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ALGAE IN WATER SUPPLIES OF OHIO

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More than 100 Ohio communities depend upon surface rather than underground sources for their water supplies. Of the 24 cities with a population exceeding 25,000 persons, six use Lake Erie as a source of water, and four, the Ohio River. Some 40 communities use water from small streams and ponds, and in most instances impoundments have been constructed on these streams to assure a continuous supply of water (Public Health Service 1948 and 1960).

Conditions in surface waters of Ohio are generally favorable for development of algae and frequently for aquatic flowering plants. The aquatic fauna will develop invariably along with the flora, but algae normally constitute the bulk of the organic content in the water. This material tends to be dispersed in water as minute particulates and as colloidal matter, the former including the living plankton and the latter their non-living products.

Because of organic matter and silt in surface water, practically every Ohio community depending upon surface water finds it necessary to purify the water by passing it through a treatment plant. Treatment in these plants involves not only elimination of pathogenic organisms but reduction to a minimum of organic and inorganic inclusions. Otherwise algae and other ingredients may give an undesirable taste, odor, color, or texture to water; they may complicate effective chlorine treatment of water, reduce flow in the distribution system, and interfere with use of water in many industrial processes.

The procedures used in treatment plants for removal of algae require frequent adjustment and attention. This is due, in part, to great variation in the number and kinds of algae present and to changes they bring about in physico-chemical characteristics of water. Algae are responsible in the treatment plant itself for difficulties such as clogging of filters and screens and the formation of slimy discolored growths on walls of the sedimentation basins.

Most communities throughout Ohio have to rely upon local sources for their supply of water. Many of these, from Lake Erie in the north to the Ohio River in the south, are rich in algae and other aquatic life and require intensive and thorough treatment.

WATER SUPPLIES OF OHIO

Ohio is divided into three physiographic provinces, the Allegheny plateau in the eastern half, the Lake plains on the shores of Lake Erie, and the Central plains of the western half of the state. Serving these provinces are two drainage basins, the Lake Erie drainage basin covers slightly more than one-third of the area of the state and the Ohio River drainage basin the remainder. Rivers in the Lake Erie drainage basin include the Maumee, Sandusky, Cuyahoga, and Grand. Rivers in the Ohio River drainage basin include the Miami, Little Miami, Scioto, Hocking, Muskingum, and Mahoning. Of the State's rivers the Muskingum has the largest drainage area, the Maumee the second largest, and the Scioto the third largest. Lake Erie has 230 miles of Ohio shoreline and the Ohio River 436 miles.

Of more than 100 lakes in the State, 27 are natural. Most of the lakes are comparatively small, only a few being larger than 5,000 acres. The artificial lakes were constructed for use as canal reservoirs and community and industrial water supplies, and for flood control, recreation, and fish propagation. The total inland water area of Ohio comprises more than 200,000 acres. It is estimated that this amount of water could produce a yearly crop of algae totaling over 1,500,000,000 lb (Tiffany, 1928).

TYPES OF ALGAE

Extensive samplings for algae in Ohio have been made as a result of studies conducted by biologists associated with universities and colleges, fisheries laboratories, and public health agencies that conduct water pollution surveys. These studies include those made by Brinley (1942a), Chandler (1940, 1942, 1944), Daily (1945), Davis (1954a, 1955), Fish et al. (1960), Hirsch (1954, 1956), Hirsch and Palmer (1958), Lackey (1938, 1939, 1941, 1956), Roach (1932, 1933), Snow (1904), Taft (1937, 1942a, 1942b, 1945a, 1945b, 1949, 1961), Tiffany (1930, 1934, 1937, 1946), Transeau (1951), Verduin (1951b, 1960), Walton (1915, 1930), Wood (1947), and S. Wright (1955). Two check lists of Ohio algae have been published, one for the non-filamentous blue-green algae (Daily, 1942) and one for all algae (Lillick and Lee, 1934).

Of the many varieties of algae recorded a considerable number are widespread and abundant and may be significant because of their dominance. In Buckeye Lake, the green algae were found to be dominant, particularly *Scenedesmus* and *Pediastrum* (Tressler et al., 1940). *Tetrastrum* also was found to be very abundant in this lake and in the Maumee River (Ahlstrom and Tiffany, 1934). In Cleveland Harbor the diatoms dominated in all seasons, *Cyclotella*, *Fragilaria*, and *Melosira* representing the most abundant genera (Davis, 1954b). For the Ohio River and its tributaries, Brinley and Katzin (1942) listed the following genera as abundant, widely distributed throughout the river basin, and present during all seasons: *Chrysococcus*, *Cryptomonas*, *Chlamydomonas*, *Cyclotella*, and *Navicula*. From 1957 to 1960, dominant algae in the Ohio River included *Cyclotella*, *Synedra*, *Navicula*, *Melosira*, *Asterionella*, *Oscillatoria*, *Anacystis*, *Chlamydomonas*, and *Ankistrodesmus* (National Water Quality Network, 1959, 1960, 1961). In the Scioto River, Lackey (1939) found the most abundant flagellate algae to include *Chrysococcus*, *Cryptomonas*, *Chlamydomonas*, *Euglena*, and *Trachelomonas*. Other common algae in the Scioto River were *Chlorella*, *Ophiocytium*, *Lagerheimia*, *Anacystis* (*Microcystis*), *Oscillatoria*, *Cyclotella*, and *Nitzschia* (Hirsch, 1954).

In a quarry pond in northern Ohio, the dominant genera varied with the season. *Asterionella* and *Fragilaria* were dominant in April, *Oocystis* and *Scenedesmus* in June, *Gloeocystis*, *Glenodinium*, *Ceratium*, *Anabaena*, *Pandorina*, and *Aphanizomenon* in July-August, and *Cryptomonas* and *Chlamydomonas* in the fall and winter (Verduin, 1959). At Turkeyfoot Lake, *Aphanizomenon* reached the greatest numbers of all blue-green algae and *Asterionella* and *Amphora* greatest of all diatoms (Kraatz, 1941). Abundant algae in the East and West Reservoirs near Akron included *Anabaena*, *Aphanizomenon*, *Oscillatoria*, *Synedra*, *Melosira*, *Fragilaria*, *Pediastrum*, and *Dinobryon* (Kraatz, 1931).

In Lake Erie diatoms constitute the greatest percentage of the algal population during all or much of the year. *Asterionella*, *Fragilaria*, *Synedra*, *Cyclotella*. *Melosira*, and *Stephanodiscus* are generally most abundant (Chandler, 1942). In some instances *Asterionella* has constituted about 90 percent of the total diatom population (Chandler, 1944).

