— Thermal Stratification —
Destroyer of Healthy Pond and Lake Ecosystems

Defining the problem and exploring solutions

By Mike McGee and Frank Gardner

IT is early spring in a small reservoir which supports an exclusive condominium and golf course development. At and near the surface of the pond, in the layer called the *epilimnion*, microscopic plants and animals (phytoplankton and zooplankton) feed on each other and are fed on in turn by small fish and other animals.

Wind and wave action at the surface causes oxygen from the air to be dissolved and dispersed throughout the surface layer.

The spring sun warms the surface of the water, as it has for the past several days On dry land, the plants, animals, and people rejoice at the sunny weather.

But danger lurks, as the surface layer grows warmer. A temperature difference of as little as three degrees Celsius between top and bottom can result in the formation of thermal layers, or strata.

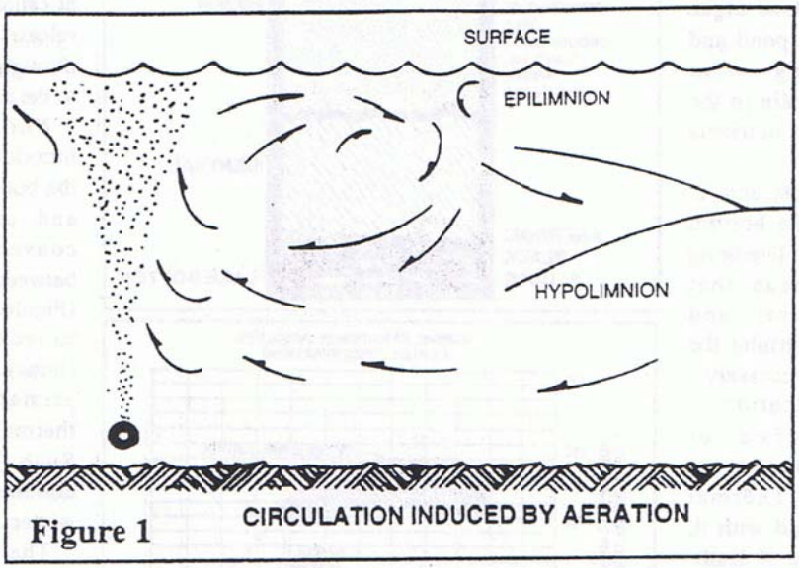

Figure 1

Literally overnight, the movement of water from bottom to top, and top to bottom through natural convection, stops. Organisms in the lower layers consume the oxygen in the water, which is not recharged The fish and other creatures die.

At the surface, conditions are ripe for an algae bloom. If this layering, or stratification, continues uninterrupted for long, blooms of certain types of toxin-producing blue-green algae will be encouraged by the presence of higher concentrations of nutrients in the water.

The phytoplankton and zooplankton die, along with the organisms that feed on them. The normal food chain ceases to exist.

Functionally dead

Foul odors may emanate from the pond. Unsightly scum may form. Pumps may be fouled and/or damaged from both the organic material and increased presence of certain minerals in the water. Waterfowl and other animals using the pond may be poisoned. Groundwater supplies may be tainted. The pond is dead.

This condition, called *thermal stratification*, has long been recognized as a serious problem, even in large, deep lakes and reservoirs. Increased interest in ecological balance and water supply and quality has led to more intensive study of the problem and its potential impact over the past 10 years.

Thermal stratification is possible, even probable, in ponds, lakes, and reservoirs whose waters are clean to begin with. Many golf courses, municipal projects, and developments choose, or are forced to choose, the use of effluent, or treated waste water.

In effluent water, the impact of thermal stratification may be much more rapid and intense. Effluent water contains a significantly higher amount of suspended nutrients (such as phosphates and nitrates) utilized by algae and bacteria to begin with. Significant algae blooms and oxygen depletion can occur in as little as 24 hours even in a pond or lake with good water quality.

