# Internal Phosphorus Loading and Sediment Characteristics: Sweeney Lake, Minnesota

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## *Approach*

Internal loading of phosphorus from sediments was determined for sediment cores collected in the north and south hypolimnetic basins of Sweeney Lake, Minnesota (Table 1). A Wildco KB Sediment Core Sampler (Wildco Wildlife Supply Co.), equipped with an acrylic core liner (6.5-cm ID and 50-cm length), was used to collect intact sediment cores (undisturbed) at each station. The core liners, containing both sediment and overlying water, were sealed using stoppers and stored in a protective box until analysis. Additional lake water was collected for incubation with the collected sediment. Six cores were collected at these stations for analysis of P release from sediment under oxic conditions (3 replicates) and under anoxic conditions (3 replicates) using methods outlined in James and Barko (1991).

In the laboratory, the cores were drained of overlying water and the upper 10 cm of sediment was transferred intact to a smaller acrylic core liner (6.5-cm dia and 20-cm ht) using a core remover tool. Lake water was filtered through a glass fiber filter (Gelman A-E), with 300 mL then siphoned onto the sediment contained in the small acrylic core liner without causing sediment resuspension. Sediment incubation systems consisted of the upper 10-cm of sediment and filtered overlying water contained in acrylic core liners that are sealed with rubber stoppers. The sediment incubation systems were placed in a darkened environmental chamber and incubated at a constant temperature for up to 3 weeks. The incubation temperature was 20 C. The oxidation-reduction environment in each system was controlled by gently bubbling either air (oxic) or nitrogen (anoxic) through an air stone placed just above the sediment surface. Bubbling action insured complete mixing of the water column but did not disrupt the sediment.

Water samples for soluble reactive phosphorus (SRP) were collected from the center of each sediment incubation system using an acid-washed syringe and immediately filtered through a 0.45 µm membrane syringe filter (Nalge). The water volume removed from each system during sampling was replaced by addition of filtered lake water preadjusted to the proper oxidation-reduction condition. These volumes were accurately measured for determination of dilution effects. SRP was measured colorimetrically using the ascorbic acid method (APHA 1998). Sampling was conducted at daily intervals for 5 days, then every other day for an additional 14 days. Rates of SRP release from the sediment (mg $m^{-2}$ $d^{-1}$) were calculated as the linear change in concentration in the overlying water divided by time and the area of the incubation core liner.

Sediment moisture content (%) and density (g/mL) were determined gravinometrically as the change in mass of a known volume of fresh sediment after drying at 105 C. Organic matter content was estimated as loss-on-ignition (LOI) by combusting sediment at 500 C for twenty-four hours. Additional sediment subsamples were dried and ground to pass through a 2 mm mesh for analysis of phosphorus (P) and iron (Fe) using ICP spectrophotometry after microwave digestion (APHA 1998). Fresh sediment was sequentially extracted with 0.1 M ammonium chloride and 0.11 M bicarbonate-dithionate for determination of loosely-bound and iron-bound P (Psenner and Puckso 1988). These functionally-defined fractions have been linked to eH-related (i.e., redox potential) sediment diffusive P flux (Boström et al. 1982; Nürnberg 1988; Jensen and Thamdrup 1993; Petticrew and Arocena 2001; Søndergaard et al. 2003; Pilgrim et al. 2007). Thus, the sum of the concentration of these variables represents redox-sensitive P and can be used to estimate internal P loading from sediment.

## *Results and Interpretation*

Sediments at both stations exhibited a high moisture content and low sediment density, indicative of fine-grained particles (Table 2). Sediment P concentrations were moderate but fell within ranges reported for eutrophic lakes world-wide (Barko and Smart 1986; Ostrofsky 1987; Nürnberg 1988). Sediment iron concentration was greatest in the south basin, resulting in a greater Fe:P ratio than for the north basin. The Fe:P ratio for Sweeney Lake was moderate, suggesting that there was excess iron available for phosphorus binding. Redox-sensitive P concentrations were high relative to literature values (Nürnberg 1988), and constituted 39 and 53% of the sediment P for the north and south basin, respectively. These trends suggested the potential for high rates of P release under anoxic conditions.

Diffusive P flux occurred under oxic conditions for sediment cores collected at both stations (Table 1). These rates were moderate but within ranges reported for eutrophic lakes (Nürnberg 1988), suggesting that sediments might contribute to the P budget of the system even under oxidized conditions. Rates of P release were 5 to 10 times greater under anoxic conditions and very high relative to other systems (Figure 1). These results suggested the potential for soluble P accumulation in the hypolimnion during periods of summer anoxia as a result of diffusive P flux from sediments.

