumer has an extremely low concentration of soluble copper compounds.

The following list of algae with the concentrations of  $\text{CuSO}_4$  effective in their elimination should allay fears in this regard. In each instance the figure following the algal name represents the number of parts of water to one part of  $\text{CuSO}_4$ .

<i>Aphanizomenon</i> .....	5,000,000	<i>Pandorina</i> .....	100,000
<i>Anabaena circinalis</i> .....	10,000,000	<i>Volvox</i> .....	4,000,000
<i>Asterionella</i> .....	8,000,000	<i>Synura</i> .....	3,000,000
<i>Synedra</i> .....	600,000	<i>Spirogyra</i> .....	25,000,000

The above list represents only a portion of an extended list published by Moore and Kellerman in the U. S. Department of Agriculture, Bureau of Plant Industry, Bulletin No. 76, 1905. These concentrations, based on water of average hardness and having a temperature of 59° F., will vary slightly in water at other temperatures and degrees of hardness. The amount of  $\text{CuSO}_4$  needed is determined on the basis of the volume of the reservoir and the kind of algae present. It may then be applied by towing a gunny sack of the crystals behind a slow moving motor boat or row boat. The process may be expedited by the installation of a pump and mixing unit in a relatively fast motor boat. Powdered  $\text{CuSO}_4$  is mixed with water pumped from the reservoir and the resultant solution sprayed from the rear of the boat. The advantage of this method is a more uniform and better application with less waste of material and time.

There is no possible way to satisfactorily predict the intervals between applications. Hardness of the water, temperature, and organic content, as well as the reappearance of resistant forms of algae all combine to make such predictions of little value. Satisfactory results depend upon regular periodic surveys by the algologist. In some reservoirs it will be found that treatment is required only during the early spring and late summer or autumn months, and may be correlated with the usual maxima of diatoms at those periods. In others, the development of blue green algae will necessitate continuous treatment throughout the summer. In the Columbus, Ohio, reservoirs, spring treatment is seldom necessary because of high turbidity.

If this turbidity is continuous or nearly continuous during the summer, treatment is either eliminated or reduced to a minimum. An excellent example of this occurred in the Griggs reservoir at Columbus during the summer of 1943. Figure 1 shows graphically that five maxima, based on total organisms present, occurred between July 1 and November 3.

In the first four instances, as the organisms approached proportions indicating the desirability of applying  $\text{CuSO}_4$ , severe storms occurred over the water shed. The resulting turbidity and consequent decrease in light available to the algae reduced photosynthesis. This in turn sharply curtailed the growth and number of algae. The fifth maximum which occurred about October 13, disappeared shortly because of an extended period of cloudy weather, some precipitation, and a sharp drop in temperature. Such turbidity provides an excellent natural control for

the algae. This method has met with success in ponds and shallow lakes where turbidity can be created by artificial means.

In any algal elimination program there is one precautionary measure of which those in charge must be cognizant. If the body of water is open to fishing, it must be remembered that  $\text{CuSO}_4$  is toxic to fish as well as to algae. Although little work has been done regarding the tolerance of fish in this respect, it is definitely known that the concentrations of copper which they can withstand vary almost as widely as they do in the algae. Likewise, the tolerance to the copper depends to a great extent upon the carbonates present, the temperature, and the amount of organic material. Some of the more common varieties of fish and the concen-

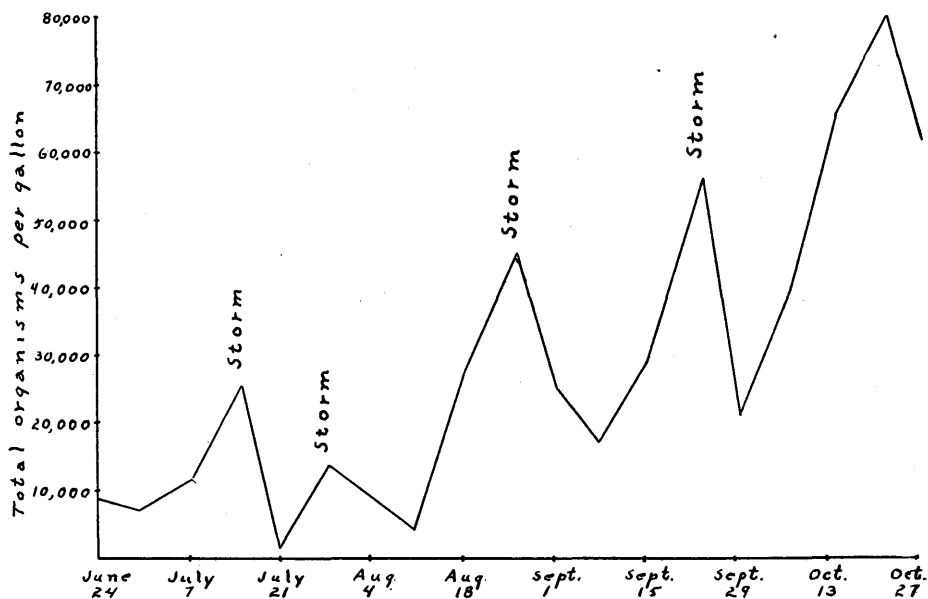


Fig. 1. Graph showing the maxima of total organisms in the Griggs Reservoir of the Columbus City Water Supply, Columbus, Ohio, during the summer of 1943.

