MAJOR CAUSE OF ALGAE AND WEEDS IN LAKE MENDOTA

M. Starr Nichols
University of Wisconsin–Madison

ABSTRACT

Because of low partial pressure of carbon dioxide in the atmosphere and the resulting low total solubility, atmospheric carbon dioxide is not the major source of carbon for algal and plant growths in hard water lakes. Bicarbonates of calcium and magnesium in the lake water are the major source. This is shown by the lowering of the hydrogen ion concentration of the lake water during extensive growths, causing a rise in pH to 9.5 to 10.0 and above following rapid growth during hot weather. At times the pH rise causes precipitation of marl deposits in calcareous waters.

The perennial problem of the summer growth of algae and weeds in Lake Mendota has caused much speculation and comment. That it is a real problem is attested to by many lake-edge dwellers and users of this lake for recreational purposes.

The cause is rooted in the process of green plant growth. The many contributory causes often are spoken of as pollution by man, and rightfully so in some respects. Green plants grow in lake waters in the same manner as grass grows on our lawns, trees grow in the forest, and the corn crop grows in the farmer's field. These plant growths, both in water and on land, are important to man as the source of the oxygen we breathe and the food we eat.

The sun is the energy source to produce these growths of green plants. Photosynthesis is the name of the process by which the plants capture solar energy. The chlorophylls in algae and aquatic weeds, using solar energy, convert carbon dioxide and lake water into extensive growths of plant tissue and at the same time liberate pure oxygen from the process. The chemical expression of this conversion is given in the following equation: \( \text{CO}_2 + \text{2H}_2\text{O} + \text{chlorophylls} + \text{solar energy} \rightarrow \text{HCOH} + \text{H}_2\text{O} + \text{O}_2 + \text{potential energy} \). The HCOH represents the simplest organic compound of the photosynthetic process. This conversion expressed in pound units
means that 44 pounds of carbon dioxide and 18 pounds of lake water are converted into 30 pounds of organic plant growth represented by HCOH in the equation and 32 pounds of free oxygen gas. This oxygen becomes, therefore, a part of the oxygen in the lake or released to the atmosphere which we breathe. It is this process that maintains the oxygen in the atmosphere at 20.99 per cent by volume. Note that no organic wastes or "pollution" are involved as such in the process.

**SOURCES OF CARBON DIOXIDE**

Some of the carbon dioxide used by the green plants growing in Lake Mendota, comes directly from the air by simple solution. The quantity of carbon dioxide present in the air by volume is 320 parts per million parts of air. Because of its small vapor pressure, 0.243 millimeters of mercury (Henry's Law), only small amounts become dissolved in the lake water. At 20 C and average air pressure, only 0.55 parts per million by weight of carbon dioxide will be dissolved in water. The total amount in the atmosphere is so very great as to constitute by weight about one pound over every square foot of surface of the earth both land and water (1) or about 13,000 tons per square mile.

Carbon dioxide in the air is in equilibrium with the carbon dioxide in all surface water—lakes, rivers, and oceans—on the earth's surface. It is from this large reservoir of carbon dioxide in the atmosphere plus that produced by decay of plant and animal residues that green plants with chlorophylls and solar energy are able to fix, in usable energy packets, the complete energy food for life on this planet, and the oxygen to use it.

A major source of usable carbon dioxide for the algae and weeds growing in Lake Mendota water, is found in its alkalinity. This alkalinity consists of the bicarbonates of calcium and magnesium represented by the following formulae: Ca(HCO₃)₂ and Mg(HCO₃)₂ respectively. The −HCO₃ of these formulae represent H₂O and CO₂ and it is a part of this CO₂ which becomes available for the production of growths of algae and weeds. From the alkalinity of 160 pounds per million pounds of lake water there is available 44 pounds of carbon dioxide for every million pounds of Lake Mendota water. Since there are 478,370,000 cubic meters of water in Lake Mendota (2) which expressed in pounds would be 1,000,000,000,000 pounds = 500,000,000 tons. In this 500,000,000 tons of water there would be 22,000 tons of carbon dioxide available from bicarbonates for photosynthesis of algae and weeds.