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Table 1. Sediment core station locations. UTM coordinates are NAD83.

| Station | UTM East | UTM North | Depth (ft) |
|---|---|---|---|
| North Basin | 473066 | 4982016 | 24.6 |
| South Basin | 473575 | 4982740 | 24.9 |

Table 2. Means (n=3) and standard errors for sediment characteristics in the North and South Basin of Sweeney Lake.

| Variable | North Basin | | South Basin | |
|---|---|---|---|---|
| | Mean | SE | Mean | SE |
| Moisture content (%) | 78.4 | 0.2 | 81.5 | 0.5 |
| Sediment Density (g/mL) | 0.243 | 0.014 | 0.221 | 0.001 |
| Total Fe (mg/g) | 13.245 | 0.101 | 25.686 | 0.309 |
| Total P (mg/g) | 0.719 | 0.045 | 0.86 | 0.018 |
| Fe:P | 18.6 | 1.2 | 29.9 | 0.9 |
| Loosely-bound P (mg/g) | 0.037 | 0.001 | 0.008 | 0.001 |
| Iron-bound P (mg/g) | 0.241 | 0.005 | 0.446 | 0.017 |
| Redox-sensitive P (mg/g) | 0.278 | 0.006 | 0.453 | 0.018 |
| Redox-sensitive P (%) | 39.0 | 2.7 | 52.7 | 1.0 |
| Oxic P release (mg $m^{-2}$ $d^{-1}$) | 3.3 | 1.1 | 1.6 | 0.1 |
| Anoxic P rlease (mg $m^{-2}$ $d^{-1}$) | 17.3 | 0.1 | 15.6 | 1.0 |

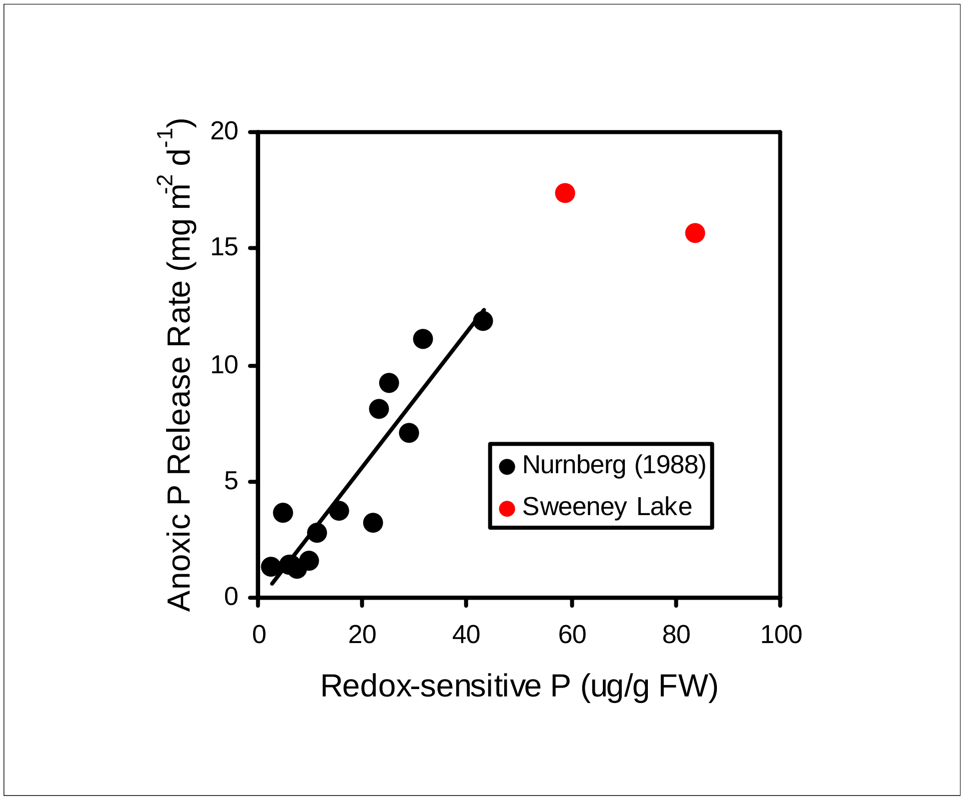


Figure 1. Comparison of Sweeney Lake sediments versus relationship between redox-sensitive P and the anoxic P release rate developed by Nürnberg (1988).