trations of  $\text{CuSO}_4$  which may safely used are given below. These figures are the result of the investigations of Moore and Kellerman. The figures represent the number of parts of water used to one part of  $\text{CuSO}_4$ .

Black Bass.....	500,000	Catfish.....	2,500,000
Sunfish.....	750,000	Carp.....	3,000,000
Perch.....	1,500,000	Trout.....	7,000,000
Goldfish.....	2,000,000		

Consistent and favorable results during the past forty years prove the efficiency of  $\text{CuSO}_4$  as an algicide. The tabulation of a few results obtained through its use in the Columbus, Ohio, reservoirs will exemplify this efficiency.

On September 21, 1942, the plankton counts at three stations in the Griggs Reservoir of the Columbus water supply showed a decided increase in the number of organisms present. In order to prevent the development of a late autumn bloom,  $\text{CuSO}_4$  was applied at the rate of nine pounds per acre. On October 5, counts were again made which showed that the development had been checked

and the number of organisms considerably reduced. During this period weather conditions were relatively constant. A tabulation of the results is given below:

Station No.	Total Organisms per Gal. before Application of $\text{CuSO}_4$	Total Organisms per Gal. after Application of $\text{CuSO}_4$
1.....	12,240	1,440
2.....	9,360	2,400
3.....	6,480	1,200

Another excellent example of algal control resulted from the investigations of Professor W. L. Huff, who, in 1915, was employed by the city of St. Paul to study the microorganisms of Vadnais Lake, St. Paul, Minnesota. The effects of  $\text{CuSO}_4$  on the microorganisms are shown graphically in Figure 2.

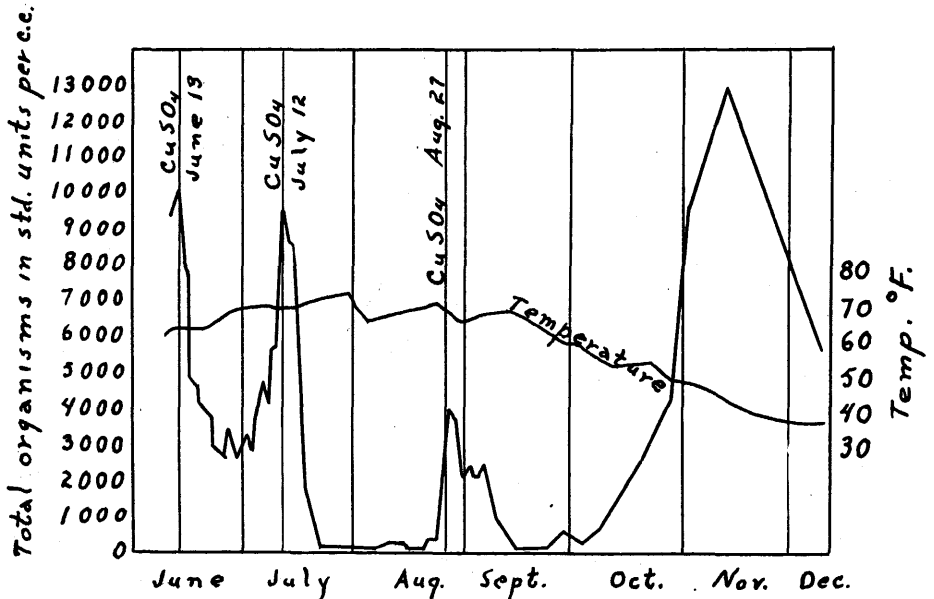


Fig. 2. Results of copper sulfate treatment of Vadnais Lake, St. Paul, Minn., 1915. After Huff.

Results, such as the above are representative and indicate the success of an algal control program.

The intention of the writer throughout the foregoing discussion has been to acquaint the reader with problems connected with algal control in water sanitation. Although most of the methods have been published, it is felt that a summary of the local work will help the average consumer to appreciate the efforts being made to supply him with the best possible water. Also that in the future the problems of water supply control as purity, freedom from odors, flavors, hardness and many other qualities will increase rather than diminish. The solution of these problems will depend upon adequately trained aquatic biologists, bacteriologists and chemists working in co-operation.