In classic thermal stratification, the warm upper layer is called the *epilimnion* (Figure 2). This layer is always highest in dissolved oxygen ($C0_2$) content. Immediately below the epilimnion is the *thermocline*, or *metalimnion*.

This layer marks the most rapid drop in temperature and oxygenation. In summer, many lake swimmers have felt this cold layer on their feet and legs.

Below the thermocline is the *hypolimnion*. The hypolimnion becomes a virtual dead zone, where the only living organisms are usually anaerobic (not needing oxygen), such as bacteria and some forms of blue-green algae.

The same is true of the next lowest layer, the *benthal*. This is composed of septic sludge and decomposing plants and animals. Finally, the lake or pond may develop a layer of black, anaerobic sludge along the bottom, below the benthal layer. In both of these lowest layers, what little $C0_2$ is available is consumed by decaying organic material.

Bottom sludge, usually consumed or processed by bottom feeders such as crayfish, becomes a repository for the chemicals contained in the pond. These may include heavy metals and other toxics, over time.

Algae blooms

Algae blooms are often the most noticeable symptom of thermal stratification. They can produce unsightly pond scum, and, through their digestive processes, give off unpleasant odors.

Surface algae blooms reduce the amount of light penetrating below the surface, hampering the life cycles of phytoplankton and other plants dependent on photosynthesis. Algae, unlike most other plants, takes in more oxygen at night than it gives off during the day as a byproduct of photosynthesis.

In addition, the presence of a heavy algae bloom both reduces wind and wave action and otherwise blocks the process of dissolving oxygen at the surface. Thus, the oxygen content of the water is further reduced.

As the oxygen content of the lower levels is gradually depleted,

the decomposition of the plants and animals killed by stratification produces more nutrients for the algae. The cycle becomes vicious.

Chemical Solutions

In dealing with the problems of thermal stratification, we often act as we do in human medicine: treat the symptoms rather than the causes of the disease. Thus, our first reaction is to kill the algae, usually with copper sulfate. Unfortunately, this approach has several drawbacks. First, a second algae bloom can occur within a week or less, according to authorities. Second, the dead algae sinks to the bottom of the pond and decomposes, consuming what dissolved oxygen may remain in the water, and providing more nutrients for future algae blooms.

Finally, the copper sulfate and its byproducts will sink to the bottom sludge, where they remain. Dredging out the sludge may mean that compliance with federal and provincial regulations governing the disposal of toxic wastes is necessary.

In any case, the application of chemicals, copper sulfate or otherwise, does not deal with the causes of the disease. Thermal stratification still exists, and with it, the continuation of the cycle of death.

Methods of Aeration

Because the principal result of thermal stratification, and its most devastating effect on life, is the drastic reduction of dissolved oxygen in the waters of the pond or lake, the most logical solutions developed over the years are based on the introduction of air (hence oxygen) to the water.

While there is no single solution that is perfect for every single situation, there are three primary methods of aerating water in ponds and lakes in use today.

One approach uses a surface-borne propeller-like device to drive surface water and air deep below the surface. In a sense, this is a stepped-up version of natural wind and wave action in creating dissolved oxygen. If the device is strong enough, the oxygenated water may penetrate to a considerable depth, thus helping the problem of oxygen depletion.

Yet another is a surface-borne fountain device, which draws water from the upper layers of the pond and both oxygenates and disperses the water through its fountain action. This method is probably the most commonly used throughout North America.

It should be recognized, however, that both of these approaches have certain drawbacks Both deal primarily with surface water, and their effectiveness in oxygenating the lower levels of a lake or pond may be limited. Fountains may also increase the loss of water due to evaporation, because the water is dispersed in a spray