For northern and central Ohio, Taft (1961) has prepared a field identification key which includes 50 common genera of algae, exclusive of diatoms. In the many reports on algae in water supplies throughout Ohio. more than 100 genera have been referred to as common or significant. In table 1, these algae are arranged alphabetically under five major groups: blue-green algae, unicellular and colonial green algae, filamentous and tubular green algae, pigmented flagellate algae, and diatoms.

QUANTITATIVE STUDIES

Procedures for quantitative measurement of algae in Ohio waters have been so varied that the results of different workers cannot be compared directly. They all indicate, however, that environmental conditions, both natural and artificial, are frequently such as to stimulate heavy algal growths.

A plan to report the volume of algae in parts per million rather than by number or area was described at an Ohio conference on water purification (Purdy, 1935).

TABLE 1

Common and significant genera of algae in water supplies of Ohio

Blue-green algae	Unicellular and colonial green algae	Filamentous and tubular green algae*	Pigmented flagellate algae	Diatoms
Anabaena	*Actinastrum*	*Audouinella*	*Carteria*	*Amphiprora*
*Anacystis***	*Ankistrodesmus*	*Basicladia*	*Ceratium*	*Amphora*
Aphanizomenon	*Botryococcus*	*Batrachospermum*	*Chlamydobotrys****	*Asterionella*
Aphanocapsa	*Chlorella*	*Botrydium*	*Chlamydomonas*	*Biddulphia*
Aphanothece	*Chlorococcum*	*Bulbochaete*	*Chrysococcus*	*Cocconeis*
Chroococcus	*Chodatella*	*Chaetophora*	*Cryptoglena*	*Cyclotella*
Coelosphaerium	*Closteriopsis*	*Chara*	*Cryptomonas*	*Cymatopleura*
Gloeocapsa	*Closterium*	*Cladophora*	*Dinobryon*	*Cymbella*
Gloeotrichia	*Coelastrum*	*Draparnaldia*	*Eudorina*	*Diatoma*
Gomphosphaeria	*Cosmarium*	*Microspora*	*Euglena*	*Fragilaria*
Lyngbya	*Crucigenia*	*Monostroma*	*Gonium*	*Gomphonema*
Merismopedia	*Dictyosphaerium*	*Mougeotia*	*Lepocinclis*	*Gyrosigma*
Nostoc	*Hydrodictyon*	*Nitella*	*Mallomonas*	*Melosira*
Oscillatoria	*Kirchneriella*	*Oedogonium*	*Pandorina*	*Meridion*
Phormidium	*Lagerheimia*	*Rhizoclonium*	*Peridinium*	*Navicula*
Plectonema	*Micractinium*	*Spirogyra*	*Phacotus*	*Nitzschia*
Pleurocapsa	*Oocystis*	*Stichococcus*	*Phacus*	*Pinnularia*
Rivularia	*Pediastrum*	*Stigeoclonium*	*Rhodomonas*	*Rhizosolenia*
Scytonema	*Scenedesmus*	*Tribonema*	*Spondylmorum*	*Stephanodiscus*
Stigonema	*Selenastrum*	*Ulothrix*	*Synura*	*Synedra*
	Sphaerocystis	*Vaucheria*	*Trachelomonas*	*Surirella*
	Staurastrum	*Zygnema*	*Uroglena*	*Tabellaria*
	Tetraedron		*Uroglenopsis*	
	Tetrastrum		*Volvox*	

*Includes some yellow-green and red algae.
**Includes *Microcystis, Polycystis, Clathrocystis.*
***Includes *Pyrobotrys.*

A more common procedure, however, is the enumeration, either as areal standard units or as the number of organisms per milliliter or liter (Wolfe, 1950). In limnological studies of western Lake Erie the number of "units" of algae were recorded. A unit consisted of a single cell (*Navicula, Stephanodiscus, Synedra*), a colony (*Coelastrum, Pediastrum*), a designated number of cells (*Dinobryon, Asterionella, Tabellaria*), or a designated length of a filament (*Melosira, Oscillatoria, Anabaena*), (Chandler, 1940).

In a pollution study, the phytoplankton of 10 Ohio streams entering Lake Erie were recorded in volumetric units, each unit being 1 cubic micron. Phytoplankton volumes varied from zero on January 4, 1951, to 125 x 10^8 μ^3 per liter on August 30 of the same year (Sullivan, 1953).

At East Liverpool, total counts of Ohio River algae reached a maximum of 24,940 per ml (clump count) and at Cincinnati, 30,010 (National Water Quality Network, 1959 and 1960). Wright (1955) recorded a maximum of 2,174 algae per ml in Maumee Bay. Verduin (1954 and 1959) reported a maximum volume of algae in western Lake Erie as 16 μl per liter and in a quarry pond in northern Ohio as 130 μl per liter. The numbers and volume of phytoplankton in the Scioto River have been reported to be far in excess of those in most streams that have been studied in the United States, a maximum algal growth of 32,933 ppm having been recorded at Chillicothe (Kehr et al., 1941). This would represent about 3 percent of the volume of water. Plankton volume in the Miami River was found to range from 1,500 to 22,000 ppm and that in the Little Miami River from 2,000 to 6,000 ppm (Brinley, 1942b).

Water entering the Akron treatment plant from Lake Rockwell has contained profuse growths. At one time the amount recorded was 42,800 areal standard units of algae, 37,500 being *Anabaena* (Gettrust, 1940). Earlier, in water from a shallow impounding reservoir on the Cuyahoga River, *Melosira* and *Anabaena* were the predominant algae and yearly averages of plankton counts ranged from 4,000 to 8,000 areal standard units (Akron Water Treatment Plant, 1924).

Certain difficulties arise in attempts to enumerate algae in water. Because of water movement, fluctuations were found to occur in sampling at one location at different times (Verduin, 1951a). Differences in counts made from trap-net and water-bottle centrifuged samples were demonstrated in water from Turkeyfoot Lake (Kraatz, 1940). In samples from the Scioto River that were treated with formalin, about 33 percent of the plankton could not be identified (Lackey, 1938c).

In spite of difficulties in quantitative enumeration, it is evident that bodies of water in Ohio support an abundant growth of algae that must be reckoned with in preparing water for its many uses.

