Lake Destratification
Suppressing Algae
Enhancing Taste
Eliminating Odors

Lake Destratification with Venturi Aerators

BACKGROUND: Lakes in temperate climates undergo seasonal variations in temperature through the water column. These seasonal variations, with the accompanying phenomena, are the most influential controlling factors within the lake.

The temperature of a deep lake in the temperate zone is about 4°C during early spring. As air temperatures rise, the upper layers (epilimnion) of the water warm up, and wind action mixes them with the lower layers (hypolimnion). However, by late spring, the differences in thermal resistance cause this mixing action to cease, and the lake approaches thermal stratification in the hot summer season. Equally important as water temperature variations is the physical change in water density with temperature changes. It is these two phenomena that create strata of vastly differing characteristics within a lake.[1]

During thermal stratification the upper layer (epilimnion) of the lake is isolated from the lower layer of the water (hypolimnion) by a temperature gradient (thermocline). The thermocline can have a sharp temperature drop per unit of depth from the upper to lower margin. When the thermal stratification is established, the lake enters the “summer stagnation period,” so named because the hypolimnion becomes stagnated.

The most important phase of the thermal regime from the standpoint of lake eutrophication is the summer stagnation period. The hypolimnion, by virtue of its stagnation, traps decaying plant and animal matter. In a eutrophic lake, the hypolimnion becomes anaerobic (devoid of oxygen) because of its thermal isolation from atmospheric mixing. The absence of oxygen leads to conditions favorable to chemical reduction, and nutrients are released from the bottom sediments to the overlying waters deteriorating water quality.

During summer stagnation and its increasing water temperatures, the bacterial decomposition of the bottom organic sediments exert a high rate of oxygen demand on the overlying waters. When this rate of oxygen demand exceeds the oxygen replenishment by molecular diffusion, anaerobic conditions begin to prevail in the zones adjacent to the hypolimnion. It has been observed that many lakes made from impoundment of streams were found to have anaerobic hypolimnetic zones within the first year of construction.

Over the years many different aeration and mixing technologies have been used with varying degrees of success to eliminate the strata. There have been diffusers on the bottom of the lake, a wide variety of surface aerators, and even various mechanical brush mixers and submersible pumps with submerged mixers. Each of these has had limited success and some have even caused additional problems like increasing turbidity by disturbing the sediment in the hypolimnion, or releasing excess nutrients which cause algae blooms that cause odors and bad taste in drinking water.

SOLUTION: In an attempt to address many or all of the problems associated with other lake destratification technologies the Illinois DEP funded a full-scale research project at a reservoir in southern Illinois. At the recommendation of the research project's consulting engineer a Venturi Aerator solution was selected. All of the limitations of the other treatment technologies were considered and an innovative design was chosen that would specifically address the following issues of concern:

1. Not be located on the lake bottom so as to disturb the decaying organic materials that would increase turbidity, scavenge oxygen and release excess nutrients into the overlying water.
2. Provide sufficient DO to the hypolimnetic zone to eliminate anaerobic conditions.
3. Reduce the thermal variation in the thermocline to be more isothermic.
4. Provide adequate mixing between the hypolimnetic and epilimnetic zones.
5. Eliminate odors from decaying organic materials and enhance the taste of finished drinking water.

In order to accomplish these goals, the Venturi Aerator system was configured with a unique suction manifold to be 3' off the bottom of the lake. This ensured that organic material would not be sucked off the bottom and pumped through the venturi unit and that the bottom of the lake would not be disturbed eliminating the risk of increased turbidity and release of excess nutrients. Additionally, the discharge piping was configured on an innovative manifold design with the discharge point also 3' off the bottom of the lake.

Example of a similar suction piping manifold showing height of the risers off the bottom of the lake (photo courtesy Seven Star Enterprises, LLC, Mankato, MN)

Using the innovative suction manifold allows a large area of the anoxic water in the hypolimnetic zone to be pumped through the venturi aerator unit where it is aerated (oxygenated). This aerated water is then returned back into the hypolimnetic zone where it is discharged vertically through the discharge nozzle on the discharge manifold. This vertical nozzle is also on a unique discharge manifold that allows it to be stabilized and rest on the bottom of the lake but the actual point of discharge for the “aerated water” is 36” off the bottom. This height off the bottom and the vertical direction of the discharge has sufficient kinetic energy to allow “drafting” of adjacent water in the hypolimnetic zone along with the vertical rise of the aerated liquids.

There is sufficient kinetic energy from the discharged liquids to create a very visible continuous rise of water at the surface. The breakthrough of the aerated liquids at the surface creates a large area of influence that has a visible 120’ diameter from this point of breakthrough. By creating large ripples there is an opportunity for increased oxygen transfer from the wind action over the lake at the air/liquid interface. This is important because on days when the wind or a light breeze would blow over the lake’s calm surface there would be only minimal oxygen exchange. However, with increased ripples there is a corresponding increase in oxygen from the atmosphere at the air/liquid interface that is a result of this induced surface turbulence.

Breakthrough at the surface is very visible as is the eddy that is created allowing additional oxygen transfer at the air/liquid interface of the lake. The two air intake hoses for the venturi aerator are located

on a float. The calm area beyond the zone of influence is over 200' feet away. Taken with telephoto lens from shore.

Of the five original goals for an effective destratification system all the requirements were satisfied by the Venturi Aerator system as follows.

1. Both the suction and discharge piping do not disturb the organic sedimentary layer in the hypolimnetic zone, as they are 3 feet off the bottom due to their unique innovative designs.
2. DO levels in the hypolimnetic zone were measured at 1.5 mg/L at the 19' level of depth of the lake where they had typically been at 0.0 to 0.5 mg/L before.
3. The wide variation in the thermocline was reduced to < 3°C, 21°C at 1' submergence and 18.5°C at 21'].
4. There is good mixing between the epilimnetic and hypolimnetic zones as is evidenced by the uniform distribution of DO. DO is 5.5 mg/L at 15' and goes up to 10.0 mg/L at 1' level. Further the Gorman Rupp pump is pumping ~80,000 gph [~1.9 mg/day] from the hypolimnetic zone and discharging it back into the hypolimnetic zone after it has been highly aerated in the venturi unit, then it is discharged vertically drafting additional anoxic water as it rises to the epilimnion. Location of the suction piping and discharge piping are offset from each other so that the same water is not being recirculated but untreated anoxic liquids are being pumped and aerated by the Venturi Aerator unit.
5. Lastly, because the organic sediment on the bottom of the lake is not being disturbed there is no increase in turbidity and no observable decaying organic materials or nutrients are being released to the overlying water where they would scavenge oxygen and enlarge the anaerobic zone. This enhances both the taste of the water and eliminates odors.

The additional benefit of creating a continuous surface turbulence to increase air exchange at the air/liquid interface is another major benefit of the venturi aerator system. The venturi aerator system achieved all the original goals established by the project's consulting design engineer for his client.

Gorman Rupp V6A60B self-priming pump is lifting water 15' from the lake and pumping it through the six-inch Model VA-1200 Venturi Aerator which is submerged in the lake

Footnote:
[1] Raman, Hullinger and Lin, “Aeration/Destratification in Lake Evergreen, McLean County, Illinois” March 1998