Since 44 pounds of carbon dioxide under the action of chlorophyll and solar energy could produce 30 pounds of algae and weeds, we have in Lake Mendota waters sufficient carbon dioxide in form
of bicarbonates to produce more than 15,000 tons of algae and weeds. If only carbon dioxide dissolved from the air was available, less than 200 tons of algae and weeds could be produced. The 15,000 tons divided by the acreage on Lake Mendota, 9,728 acres (15.2 sq. miles (2)), gives a crop of 1.8 tons per acre—equivalent to a small crop of alfalfa on land.

Note. As the bicarbonate (carbon dioxide) is used by the lake plants, there is a continuous addition of carbon dioxide from the air and from carbon dioxide from decay processes. The lowering of the hydrogen ion concentration of lake water to pH 9 or 10 or higher shows the rapid decrease of bicarbonate ion to approach only normal carbonates of calcium and magnesium to be present at times in late summer, when algal growth has been rapid. It is at this stage of growth that marl formation takes place. During times of slow growth or no growth, the hydrogen ion concentration rises and the pH drops to 7.8 or 8.0 and the bicarbonates of calcium and magnesium are at least partially formed again.

SOURCES OF OTHER FOOD FOR ALGAE AND WEEDS

Not mentioned in the above conversion equation for photosynthesis are the 3 pounds of nitrogen, 0.33 of a pound of phosphorus as compounds, and trace quantities of magnesium and other minerals in solution in the Mendota lake water.

Lake Mendota is partially spring-fed with water containing nitrate nitrogen. Streams such as Yahara River, Token Creek, Six-Mile Creek, Pheasant Branch, Merrill Springs Creek and University Creek furnish drainage water containing bicarbonates, both nitrogen and phosphorus compounds and small amounts of other minerals. Rain and snow contribute 8 to 10 pounds of nitrogen in form of compounds each year for every acre of Lake Mendota’s surface, or a total of more than 40 tons of actual nitrogen.

Attempts are being made to curtail the input to the lake of nitrogen and phosphorus from farm operations but the seepage (base flow) flow found by Minshall, Nichols and Witzel (3) would add slightly more than one pound of nitrogen per acre per year from the 89,600 acres (140 square miles) of land draining into Lake Mendota; this represents 44 tons of nitrogen as fertilizer loss from farm practice. In addition to this nitrogen from seepage flow, the amount of phosphorus in farm loss from seepage flow was found to be 0.09 pounds (1 pound of phosphorus is equivalent to 4.6 pounds $P_2O_5$). From 140 square miles of drainage entering Lake Mendota this loss would amount to four tons of phosphorus per year. The above values were calculated from a survey of drainage seepage of Southwestern Wis-
consin farm land in which sampling was made from streams draining 643 square miles during the year 1969. Samples were obtained when there was no flood flow and represented the basic flow or seepage flow. Samples were obtained from 38 streams with flows ranging from two cubic feet per second (over 1.22 million gallons per day) to 31 cubic feet per second (19 million gallons per day). Over 500 separate analyses were made.

The amount of fertilizer nitrogen and phosphorus from surface drainage will be considerably more than from seepage flow. From another research project by the same workers (4) it was found that the average loss per acre per year from surface drainage was 2 pounds of nitrogen and 0.46 pounds of phosphorus. These values, applied to Lake Mendota drainage waters, would add 89 tons of nitrogen and 20 tons of phosphorus. The drainage areas of these experiments were planted to corn and were fertilized with manure only at the time of planting. No cultivation was used. The percentage of the land in Dane County planted to corn was given by the Dane County Agricultural Agent, Mr. Thomas O'Connell, as about 34 percent on the average. Out of 600,000 acres of farm land, 204,000 acres would be planted to corn.

While the values of seepage flow should properly apply to the drainage into Lake Mendota, the runoff of surface flow might be less accurate when calculated from a small experimental plot of 0.1 acre of crop land, as the basis for Lake Mendota fertilizer input. The values over three calendar years were rather uniform, however, varying only from 1.25 to 2.8 pounds per acre per year for nitrogen fertilizer and from 0.3 to 0.55 pounds per acre per year for phosphorus.

**AVERAGE VALUES OF ELEMENTAL COMPOSITION OF THE BIOSPHERE**

The biosphere includes both animal and vegetable living bodies. The average composition of body substance of the biosphere on a dry weight basis is given in the following Table 1, calculated from results given by Edward Deevey Jr. (5).

