A Technique for Eliminating Thermal Stratification in Lakes

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A TECHNIQUE FOR ELIMINATING THERMAL STRATIFICATION IN LAKES[1]

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ABSTRACT. The design, installation, and operation of a compressed air system to eliminate thermal stratification in lakes is described. During a year-long field test on a 19 ha lake, this system effectively eliminated thermal stratification, increased dissolved oxygen, and kept part of the lake ice-free during winter. This system has the capability for use in larger reservoirs and, used for control or elimination of stratification in lakes, is a promising tool for alleviating problems caused by thermal stratification.
(KEY TERMS: destratification; recirculation; aeration; compressed air)

Resource managers and aquatic scientists are well aware of lake management problems caused by thermal stratification. Fish die-offs can be directly associated with thermal gradients, stagnation, and ice cover [Greenbank, 1945]. Fish distribution is often adversely affected by severe thermal stratification [Dendy, 1945; Sprugel, 1951; Mayhew, 1963]. Plankton blooms may limit recreational use [Wirth and Dunst, 1967] or commercial water use [Bernhardt, 1967]. Drinking water quality often deteriorates during anaerobic hypolimnion withdrawal [Derby, 1956; Nickerson, 1961]. Some reservoirs develop very high evaporation rates during summer due to warm surface water [Koberg and Ford, 1965].

Solutions to the above problems often have involved attempts to eliminate or lessen thermal stratification. The literature concerning such efforts is extensive and deals particularly with fish die-offs due to oxygen deficiency. Much less work has been done to apply destratification to solutions of other water management problems caused by thermal stratification. Part of this lack of study is due to the complex apparatus needed to eliminate stratification.

This paper describes the design, installation, and operation of a destratification system and presents field test results in eliminating stratification and maintaining dissolved oxygen.

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STUDY AREA

Parvin Lake, a Colorado Division of Game, Fish, and Parks research station, was selected for experimental destratification. This lake has the advantages of considerable limnological background data, controlled public access, electrical power, and laboratory facilities.

Located at 2500 m elevation, the lake covers 19 ha and has a maximum depth of 10 m

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(Figure 1). Summer surface temperature usually does not exceed 21C. Low dissolved oxygen is found in deep water during summer and winter. Ice cover usually lasts from November to April and reaches 40-60 cm thickness.

DESTRATIFICATION EQUIPMENT

Aerators selected for this study were manufactured by the Polcon Corporation, Montreal, Canada. Each aerator (Helixor®) consisted of a one-piece 46 cm diameter polyethylene tube containing a continuous polyethylene coil, which divides the tube into two separate longitudinal sections (Figure 2). Air is released at the Helixor bottom through several small holes. The coiled design lengthens the air-water interface compared to a simple perforated pipe. Upwelling is created by bottom water drawn up the tube. Two Helixors were used in Parvin Lake.

Compressed air was provided by a Gardner-Denver single stage air cooled compressor mounted in the laboratory (Figure 1). Maximum displacement of this compressor was rated at 2.1 m^3/min and maximum pressure at 4.2 kg/cm^2. The system was run continuously by a single compressor, although a second was connected into the system as an alternate.

Heavy duty (7 kg/cm^2) capacity polyethylene pipe (3.8 cm diameter) connected Helixor and compressor. Concrete blocks, 20 cm cubic (15 kg), were attached at 3 m intervals along the pipe to serve as anchors.

INSTALLATION AND OPERATION

Each Helixor was placed in deep water and were several hundred m from each other (Figure 1). Sections of plastic pipe were joined to form a single piece of appropriate length. Joints were heated by torch and fastened with four stainless steel clamps. One end of the pipe was then attached to the compressor outlet, the other pulled by boat to the desired location, and Helixor attached.

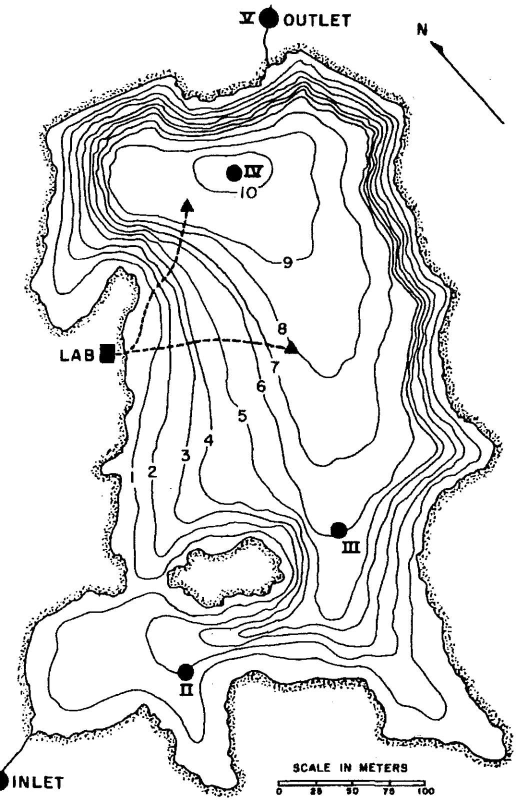

Fig. 1. Parvin Lake showing depth contours, sampling stations (circles), Helixors (triangles), and compressors (square). Dashed line indicates location of plastic pipe.