ALGAL BLOOMS AND MATS

Algal blooms are of frequent occurrence in Ohio and have been reported for many different genera. Among blue-green algae reported as forming blooms in the state are *Anabaena* (Daily, 1945; Kraatz, 1941), *Anacystis* (*Microcystis*) (Wright and Parkinson, 1961), *Aphanizomenon* (Kraatz, 1941), *Coelosphaerium* (Daily, 1942; Kraatz, 1941), *Gomphosphaeria* (Hirsch and Palmer, 1958), and *Raphidiopsis* (Daily, 1945). Flagellate algae that have produced blooms in the State are *Cephalomonas* (Lackey, 1957), *Chlamydomonas* (Brinley, 1942b; Schultz, 1952), *Euglena* (Lackey and Smith, 1940; Walton, 1915; Wickliff, 1925), *Peridinium* (Lackey, 1949), *Pandorina* (Brinley, 1942), *Platydorina* (Taft, 1941a), *Uroglena* (Lackey, 1957), and *Volvox* (Wickliff, 1925). *Peridinium* produced a brown-colored bloom (Lackey, 1949). Red-water conditions due to *Euglena sanguinea* have occurred frequently in Ohio in July and August (Walton, 1915).

Two green algae that form blooms are *Pediastrum* (Davis, 1955) and *Staurastrum* (Wickliff, 1925). In Lake Erie, diatoms have sometimes made the water appear brownish because of their abundance, *Asterionella* and *Melosira* generally in such cases being the dominant genera (Chandler, 1944). A bloom of *Melosira* was present in O'Shaughnessy Reservoir at Columbus in early summer (Wright and Parkinson, 1961).

One of the worst algal problems in the history of the Cincinnati water supply occurred in 1957. Beginning in July, there were 2 months of successive blooms, first of *Synedra*, next *Melosira*, followed by *Anabaena*, and finally *Oscillatoria*. Blooms of *Asterionella* accompanied by objectionable river odors have also occurred in the Ohio River at Cincinnati (Enright, 1959).

Surface mats formed by algae are of common occurrence in Ohio. They are formed by various filamentous genera, including *Cladophora*, *Mougeotia*, *Oedogonium*, *Oscillatoria*, *Spirogyra*, *Stigeoclonium*, *Ulothrix*, and *Vaucheria* (Brinley, 1942a; Daily, 1945; Hirsch and Palmer, 1958; Schultz, 1952). Planktonic algae such as *Euglena* and diatoms are often present in large numbers associated with the filamentous algae in the mats (Schultz, 1952).

In the Scioto River between Columbus and Piketon, masses of attached and floating algae have been observed throughout most of the year. Among algae attached to the stream bottom were *Phormidium* and *Stigeocolium*; those found in floating mats included *Spirogyra* and *Hydrodictyon* (Hirsch, 1956).

ALGAE IN RIVERS

Larger rivers are the source of raw water supplies for cities and towns and are also recipients of treated and untreated sewage and industrial wastes. These wastes may affect the algal flora in various ways. Planktonic algae in the Ohio River are more abundant downstream from each city than immediately above. Below Steubenville, regular occurrence of *Euglena viridis* has been reported and below Portsmouth, minute green algae have been reported very abundant (Purdy, 1923). The fish population may benefit from increases in algae because they serve, directly or indirectly, as food for fish (Brinley, 1943).

During periods of prolonged industry-wide shut downs, certain wastes toxic to algae are not released into the river and the numbers and kinds of algae become unusually high. This has been reported for the Mahoning River (Ohio Dept. Health, 1954) and the Ohio River (Palmer, 1961).

Among substances affecting algal growth in the Ohio River at Cincinnati are oily materials, toluene, xylene, DDT, detergents, pyridine, nitriles, alcohols, aldehydes, ketones, and esters. Some may have adverse effects on algae, whereas others may stimulate their production (Middleton et al., 1958). Certain algae have been found growing rapidly in the presence of oily wastes in water at Cincinnati (Ludzack and Kinkead, 1956).

The Ohio River is reported to possess a plankton population characteristically different from that of its tributaries, which have fewer diatoms and a far wider range of flagellate algae. In the middle third of the Ohio River, a large bloom of diatoms is sometimes the striking feature of the plankton. At Cincinnati, the algae most likely to be found are the diatoms *Synedra*, *Melosira*, *Navicula*, *Cycloetella*, *Asterionella*, and *Stephanodiscus;* the green algae *Scenedesmus*, *Staurastrum*, and *Pediastrum;* the blue-green algae *Anacystis* (*Microcystis*), *Anabaena*, and *Oscillatoria;* and the flagellate algae *Chlamydomonas* and *Dinobryon*. The predominant form found more than 60 years ago, *Synedra*, was still the predominant alga in 1959 (Enright, 1959).

High biological productivity in the Scioto River has resulted from discharge of organic wastes into the stream. Extensive growths of filamentous algae are present during summer and fall. A year-round study of phytoplankton in the river near Piketon showed that large populations were present during much of the year. A number of organisms frequently associated with taste and odor conditions and clogged filters were encountered. Both of these problems could be expected in a water treatment plant using water of this type (Hirsch, 1956). The flagellate algae *Rhodomonas*, *Cryptomonas*, *Mallomonas*, *Synura*, *Uroglenopsis*, *Dinobryon*, and *Chrysococcus* have been found in cleaner portions of the Scioto River but absent or scarce in polluted areas (Lackey, 1941).

Some species of *Euglena*, *Phacus*, and *Trachelomonas* were found abundant in polluted areas of the Scioto (Lackey, 1938a). Other algae found thriving in polluted ares included *Oscillatoria*, *Chlamydobotrys*, *Spondylomorum*, *Eudorina*, and *Pandorina* (Kehr et al., 1941). *Euglena viridis* in the Scioto River has been considered the most reliable indicator of water with high organic content (Lackey and Smith, 1940).

Lytle Creek, near Wilmington, had 101 species of microbiota in clean water but only 43 species immediately below the zone of pollution (Lackey, 1956). Phytoplankton were almost 10 times as numerous in Lytle Creek 2 miles below a sewage outfall as in the stream above the outfall (Cooke, 1961).

In the Hocking River algae persisting during autumn, winter, and spring were *Lyngbya*, *Closterium*, *Navicula*, *Melosira*, *Synedra*, and *Pinnularia*. There were 42 genera of algae in the autumn, 33 in winter, and 20 in spring (Roach, 1932).

The Miami River flows through a densely populated industrialized area and receives domestic and industrial wastes from a number of communities. It had a dense algal population composed principally of a mixture of green algae, diatoms, and flagellate algae (Brinley, 1942b).

At Upper Sandusky, during a severe drought, pumping from the Sandusky River to the reservoir had to be stopped because of the large number of microorganisms. Above the intake the water was grass-green from the presence of algae (Lathrop, 1931).

In Cleveland Harbor it was difficult to find any close relationship between the volume of plankton and the amount of pollution, since turbidity, temperature, and presence of organisms both from Lake Erie and the Cuyahoga River strongly influence the algal flora of the harbor (Davis and Rooney, 1953; Davis, 1954b). Some of the most abundant algae found in the harbor were *Melosira*, *Asterionella*, and *Pediastrum simplex* (Davis, 1955).