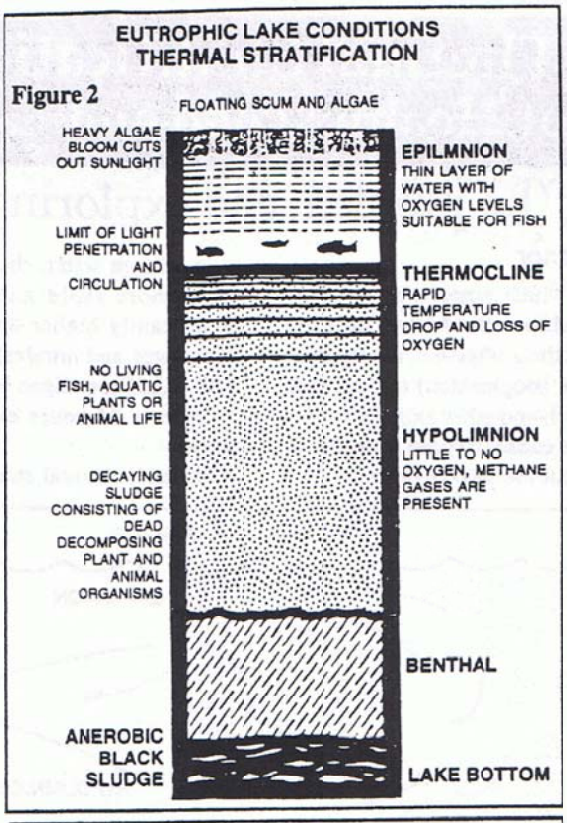

Figure 2

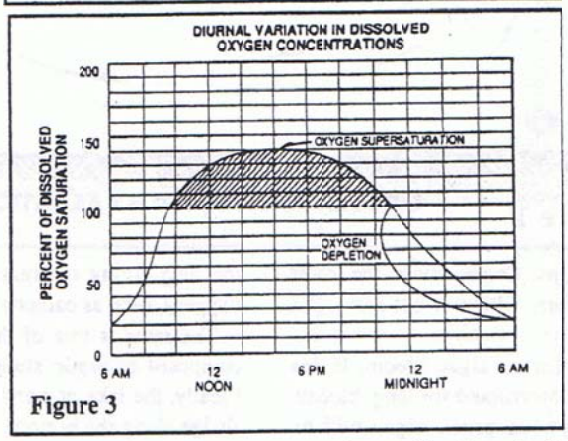

Figure 3

similar to that in sprinkler systems. Both may consume high levels of power while in operation. They may be noisy. Finally, and most importantly, neither directly addresses the conditions that produce thermal stratification.

An approach that many researchers have deemed effective is fine bubble, bottom-laid, linear aeration. This method, sometimes used in conjunction with an ozone generator, consists of a low-power (often as low as 1/2 hp) compressor which forces air through special hose laid on the bottom of the pond or lake. Apertures at calculated intervals along the hose release fine bubbles of air, which rise through the thermal layers of the lake to the surface.

Not only does this method introduce air and oxygen throughout the body of water, but it simulates — and stimulates — the natural convection movement of water between the layers of a pond or lake (Figure 1). It has been demonstrated to reduce the surface temperature (hence evaporation), and thus the primary condition necessary for thermal stratification to take place. Such systems also reduce or eliminate icing of ponds or lakes in winter.

The addition of ozone (0_3) to a fine-bubble, bottom-laid aeration system can provide certain advantages. It increases oxidation of organic and inorganic materials, and kills bacteria on contact. This helps to keep pumps and other water system equipment free from fouling.

Ozone also helps suspended solids drop out of solution in water, by reducing the surface tension of water molecules. It aids in the breakdown of hydrocarbons, chlorinated hydrocarbons, PCBs, and other toxic chemicals into lesser compounds. Ozone dissolves into water more than 12 times as quickly as O_2 thus raising the level of dissolved oxygen more quickly.

There may be drawbacks to these systems, as well. Some versions produce large bubbles, which stir the bottom sediments and disperse them throughout the water. Such systems may also actually trigger algae blooms following initial installation, depending on conditions, although such blooms are usually short-lived. Whatever approach is selected, the greatest necessity is advance testing and measurement of water chemistry, quality and volume. Only then can an effective system be selected and employed. Prevention and/or solution of thermal stratification may be the most important water problem you face.

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