# Internal Phosphorus Loading and Sediment Phosphorus Fractionation Analysis for West Goose Lake, Minnesota

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## OBJECTIVES

The objectives of this investigation were to determine rates of phosphorus (P) release from sediments under laboratory-controlled anoxic (i.e., anaerobic) conditions and to quantify biologically-labile (i.e., subject to recycling) and refractory (i.e., biologically inert and subject o burial) P fractions in sediments collected in West Goose Lake, Minnesota.

## APPROACH

*Laboratory-derived rates of P release from sediment under oxic and anoxic conditions:* Triplicate sediment cores were collected by Wenck Associates from a central station in West Goose Lake in October, 2010, for determination of rates of P release from sediment under anoxic conditions. All 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. Surface water collected from each lake 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 were sealed with rubber stoppers. They were placed in a darkened environmental chamber and incubated at a constant temperature (25 $^{o}$C). The oxidation-reduction environment in the overlying water was controlled by gently bubbling nitrogen (anoxic) or air (oxic) through an air stone placed just above the sediment surface in each system.

Water samples for soluble reactive P were collected from the center of each system using an acid-washed syringe and 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. Soluble reactive P was measured colorimetrically using the ascorbic acid method (APHA 2005).

Rates of P release from the sediment (mg $m^{-2}$ $d^{-1}$) were calculated as the linear change in mass in the overlying water divided by time (days) and the area ($m^2$) of the incubation core liner. Regression analysis was used to estimate rates over the linear portion of the data.

*Sediment chemistry:* The upper 10 cm from an additional core collected from the lake was sectioned for analysis of moisture content (%), sediment density (g/mL), loss on ignition (i.e., organic matter content, %), loosely-bound P, iron-bound P, aluminum-bound P, calcium-bound P, labile and refractory organic P, total P, total iron (Fe), total manganese (Mn), and total calcium (Ca; all expressed at mg/g). A known volume of sediment was dried at 105 $^{o}$C for determination of moisture content and sediment density and ashed at 500 $^{o}$C for determination of loss-on-ignition organic matter content (Håkanson and Jansson 2002). Additional sediment was dried to a constant weight, ground, and digested for analysis of total Fe and Ca using standard methods (Plumb 1980; APHA 2005). Phosphorus fractionation was conducted according to Hieltjes and Lijklema (1980), Psenner and Puckso (1988), and Nürnberg (1988) for the determination of ammonium-chloride-extractable P (loosely-bound P), bicarbonate-dithionite-extractable P (i.e., iron-bound P), sodium hydroxide-extractable P (i.e., aluminum-bound P), and hydrochloric acid-extractable P (i.e., calcium-bound P). A subsample of the sodium hydroxide extract was digested with potassium persulfate to determine nonreactive sodium hydroxide-extractable P (Psenner and Puckso 1988). Labile organic P was calculated as the difference between reactive and nonreactive sodium hydroxide-extractable P. Refractory organic P was estimated as the difference between total P and the sum of the other fractions.

## RESULTS AND INTERPRETATION

Phosphorus mass and concentration did not increase in the overlying water column until day 6 of incubation (Figure 1). However, concentration increases occurred between day 6 and 16 and exceeded 0.15 to 0.3 mg/L toward the end of the incubation. The mean anoxic P release rate was 2.0 (± 0.5 S.E) mg·m$^{-2}$·d$^{-1}$, which was relatively high and comparable to anoxic P release rates measured in other eutrophic systems in the region.

Sediment from West Goose Lake exhibited very high moisture content and low sediment density, indicating fine-grained, flocculent sediment (Table 1). Loss-on-ignition organic matter content was high at 48.4%. The total P concentration of the sediment was also moderate at ~ 1.58 mg·g$^{-1}$ (Table 2) compared to other eutrophic lakes (Nürnberg 1988). The biologically-labile (i.e., subject to recycling; loosely-bound P, iron-bound P, and labile organic P) P concentration accounted for 19% of the total sediment P (Figure 2 and Table 2). Labile organic P was relatively low at 0.083 mg/g and redox-sensitive P (i.e., loosely-bound and iron-bound P) represented ~ 14% of the total P (Table 2). Iron-bound P was the dominant fraction of redox-sensitive P and the concentration fell within ranges reported for other eutrophic systems. The mean rate of P release under anoxic conditions versus the concentration of redox-sensitive P fell within the low range compared to other systems (Figure 3; Nürnburg 1988).