Sullivan (1953) considered the majority of planktonic algae in the mouths of 10 Ohio streams entering Lake Erie to be organisms from the Lake that had moved into the river. The most important genera were *Melosira*, *Fragilaria*, *Asterionella*, *Stephanodiscus*, *Pediastrum*, and *Cyclotella*. *Melosira* was found throughout the year and was the most common diatom.

PHYTOPLANKTON OF LAKE ERIE

Since a biological research laboratory is located in western Lake Erie, much more information is available on algae of this area than for that of the middle and eastern portions of the lake. One report lists 124 species and varieties of algae for eastern and central Lake Erie (Fish et al., 1960), whereas another lists 599 for western Lake Erie (Taft, 1945b). Taxonomic studies by Taft (1937, 1941b, 1942a, 1942b, 1945a, 1946, 1949b), Tiffany (1930, 1934, 1937, 1946), and Tiffany and Ahlstrom (1931) have added many new species of algae for the western area.

In western Lake Erie the main algal communities include the diatoms *Tabellaria* and *Cyclotella* in spring; the green algae *Oocystis*, *Dictyosphaerium*, *Pediastrum*, *Schroederia*, and *Scenedesmus* in summer; the diatoms *Asterionella*, *Fragilaria*, and *Synedra*, together with the blue-green algae *Aphanizomenon*, *Oscillatoria*, *Coelosphaerium*, *Merismopedia*, and *Anacystis* (*Microcystis*) in autumn; and the diatoms *Melosira* and *Asterionella* in late autumn and winter (Wright, 1955; Chandler 1942, 1944; Hintz, 1955).

Occasionally large areas in Lake Erie have been occupied by almost pure stands of one species, e.g., *Tabellaria fenestrata* constituted 97 percent of those in an area of 1,300 km^2 in 1949 (Verduin, 1951b). Diatoms as a group frequently have represented from 70 to almost 100 percent of the total population (Chandler, 1940). In one series of measurements, the spring crop consisted of 94 percent diatoms and 2 percent blue-green algae, whereas the fall crop was 76 percent diatoms and 20 percent blue-green algae (Chandler and Weeks, 1945).

Although horizontal distribution was not uniform, vertical distribution was reported to be essentially homogeneous, but with greatest abundance near the surface at one time and near the bottom at another time (Wright and Tidd, 1933). Chlorophyll-bearing forms were present in greatest numbers at the surface between 3 and 5 PM (Stehle, 1923).

Approximately 150 species of filamentous algae have been reported for the west end of Lake Erie, over 130 being green algae and most of the remainder blue-green algae (Tiffany, 1937). Thirteen species of charophytes have been collected from the Put-in-Bay region (Wood, 1947). The stoneworts appear to be an important source of food for Lake Erie carp (Tiffany, 1931).

From year to year the phytoplankton crop in Lake Erie may vary considerably. For example, the crop in 1942 was estimated to be about half that of the previous year. Algal production is influenced by changes in such factors as temperature, rate of eastward flow of the water, and the amounts of nutrients received from streams emptying into the lake (Chandler and Weeks, 1945). Variation in turbidity is a particularly important factor. The largest crops of phytoplankton were found to develop in waters of intermediate turbidity (Verduin, 1954).

One important source of phosphorus in western Lake Erie is the discharge from rivers. The Maumee and Detroit rivers together have been estimated to discharge 530 metric tons per year of bottom sediments rich in phosphorus (Curl, 1959).

Studies have indicated that equal volumes of various algae have different photosynthetic rates. The rate for *Asterionella-Cyclotella* was double that for *Stephanodiscus* (Verduin, 1952a). The rate for *Asterionella-Tabellaria-Melosira* was more than 10 times that for the attached filamentous algae *Cladophora* and *Ulothrix* (Verduin, 1952b). *Ulothrix* communities showed higher relative efficiency in dim light than *Cladophora* (McMillan and Verduin, 1953). A June population of *Cyclotella*, *Fragilaria*, *Cryptomonas*, and *Pediastrum* had a considerably higher rate than a July population of *Microcystis*, *Ceratium*, *Aphanizomenon*, and *Cyclotella* (Verduin, 1960). The photosynthetic yield per square meter per day of surface water had a summer maximum more than seven times that in winter (Verduin, 1956). The high photosynthetic rates were found in areas of low estimated plankton levels, indicating the presence of large populations of undetected minute algae (McQuate, 1956). The maximum rate during the day occurred between 7 and 10 AM (Verduin, 1957).

Additional accumulated data on the ecology of the western end of Lake Erie have been assembled in a recent publication (Langlois, 1954). These data are the result of many years of research conducted at the Franz Theodore Stone Laboratory of The Ohio State University at Put-in-Bay, Ohio.

ALGAE IN RESERVOIRS

Construction of water storage reservoirs has occupied a prominent place in Ohio during recent years. Droughts and low water supplies for domestic use, for industry, and for agriculture have indicated the need for more impoundments. Demand for lakes for fishing and other recreational uses is also increasing (Wickliff, 1944).

Impounded water is an excellent environment for continuous growth and accumulation of aquatic organisms including both planktonic forms and those that develop in shallow margins and bays. Roach (1933) reported phytoplankton counts ranging from 85,000 to 710,000 per liter in 16 lakes and reservoirs in Ohio. The count for Rockwell Reservoir was almost three times that for Griggs Reservoir. Dominant algae in Atwood Reservoir in eastern Ohio were *Asterionella*, *Chroococcus*, *Coelastrum*, *Diatoma*, *Dinobryon*, *Quadrigula*, and *Scenedesmus*, according to Wright (1954). He found that in June *Dinobryon* constituted 83 percent of the total phytoplankton population.

Artificial lakes in Ohio tend to show a production of plankton within 1 month after filling. Both zooplankton and phytoplankton show a decided drop in numbers after the initial year. Later, the phytoplankton again increases and average counts for lakes 3 to 100 years of age are over 150,000 per liter (Wickliff and Roach, 1937).

The new Hoover Reservoir supplying part of the water for Columbus had an algal population, during its first four years, principally of the Diatomaceae and Chrysophyceae. In June 1960, *Mallomonas* was exceptionally abundant in the reservoir and Chrysophyceae were present throughout the summer (Wright and Parkinson, 1961). In 1958 *Anabaena* caused concern because of its high numbers and in 1959 *Dinobryon* and *Mallomonas* were abundant in the upper end of the reservoir. Evidence indicates that Hoover Reservoir will support "periodic and dangerous populations of certain species that cause odors and flavors" (Wright and Parkinson, 1960).