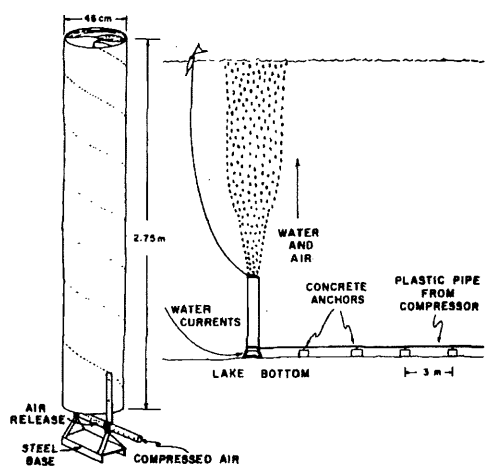

Fig. 2. Diagram of Helixor used to destratify Parvin Lake. Internal coil divides tube into two equal sections.

Boats were worked along the floating pipe from the Helixor toward the laboratory as concrete anchors were attached with clamps. Helixor and nearby pipe were gradually lowered by rope as additional anchors were added. Once in position with properly connected pipe, the system was nearly maintenance free.

Valves and pressure gauges were attached to both Helixor pipes at the laboratory to permit separate control. Periodic adjustments were made with these valves to adjust for depth differences between Helixors. Normal operating equilibrium pressure was reached at 1.0 - 1.4 kg/cm^2.

SAMPLING

The destratification system was in operation continuously from November 1, 1969, to October 31, 1970, except for a few short maintenance stops. A monthly sampling program was carried out during this year and during the previous year to determine effectiveness of the system in altering thermal stratification.

Five permanent sampling stations were selected and marked (Figure 1). Station I was located in the inlet stream about 50 m above the entrance to the lake. Station II was in water 2 m deep and outside the main body of the lake. Station III was in water 6 m deep. Station IV was in the deepest part of the lake (10 m). The outlet stream (station V) was sampled about 50 m below the lake.

Samples and measurements at each station were taken on a single day near the middle of each month.

RESULTS

Thermal gradients are small and persistent in winter, and very pronounced in summer. These gradients were eliminated in winter and nearly eliminated in summer (Figure 3). The thermal stratification cycle in 1968-69 is similar to other years and can be used as the norm for comparison. During the destratified year, the lake was 1-3C cooler during winter, but 2-5C warmer in the deep water in summer.

Dissolved oxygen was clearly influenced by destratification (Figure 4). Winter oxygen loss in deep water failed to develop, while summer loss in deep water was retarded compared to other years.

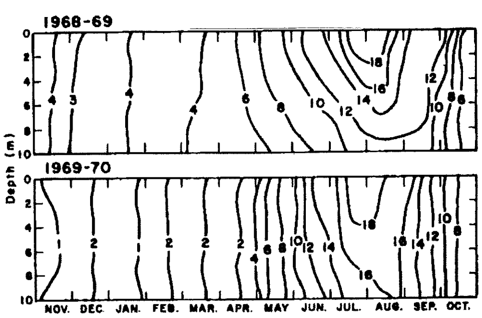

Fig. 3. Temperature (C) in Parvin Lake from November to October during 1968-69 and during attempted destratification, 1969-70 (station IV).

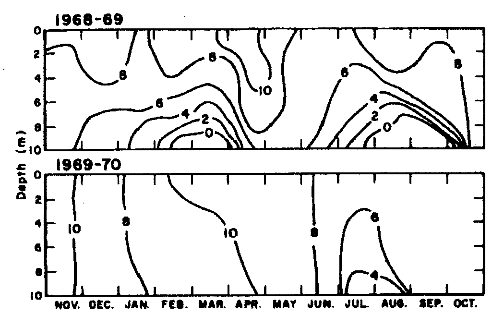

Fig. 4. Dissolved oxygen (mg/l) in Parvin Lake from November to October during 1968-69 and during attempted destratification, 1969-70 (station IV).

The horizontal influence of the destratification system was estimated by comparing temperature and dissolved oxygen between stations (II, III, and IV). Both parameters showed the lake fairly homogeneous with the exception of mid-summer, when slight thermal stratification and oxygen depletion developed.

Ice-free areas of 200-300 m diameter around each Helixor were maintained throughout winter.

DISCUSSION

The destratification system was effective in eliminating thermal stratification and increasing dissolved oxygen levels. The slight thermal stratification and dissolved oxygen depletion that developed during summer can be explained by the relatively high volume of inflow water, high air temperature, and low wind velocity.

As environmental factors, water column stability and water temperature are exceedingly influential. Having the capability to control or at least alter water column stability and temperature is a promising tool for alleviating some problems caused by thermal stratification.

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