FAILURE OF SPRING TURNOVER IN ONONDAGA LAKE, NY, U.S.A.

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Abstract. Onondaga Lake, N.Y., failed to turnover in the spring of 1986 because of the strong chemical stratification under the ice that developed as a result of ionic discharges from an alkali plant. This stratification had a negative impact on the O₂ resources of the lake, as the lower depleted layers of the lake were not replenished with O₂. Anoxia and anaerobiosis in the bottom water expanded following 'ice-out'. Comparison of characteristics observed for the winter through spring interval of 1986 with historic data indicates Onandaga Lake has failed to experience spring turnover in a number of years (approximately 7 of the last 18 yr) because of the ionic discharges from the alkali plant.

1. Introduction

Most deep lakes in north temperate climates are dimictic; i.e., they stratify in summer and under the ice in winter, and mix top to bottom under isodensity conditions during turnover periods in spring and fall. Turnover is an extremely important feature of this regime with regard to a number of water quality characteristics. In particular, the occurrence of turnover is critical in productive lakes with small to medium hypolimnia to replenish O₂ resources following depletions that develop during stratification periods. The irregular occurrence of incomplete vernal mixing (i.e., failure of spring turnover to occur) has been reported for several lakes (Hutchinson, 1941; 1957; Stewart and Stewart, 1983); these are usually sheltered systems that are deep relative to their surface area. The presence of an unusually dense lower layer, usually associated with ionic concentrations and manifested as chemical stratification, can regularly prevent complete turnover during the high kinetic energy input periods of spring and fall (e.g., meromixis (Hutchinson, 1957; Wetzel, 1983)).

Documented here is: (1) the failure of Onondaga Lake, New York, to turnover in the spring of 1986 as a result of chemical stratification of industrial origin; and, (2) the negative impact this had on the O₂ resources of the lower layers of the lake. Further, the characteristics of 1986 are used to identify similar occurrences since 1968.

2. Onondaga Lake

Onondaga Lake is a small (volume of \(1.41 \times 10^6 \text{ m}^3\), mean depth of 12.0 m), unsheltered, hypereutrophic, polluted (Stewart, 1979) lake located in metropolitan Syracuse, NY. Large quantities of ionic waste (mostly Cl⁻, Ca²⁺, and Na⁺) have been discharged by an alkali manufacturer to the lake for more than 100 yr (average load of

approximately $2.5 \times 10^6 \text{ kg d}^{-1}$ over the last 15 yr). The alkali facility discontinued its operation in February 1986. A substantial chemical component of density stratification developed annually, under the ice and during open water stratification periods (Effler et al., 1986a; Onondaga County, 1970–1986). This occurred as a result of the plunging of the dense (Effler and Owens, 1986) ionic waste discharge, particularly during periods of low vertical density differences (Effler et al., 1986a). Other effects of the ionic waste discharge on the stratification regime of the lake included (Effler et al., 1986a): (1) extended periods of stratification, (2) elevated magnitude of stratification, and (3) irregular and abbreviated turnovers.

The $O_2$ resources of the hypolimnion of Onondaga Lake are extremely limited; the entire hypolimnion is anoxic by at least late June of every year, and sulfide accumulates to high concentrations by late summer (Effler et al., 1986b). The ionic waste discharge has been a major cause of the limited $O_2$ resources due to the alterations to the stratification regime (Effler et al., 1986b).

3. Methods

The lake was sampled on 12 occasions in the February through mid-May interval of 1986, at 1 m depth intervals, at a deep water location. Temperature was measured with a Montedoro-Whitney TC5 thermistor (sensitivity of $\pm 0.05 \, ^\circ C$). Chloride was determined by the $\text{Hg(NO}_3\text{)}_2$ titration method (American Public Health Association, 1982). Dissolved oxygen (DO) was determined by the modified Winkler method (American Public Health Association, 1982) on samples collected under the ice. After 'ice-out' DO was measured with a YSI (Model 54) DO meter. The meter was calibrated against modified Winkler determinations. Total dissolved sulfide was determined on samples collected from anoxic depths, and 'fixed' with zinc acetate in the field, by the titrimetric iodine method (American Public Health Association, 1982).

Density stratification was estimated each day, according to the contribution of the chemical and thermal components, from the paired temperature and $\text{Cl}^-$ concentration data, with the equation of state developed specifically for Onondaga Lake (Effler et al., 1986c). The estimates of density are expected to be within 50 ppm, based on realistic ranges of sampling and measurement error (Effler et al., 1986a).

4. Results and Discussion

4.1. Stratification

The failure of the lake to turnover in the spring of 1986 is clearly documented by the stratification information presented in Figure 1(a–c). The chemical stratification that developed under the ice as a result of the plunging of the industrial ionic discharge (e.g., Effler et al., 1986a) failed to break-up following the loss of ice from the lake ('ice-out'; Figure 1a). The chemical stratification was forced deeper in the lake, vertical gradients became stronger, and the concentration of $\text{Cl}^-$ in the lower-most layers decreased