Ponds and small lakes often are high in nutrients and support dense growths of algae. A pond in a quarry at Bowling Green had an abundance of *Pandorina*, *Chlamydomonas*, and *Cryptomonas* that were present even during winter (Cowell, 1960). In Urschel's Quarry photosynthesis by phytoplankton was found to occur actively in all seasons of the year (Tryfiates, 1960).

Ponds at Xenia, Newtown, and Piqua, became milky shortly after noon, each day, and remained in this condition until cooling started in the evening. Milkiness was due to precipitation of calcium carbonate that was caused in turn by utilization of carbon dioxide in the water by algae. It occurred during the period of very active photosynthesis. In several instances the causative organisms were species of *Spirogyra*, and in another *Peridinium* and *Ceratium* (Langlois, 1954).

Algae found in the digestive tract of gizzard shad and other fish from Buckeye, Indian, and St. Mary's lakes and Akron Reservoir, as well as from other impoundments have included the blue-green algae *Merismopedia* and *Anacystis* (*Microcystis*); the flagellates *Euglena*, *Phacus*, and *Peridinium;* the green algae *Scenedesmus*, *Pediastrum*, and *Coelastrum*; and the diatoms *Melosira* and *Navicula*. The gizzard shad is used in turn as food by most game fish present in Ohio lakes and reservoirs (Cassaday et al., 1930; Tiffany, 1921).

Control of lands surrounding reservoirs makes it possible to reduce contamination, fertilization, and siltation in impounded water (LaDue, 1957). Akron purchased several thousand acres around Lake Rockwell, an impounding reservoir, and modified the agricultural practices on this land, including the substitution of forested areas for cultivated areas (LaDue, 1948).

CONTROL OF ALGAE

In reservoirs and lakes control of planktonic algae has been attempted by use of algicides, commonly copper sulfate. Various results have been reported from its use. At 0.25 to 0.35 ppm the reservoir at Norwalk was kept in good condition except for occasional growths of the more resistant algae (Hall, 1936). At Youngstown a heavy growth of *Coelosphaerium* in Mineral Ridge Reservoir was treated effectively with copper sulfate applied at the rate of about 0.2 ppm (Van Arnum, 1935). In the same area Lake Meander was first marked off into sections, each holding not less than 200 million gal. Treatment then was carried out by section, with slightly higher concentrations being used in the deeper portions of the lake. Less than 0.5 ppm was found to be sufficient copper sulfate for most planktonic organisms, but a few required up to 9.5 ppm (Van Arnum, 1938).

For industrial water supplies, various concentrations of copper sulfate have been recommended: for diatoms, 0.07 to 0.5 ppm; for blue-green algae, 0.1 to 0.5 ppm; and for green algae, 0.1 to 10.0 ppm (Taft, 1949a). Algae and scale were found to be troublesome in external water systems of cooling towers of a fuel-gas industry near Lucas. Daily treatment has inhibited heavy algal growths (Bradbury and Hostler, 1959).

Neal (1931) has emphasized that copper sulfate treatment may be necessary as a preventative, even when algal growths are not serious. Treatment with low concentrations of the algicide at monthly intervals throughout the warm weather season, beginning in April, was considered effective in preventing growth of algae in reservoirs (Public Works, 1922). At Columbus, however, more than two treatments during the summer seldom were necessary (Taft, 1949c). By 1960, Dublin Road intake reservoir at Columbus showed high algal counts requiring copper sulfate treatment to be carried out every two weeks during the summer (Wright and Parkinson, 1961).

For effective early spring treatment at Lima, copper sulfate crystals were put on the ice cover in the secondary reservoirs just before the ice broke up (Van Arnum, 1936).

At Warren, during the algal season, application of ammonia-chlorine prevented multiplication of bacteria between the inlet basins and filters. Algae in the raw water had resulted in rapid bacterial multiplication before the treatment was used (O'Connor, 1931).

Although algal growth can be very troublesome to purification plants that use water directly from streams, destroying the growth in the same manner as in a reservoir is impossible. Removal by heavy dosages of coagulant and killing with chlorine after the water enters the treatment plant are generally only partially successful. An algicide has sometimes been added in the primary settling basin (Waring, 1922).

At Tiffin, where water was obtained from the Scioto River, copper sulfate at the rate of 15.5 lb per million gal completely eliminated two kinds of algae, *Synura* and *Dinobryon*. The experience was repeated 2 years later, in October 1948. On other occasions the Tiffin plant has used this method on *Anabaena*, *Euglena*, and *Melosira*. Results at Tiffin indicate that algae can be killed quickly with copper sulfate (Flentje, 1952).

Reports on control of attached aquatic growths in Ohio are concerned almost entirely with higher plants rather than algae. The dominant aquatic plants vary with the lake. At Lake St. Mary's, cattails have been the abundant form; at Lake Loramie, introduced lotus; at the Portage Lakes and East Harbor, water milfoil; and at Buckeye Lake and Indian Reservoir, hornwort, ditch moss, and duckweed. Control at Buckeye Lake was accomplished by removing part of the submerged and floating hornwort; wind action then scattered the duckweed (Wickliff, 1949).

In the past, mechanical control at Buckeye Lake was carried out with "moss-boats," which were specially constructed, flat-bottom boats, propelled with a paddle wheel and equipped with cutter bar and rake. Since 1946, chemical methods have been tested and used. A most exasperating problem has been the heavy aftergrowth in seemingly dead plants, particularly following the use of 2,4–D, even after the second treatment (Handley, 1949). Attached growths of aquatic plants were not killed at Lake Meander when copper sulfate was applied at the rate of 3 ppm (Van Arnum, 1939).

Tests with CMU (chlorophenyl dimethyl urea) at a fish hatchery in Newtown revealed that CMU is effective in eliminating floating algae. *Cladophora* was more resistant than *Spirogyra*, *Mougeotia*, and *Hydrodictyon*. At 2 ppm, all species of blue-green algae and diatoms tested were prevented from developing (Maloney, 1958).

Mechanical methods for reducing the amount of floating vegetation, including algae, have involved the use of strands of barbed wire, rope, ribbons of small mesh chicken wire, and heavy plank floats with a series of rake-like teeth underneath (Wickliff, 1945). At Warren, water was passed through a travelling screen located beyond the bar screens near the water supply intake. The travelling screen removed some types of algae and also fish, leaves, and frazzle ice that got past the bar screens (O'Connor, 1947).

TASTE AND ODOR

In Ohio, algae are present in sufficient numbers and kinds in surface waters to be an almost constant potential source of tastes and odors. Most treatment plants in Ohio are now prepared to use activated carbon or other materials or procedures to reduce this trouble to a minimum.