**TABLE 1. ELEMENTS PRESENT IN BIOSPHERE (DRY WEIGHT)**

<table>
<thead>
<tr>
<th>Element</th>
<th>% wt.</th>
<th>Element</th>
<th>% wt.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydrogen</td>
<td>0.66</td>
<td>Silicon</td>
<td>1.21</td>
</tr>
<tr>
<td>Oxygen</td>
<td>52.30</td>
<td>Magnesium</td>
<td>0.87</td>
</tr>
<tr>
<td>Carbon</td>
<td>40.00</td>
<td>Phosphorus</td>
<td>1.26</td>
</tr>
<tr>
<td>Nitrogen</td>
<td>0.50</td>
<td>Sulfur</td>
<td>0.45</td>
</tr>
<tr>
<td>Calcium</td>
<td>0.88</td>
<td>Aluminum</td>
<td>0.56</td>
</tr>
<tr>
<td>Potassium</td>
<td>0.26</td>
<td>Total</td>
<td>98.55</td>
</tr>
</tbody>
</table>

---
The small percentage not accounted for in this table would include elements not determined such as iron, manganese, boron, zinc, selenium, vanadium, chromium, molybdenum, iodine, fluorine, copper, sodium and cobalt. It is to be noted that 93 percent of the weight of growth consists of carbon, hydrogen and oxygen, the principal constituents of plant carbohydrates such as starch and cellulose-type compounds of algae and weeds.

Nitrogen and sulfur are essential elements in proteins, and phosphorus is an essential element in metabolism of animal and plant tissue. One atom of magnesium is needed for each molecule of chlorophyll. Silicon is needed in the shells of diatoms (algae). Calcium is a principal skeletal element of animals.

 SOURCES OF CALCIUM AND MAGNESIUM BICARBONATES IN LAKE MENDEOTA WATER

The natural recycling in soils of waste organic matter such as animal manures, corn stalks, straw, weeds and other waste organic matter by aerobic and anaerobic decay converts the carbon in these wastes to carbon dioxide. The conversion may be rapid or slow depending on the availability of soil nutrients and microbial activity. The carbon dioxide formed by decay is dissolved by rain water and the carbonic acid formed attacks the calcium and magnesium carbonates present in the soil naturally or added as agricultural lime, and as this carbon dioxide charged water passes deeper, it dissolves the carbonates present in the rock strata to form the soluble bicarbonates of calcium and magnesium. These bicarbonate waters are intercepted for our domestic water supply and the drainage water from soil and springs often contain large amounts of bicarbonates, as are found in Lake Mendota. Madison city water intercepted at depths of from 200 to 1,000 feet by our deep wells contains nearly double the bicarbonates of the water of Lake Mendota.

SUMMARY

1. Carbon dioxide and water have always been the principal quantity of food materials used by algae and weeds and, in fact, all plant growth; they contribute more than 90 percent of the weight of these growths in terms of dry weight of tissue.

2. In the absence of carbon dioxide or a deficiency from sources other than the atmosphere, the low partial pressure of carbon dioxide in the air limits the rate and quantity of solution of this gas in lake water to the extent that large and extended blooms of algae and weed growths would be materially limited. In lakes with a low bicarbonate content, carbon dioxide could be a critical factor for extensive growths of algae and weeds.
3. In the case of Lake Mendota there is an ample supply of carbon dioxide available in the bicarbonates, while the air acts only as a slowly available reservoir.

4. Minerals such as nitrogen, phosphorus, sulfur and traces of many other elements must be in adequate supply in these bicarbonate waters, if growths of algae and weeds occur in sufficient quantity to become a nuisance.

5. There seems to be an adequate supply of phosphorus and nitrogen in Lake Mendota water from drainage into the lake from farm land, through precipitation (rain and snow), and from springs flowing into the lake at the bottom. Nitrogen and phosphorus are also furnished by a rapid recycling of these elements and their compounds. Phosphorus is available for metabolic activity of growing algae. Both phosphorus and nitrogen become readily available through active decomposition of dead algae and weed substance by organisms of decay. These decay processes are active continuously both day and night and summer and winter (but less active in cold temperatures).

6. While the use of fertilizers are necessary for world food production, agriculturists are cognizant of the losses by land drainage. Contour plowing is one of the steps already taken by many farmers to retain fertilizers not immediately used by plants, and to prevent erosion losses. Current practices for manure handling also help to keep drainage levels low.

REFERENCES