Biologically refractory sediment P (i.e., subject to burial; aluminum-bound P, calcium-bound P, and refractory organic P) was very high and accounted for most of the total sediment P (Figure 2 and Table 2). The refractory organic P fraction represented the greatest percentage of biologically-refractory P. Sediment total Ca was low at only ~ 12 mg/g. The sediment total Fe:P ratio was 6.0 (Table 2). Ratios > 10 have been associated with regulation of P release from sediments under oxic conditions (Jensen et al. 1992). Total Mn concentrations were low (Barko and Smart 1986).

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| Table 1. Textural characteristics for sediments collected in West Goose Lake. | | | | |
|---|---|---|---|---|
| Station | Moisture Content (%) | Density ($g/cm^3$) | Bulk Density ($g/cm^3$) | Loss-on-ignition (%) |
| West Goose | 86.7 | 0.139 | 1.088 | 48.4 |

**Table 2. Mean (1 standard error in parentheses; n=3) rates of phosphorus (P) release, concentrations of biologically labile and refractory P, and metals concentrations for sediments collected in Clear Lake, MN. DW = dry mass, FW = fresh mass, Fe = iron, Mn = manganese, Ca = calcium.**

| Station | | Redox-sensitive and biologically labile P | | | | Refractory P | | |
|---|---|---|---|---|---|---|---|---|
| | Anoxic P release (mg $m^{-2}$ $d^{-1}$) | Loosely-bound P (mg/g DW) | Iron-bound P (mg/g DW) | Iron-bound P (mg/g FW) | Labile organic P (mg/g DW) | Aluminum-bound P (mg/g DW) | Calcium-bound P (mg/g DW) | Refractory organic P (mg/g DW) |
| West Goose | 2.0 (0.5) | 0.075 | 0.141 | 0.019 | 0.083 | 0.148 | 0.176 | 0.947 |

| Station | Total P (mg/g DW) | Redox P (mg/g DW) | Redox P (mg/g WW) | Redox P (%) | Bio-labile P (%) | Refractory P (%) | Total Fe (mg/g DW) | Total Mn (mg/g DW) | Total Ca (mg/g DW) | Fe:P |
|---|---|---|---|---|---|---|---|---|---|---|
| West Goose | 1.576 | 0.216 | 0.013 | 13.7% | 19.0% | 81.0% | 9.43 | 0.24 | 12.30 | 6.0 |

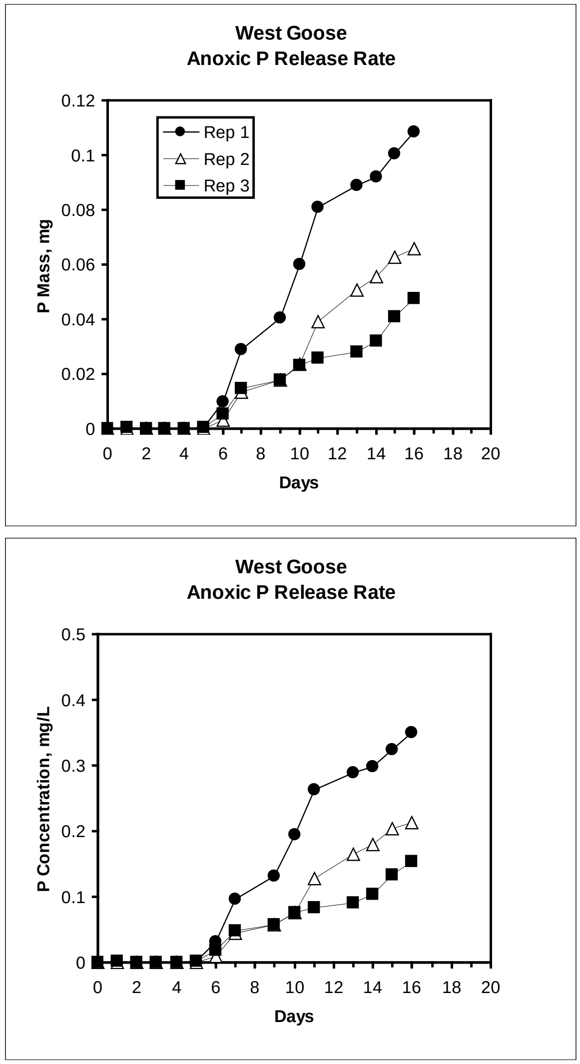


Figure 1. Changes in soluble reactive phosphorus mass (upper panel) and concentration (lower panel) in the overlying water column under anoxic conditions versus time for sediment cores collected in West Goose Lake.