Apparatus for feeding carbon varies from large modern automatic units (Van Arnum, 1950) to a simple homemade rig composed of a wooden keg and a gearbox from an old washing machine (Monroeville Water Treatment Plant, 1954). One small town, 20 miles from Cincinnati, used a washing machine for mixing and feeding carbon during a sudden occurrence of taste and odor. The condition developed in December, 1958, and was due to the presence of "apple seed clusters" of *Synura*. Threshold odor of the raw water was over 500. The strong distinct odor was cucumber-like to fishy and was accompanied by a bitter taste. Tests indicated that it would have required up to 1500 lb of activated carbon per million gal of water to produce a palatable water from this supply (Enright, 1959).

Warren, Ohio, reported in 1947 that it had used activated carbon every summer since 1931 and claimed to be one of the first cities in the United States to use this treatment for the control of tastes and odors in the water supply (O'Connor, 1947).

According to Edwards (1926), Ironton experienced considerable difficulty caused by algae. The dams on the Ohio River created conditions that aided the growth of algae. Mild prechlorination resulted in strong tastes from the killed algae. Superchlorination followed by dechlorination with sulfur dioxide also did not eliminate the chloro-phenolic tastes.

Cleveland reported in 1943 that anhydrous liquid ammonia was being used for control of the chloro-phenolic taste and odor and powdered activated carbon for all others (Marshall, 1943). Earlier, breakpoint chlorination tests at Cleveland were made on raw Lake Erie water that had a grassy, green-corn odor when algae were present. When breakpoint was exceeded, followed by dechlorination, the water became tasteless and odorless (Irvin, 1941).

Control of tastes and odors due to algae has been especially difficult during periods of severe drought. This condition prevailed in 1930 in Ohio, when many communities reported this problem.

The Ohio River and its tributaries, during the 1930 drought, acquired a taste described as a musty, moldy, burnt leather or "river" taste, forcing many cities to experiment with various treatments in attempts to counteract the condition. Cincinnati, East Liverpool, Marietta, Pomeroy, and Warren used ammonia-chlorine. Warren had severe taste and odor due to *Synura*. Barberton treated its water supply with activated carbon to combat tastes and odors produced by a thick mat of many kinds of algae that floated on the surface of the reservoir for 2 miles above the dam (Waring, 1931). *Asterionella* caused grassy tastes and odors in Barberton reservoir, and the odors spread through the distribution system. These were removed by adding activated carbon at a rate of 20 lb per million gal. In a previous year, ammonia-chlorine treatment was ineffective in controlling an objectionable taste and odor produced by *Anabaena*, but lime softening was effective (Rollins, 1936).

Ironton used a lime treatment that greatly minimized the taste (Baylis, 1932). Chesapeake, on the Ohio River, used water after treatment with activated carbon. Delaware used potassium permangnate to counteract odors in water from the Olentangy River (Waring, 1931). During this same drought period, Columbus, for the first time, had luxuriant growths of *Anabaena* and *Oscillatoria* in Griggs and O'Shaughnessy reservoirs and used copper sulfate to prevent development of odors (Neal, 1931). In previous years the tastes and odors were described as earthy and had been simultaneous with river rises. Tastes due to decomposition had been rare because of oxygen absorption by the water as it passed over the dam and a succession of rapids before reaching the intake line to the treatment plant (Waring, 1923).

Cities in the Lake Erie plains area also had taste and odor problems during the 1930 drought. At Cleveland intense tastes and odors due to microorganisms developed for the first time. These organisms were probably blue-green algae (Ohio Department of Health, 1935). At Akron bad tastes occurred, with *Coelosphaerium*, the dominant genus, reaching a maximum of 100,000 areal standard-units. Treatment of raw water was carried out with chlorine (Gettrust, 1932). During the year previous to the drought, East and West Reservoirs near Akron had a less offensive mixed algal flora containing blue-green algae during the warmer season but predominated by diatoms during the cooler period of the year. *Anabaena* was in greatest abundance during the summer, except for a short time when *Aphanizomenon* was dominant. Of the diatoms, *Asterionella* was outstanding in productivity. The algal flagellates *Dinobryon* and *Ceratium* reached their maximum numbers in early summer (Kraatz, 1931).

Defiance experienced difficulties with tastes and odors, especially during this same drought period, in its water supply from the Maumee River. The water had disagreeable tastes due to phenols, algae, and decaying organic matter. In June a musty taste was apparently due to algae. Odors from algae were always very pronounced in mixing and settling basins of the treatment plant. Ammonia-chlorine added at the time of filtration had no affect on algal tastes, but activated carbon gave satisfactory results, since no disagreeable tastes and odors were present in the water after filtration (Taylor, 1931 and 1932).

Toledo and Norwalk experienced unprecendented growths of *Anacystis* (*Clathrocystis*) and other algae in their water supply at a time when Toledo obtained its water from the Maumee River (Waring, 1931). Trouble with tastes and odors had been experienced for 10 years and intermittently for the previous 22 years. During summers algae and other microorganisms in the water were abundant. The water therefore had a high organic content; its intense taste was believed to result from decomposition of thousands of tons of the organic matter. In an attempt to remove the taste, complete aeration was practiced, along with softening, addition of activated carbon, and chlorination (Furman, 1930 and 1932).

Reports from communities throughout Ohio, since 1930, indicate that the occurrence of tastes and odors has continued to be a problem. In July and August, 1954, an offensive pigpen odor, characteristic of some blue-green algae, was present in the Berea water supply. Source of the water was the East Branch of Rocky River which was directed into a quarry hole for primary settling. Threshold odor of the water was 30. Activated carbon at a rate of 12 ppm reduced the odor to 4, with a faint musty odor remaining. Water treated in this manner was considered palatable (Shellenberger, 1955).

At Lorain, on Lake Erie, the raw water intake was located in the lake but only 1.5 miles from the mouth of Black River. The river as well as the lake influenced the quality of the city water supply. Algae constituted a perpetual problem during all seasons. They caused tastes and odors, poor coagulation, short filter runs, and variant chlorine demands. *Anabaena* produced most of the tastes and odors, but *Asterionella*, *Synedra*, and *Synura* were also responsible. Algae reached concentrations as high as 5,000 areal standard units. Activated carbon dosage was commonly 0.5 ppm but occasionally was increased to 5.0 ppm for control of more intense odors (Campbell, 1951).

At Painesville, which also uses water from Lake Erie, tastes and odors have occurred mostly during spring and fall. In July of one year, however, a severe taste and odor problem was caused by blue-green algae, which were present in sufficient numbers to decrease the length of filter runs. Activated carbon, together with chlorination, was used to produce a palatable water (Allison, 1954).

At Cincinnati, facilities for breakpoint chlorination of the raw water were installed in 1949 for taste and odor control; however, activated carbon treatment was also required (Enright, 1954). Much taste and odor production has been considered to be due to organic matter, including large populations of algae in the water. Stagnant, "algal" tastes have been common (Bahlman, 1941), and an earthy taste has occurred at times when the river rose suddenly (Waring, 1923).

From 1917 to 1959, there have been 64 severe taste and odor outbreaks at Cincinnati. Of these 21 have been listed as being due to natural or aquatic growths and 43 to industrial wastes. All but one of the industrial-type incidents occurred in the winter months. *Anabaena*, *Asterionella*, and *Synedra* are among the algae associated with periods of taste and odor, particularly during the warmer seasons. In 1957, 270 tons of activated carbon were required in 27 days to reduce the odor to a palatable range. The two principal tools for taste and odor control at Cincinnati have continued to be breakpoint chlorination and activated carbon (Enright, 1959).

At Toledo, it was reported in 1948 that the most serious taste and odor problems were caused by blue-green algae in late August, September, and part of October, with *Anabaena* the chief offender. In the fall of 1946 a heavy concentration of these organisms caused severe taste and odor. In attempts to control the trouble, chlorine dioxide was used but no reduction in taste and odor intensity resulted (Kruger, 1948).

At Columbus, wide variations in the quality of water taken from the Scioto River require close plant supervision. The city arranged to cope with extremely severe taste and odor conditions, which occur in all seasons, but most often during three distinct periods. Each condition produces a characteristic odor and requires a different treatment. For corrective treatment, activated carbon was first used in Columbus in 1936, and has produced a palatable treated water in most instances (Hoover, 1941).

At Tiffin, which has taken water from the Scioto River, it was found possible to control tastes and odors caused by *Synura* and *Dinobryon* with heavy doses of copper sulfate to insure killing, followed by removal of the dead organisms during a 6-hour settling period in the treatment plant. Previously high carbon dosages of 10 lb per million gal had failed to remove the taste and odor (Flentje, 1952).

Odors in water supplies of Ohio apparently were prevalent even before the turn of the century. Analyses of surface waters were made by the State Board of Health during the period from 1898 to 1900. Approximately 1,000 examinations were made of water samples from 22 rivers, 10 smaller streams, and from Lake Erie. Only 137 of these had no odor; 238 had an earthy odor; 220 a musty or moldy odor; 48 a sour odor; 16 a woody odor; and 3 a fishy odor. The predominant odors for some of the river waters at that time were as follows: Blanchard River at Findlay, putrefactive; Mahoning River at Youngstown, slightly musty; Muskingum River at Zanesville, earthy; and Scioto River at Columbus, slightly musty, earthy, and foul (Foulk, 1925).

In 1957 a questionnaire on odor-producing algae was sent to water treatment plants throughout the United States, and 12 Ohio communities replied. The following 16 algae were listed two or more times as responsible for tastes and odors in Ohio water supplies: the diatoms *Asterionella, Diatoma, Synedra,* and *Tabellaria;* the blue-green algae *Anabaena, Aphanizomenon,* and *Coelosphaerium;* the pigmented flagellate algae *Ceratium, Dinobryon, Eudorina, Mallomonas, Pandorina, Peridinium, Synura,* and *Volvox;* and the green alga *Pediastrum.* The three algae most often implicated were *Asterionella, Anabaena,* and *Synedra.* Odors that were indicated in the answers as associated with algae in water included aromatic, cucumber, earthy, fishy, grassy, moldy, and vile (Sigworth, 1958).

CLOGGING OF FILTERS BY ALGAE

Sand filtration drastically reduces the algal content of water, but organisms held by the sand accumulate until the filter eventually becomes clogged. The sand then requires washing before reuse. The shorter the filter run, the more costly the treatment, both in dollars and in wash water.

A number of methods have been used to increase the length of filter runs. At Warren abundant surface growth of algae in treatment basins ahead of filters was eliminated by chlorination, thus reducing the algal load on the filters (Schoepfle, 1928). Later, ammonia-chlorine was used; this increased the average length of filter runs by 16 percent (O'Connor, 1931). At Sandusky prechlorination was used to reduce algal slime on the sand, which then became coated with alum and improved the efficiency of filtration (Cox, 1931).

An increase in capacity of sedimentation basins at Akron permitted settling out of a large quantity of aquatic organisms and thus reduced the demand on the filters (Dixon, 1920). *Melosira* and *Anabaena* were the predominant organisms. The yearly average of all algae was about 6,000 areal standard units and the maximum reached 36,000. Heavy application of the coagulant and "cracking" of sand beds between washings helped to increase filter runs when algae were abundant (Akron Water Treatment Plant, 1924).

At Cleveland it was found that both the number and kinds of algae in Lake Erie water affect the length of filter runs. Diatoms were the most abundant organisms with *Melosira* predominating. Diatoms appeared to be the chief offenders in filter clogging. Coagulation with alum and subsequent sedimentation reduced the number of organisms in water applied to the filters by almost 90 percent (Marshall, 1930; Lawrence, 1931a). In addition to *Melosira*, other diatoms common in the water supply of Cleveland have been *Cyclotella*, *Fragilaria*, *Asterionella*, *Tabellaria*, *Stephanodiscus*, *Navicula*, *Synedra*, and *Rhizosolenia* (Davis, 1954a).

At Cincinnati exceedingly short filter runs were caused by microorganisms, mainly the diatom *Synedra*, present in the river. A three- or fourfold increase of chemicals in the coagulation basins brought no benefit, but very promising results were obtained with double coagulation combined with long reservoir detention periods. Nine-hour filter runs were lengthened to 20 hours by these changes in treatment (Bahlman and Evans, 1928). Short filter runs at Cincinnati have seriously interfered with operating routines; during one summer, 8.9 percent of the wash water was used in 1 week (Bahlman, 1941).

When Bucyrus obtained water from shallow impounding reservoirs, which were ideal for algal growths, shortened filter runs resulted when either *Anabaena* or *Synedra* was abundant. When filter runs decreased the water had an oily appearance and the sand bed was covered with fine cracks (Cameron, 1927).

OTHER TREATMENT PLANT PROBLEMS

At treatment plants algae not only cause tastes and odors and shorten filter runs but they also clog intake screens, form unsightly mats on walls of sedimentation basins, cause difficulties in production of an alum floc, react with chlorine used to destroy pathogens, and change the pH and other physio-chemical characteristics of water (Furman, 1932).