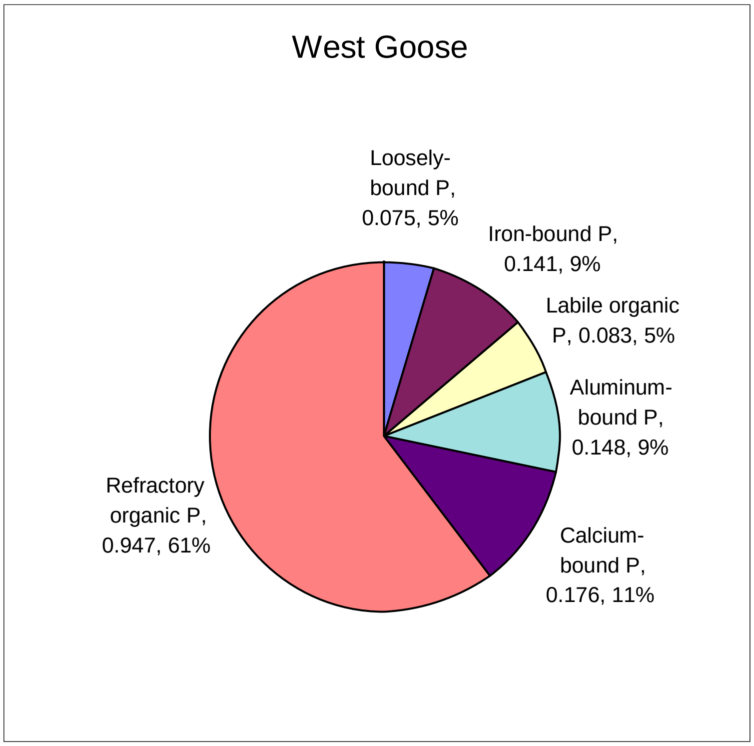


Figure 2. Total phosphorus (P) composition for sediment collected in West Goose Lake. Loosely-bound, iron-bound, and labile organic P are biologically reactive (i.e., subject to recycling) while aluminum-bound, calcium-bound, and refractory organic P are more inert to transformation (i.e., subject to burial). Values next to each label represent concentration (mg/g) and percent total P, respectively.

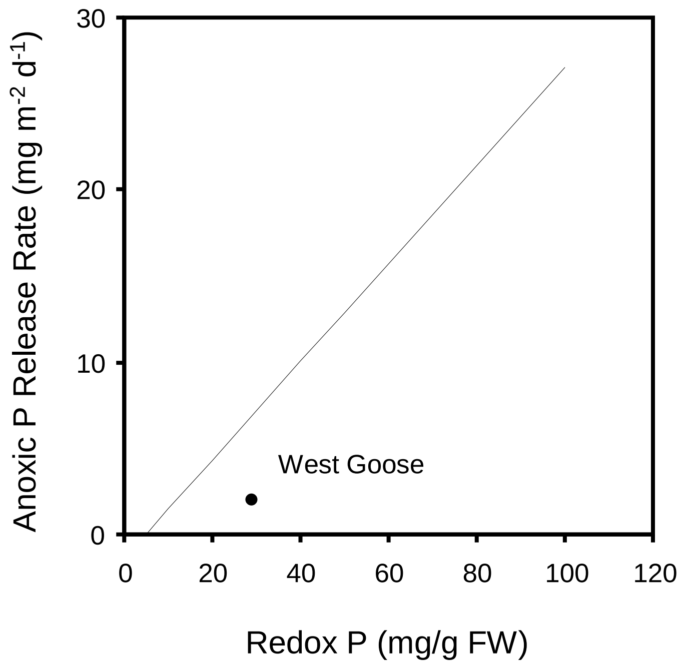


Figure 3. Redox-sensitive (i.e., loosely-bound plus iron-bound P) phosphorus (P) versus the anoxic P release rate (regression line) from Nürnburg (1988). The solid circle represents results for West Goose Lake sediment. WW = Fresh or wet weight mass.