Prior to the time that prechlorination was started at the treatment plant in Warren, algae grew abundantly at the surface of the water in the settling basins. Chlorination of the raw water eliminated the growth entirely and also increased the length of filter runs (Schoepfle, 1928).

Phormidium and *Synedra* were present in the sedimentation tank of the water works at Alliance, and filamentous algae, such as *Spirogyra*, have clogged intake screens (Walton, 1930). The use of activated carbon in the sand filter influent appeared to aid in preventing growths of algae on walls of the filter basin at Toledo (Furman, 1932).

At Cincinnati a spike rush, *Eleocharis*, formed extensive turflike growths on the sloping brick floors of primary and secondary settling reservoirs. The plants were not tightly anchored and were easily cleaned from brick flooring with fire hoses (Cooke et al., 1957).

Adjustment of procedures for coagulation and sedimentation permitted settling out 88.7 percent of the organisms in water at Cleveland. Algae that did not settle out readily were *Melosira* and *Nitzschia*. *Melosira* appeared to be the chief offender in filter clogging (Marshall, 1930). At Lorain daily algal counts were found to be an aid in adjusting alum dosages and in accounting for sudden changes in chlorine demands (Campbell, 1951).

Toledo abandoned use of the Maumee River in 1941 for its new Lake Erie water supply system. Growths of algae in the lake presented problems never encountered in the river. Turbidity of the river had helped to produce a floc that enabled algae to be precipitated without much difficulty. The lake was found to have heavy algal growths, especially in late summer and in winter, but low turbidity. Organic matter from algae made coagulation difficult and also shortened filter runs (Schoonmaker, 1945).

Penetration of algae through sand filters has also been a problem in treatment plants. Sand shrinkage in filters at Akron was enough to permit water and algae to pass between the walls and the sand (Gettrust, 1932).

ORGANISMS IN DISTRIBUTION SYSTEMS

One of the most common interferences with quality of treated water has been the growth of algae and other microscopic organisms in open reservoirs in distribution systems. Algae found in this type of storage reservoir at Cincinnati included *Cladophora*, *Trachelomonas*, *Navicula*, *Cosmarium*, and *Oscillatoria* (Walton, 1915, 1930). At Cleveland ammonia-chlorine was applied to the distribution system to inhibit bacterial aftergrowths and to control algae in distant reservoirs in the sytem (Braidech, 1931; Lawrence, 1931b). Since 1927, Ohio had not approved the construction of additional open reservoirs in distribution systems (Waring, 1933).

Clear water reservoirs have been subject to contamination with chironomid larvae or red worms. In 1935 at Cincinnati, dense patches of the pupae appeared, covering hundreds of square feet of water surface and requiring weekly skimming (Hibbs, 1938). Some of the worms were found in water lines of apartment houses with large intakes. Frequent cleaning of the reservoir floor was practiced to prevent accumulation of a food supply for the blood worms. Complete covering of the reservoir was recommened as the only effective preventative (Bahlman, 1932).

Growth of algae in distribution lines of water systems in Ohio has not been reported. Some algae, however, have been isolated from drinking water. *Rivularia* was isolated at Gambier, and *Lyngbya nigra* was found on a city drinking fountain at Mansfield (Walton, 1930). Diatoms can be readily demonstrated in many treated waters by passing the water through a membrane filter.

Schoepfle (1932) reported that although the raw water supply of Sandusky had no perceptible odor, odors did occur in the distribution system and became progressively worse as water passed through the system. These odors were considered to result from decomposition of organic matter, principally from algae. Norwalk also reported taste and odor problems in circulated water containing algae (Hall, 1940).

Corrosion of water lines by bacteria in the distribution system of a city in Ohio has been reported by Griffin (1942). Chlorination of the water reduced the rate of corrosion. Sulfate-reducing bacteria were responsible for serious corrosion occurring in industrial cooling water lines in Canton. These bacteria were controlled through the use of chlorine (Wilson, 1945). Experiments and practical experience in the southern part of Ohio also indicated that corrosion caused by bacteria could be controlled by chlorination (Griffin, 1943).

Use of treated water from distribution systems in outdoor swimming pools does not insure against algal growths. At Springfield, for example, a swimming pool contained a number of green algae that were growing abundantly. These included *Scenedesmus obliquus*, *Chlorella elliposidea*, and *Ankistrodesmus falcatus* (Walton, 1930).

Chlorine in swimming pool water effectively prevents development of many algae but is often insufficient if a decided growth has begun. Copper sulfate has been used as an algicide at Columbus at a rate of 2 lb per 100,000 gal of pool water, 2 or 3 times per week. One of the best preventatives against attached algal growth has been the frequent use of a wall brush and a vacuum cleaner on walls of swimming pools (Becker, 1940).

TOXIC ALGAE

Reports on toxic algae in Ohio appear to be limited to observations and studies on algae in the Ohio River. An extensive outbreak of gastroenteritis occurred successively at Ironton, Portsmouth, and Cincinnati, as well as in cities across the river in Kentucky. Evidence suggested that the outbreaks resulted from presence of soluble substances formed in pools during extremely long periods of low water (Crohurst, 1938).

Blue-green algae collected in or near Cincinnati were tested for toxicity to mice. Cultures of *Microcystis aeruginosa* contained the toxic principle, but samples of *Aphanizomenon flos-aquae*, *Anabaena spiroides*, and *Oscillatoria* sp. were non-toxic (Wheeler et al., 1942).

Squirrels along the shores of Lake Erie and cattle wading in streams have been observed eating the green alga *Cladophora* with no resultant toxic effects (Tiffany, 1928).

PRESENT STATUS OF ALGAE IN OHIO WATER SUPPLIES

Widespread use of modern methods of water treatment in Ohio has done much to counteract problems caused by algae. The procedures can be expensive and relatively inefficient, however, when problems are not recognized until they are in an acute stage. Detection of the numbers and kinds of algae carried out on a regular schedule throughout the year would provide information that could help control algae before they have become serious problems.

As more and more water is impounded, the algal load increases. Impoundments do, however, afford additional opportunities for control of the watershed, for use of algicides, for sedimentation, for self-purification, and for selective withdrawal of water from whatever depth or location is found to be most free of microorganisms and other materials that affect its use.

Domestic wastes, many industrial wastes, agricultural fertilizers, and soil containing nitrogenous or phosphoreted materials emptied or washed into water supplies stimulate algal growth. Detergents represent one of the newer sources of phosphorus for waters that receive treated or untreated sewage of cities and towns. It is evident that measures that reduce the inflow of algal nutrients into water will help insure water supplies with a minimum of problems due to algae.

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