Large constructed wetlands, known as stormwater treatment areas (STAs), have been deployed to remove phosphorus (P) in drainage waters before discharge into the Everglades in South Florida, USA. Their P removal performance depends on internal P cycling under typically hydrated, but with occasionally desiccated, conditions. We examined the spatial and temporal P removal capacity under different hydrologic conditions along a STA flow path. While inflow soils are P enriched, the outflow region of the wetland contained P-unsaturated soils with minimal net recycling of bound soil P to the water column as plant-available P. The outflow-region soils were characterized by low porewater soluble reactive P (SRP) (<40 μg L⁻¹) and high total sulfide (TS) (2–9 mg L⁻¹) concentrations, and total ammoniacal nitrogen (TAN) and SRP flux rates that averaged 1.51 and 0.002 mg m⁻² d⁻¹, respectively. Pronounced increases in porewater and surface-water concentrations of SRP, dissolved organic P (DOP), and TAN were observed immediately after rehydration of the cell after an extended drought. Elevated total P concentrations persisted at the outfall of the cell for several months thereafter, resulting in an annual outflow total P concentration nearly threefold higher than the long-term mean. Relative to processes that can occur during extended periods of inundation, such as sulfate-enhanced P release from organic matter mineralization or iron sulfide formation, aerobic oxidation of organic matter during prolonged dryout periods is a more significant biogeochemical process in compromising soil P retention in STAs.

Six large (913–6695 ha) treatment wetlands, called stormwater treatment areas (STAs), have been constructed to remove phosphorus (P) from Lake Okeechobee discharges and agricultural drainage waters (ADW) before being released into the Everglades (Chimney and Goforth, 2001). Phosphorus precipitation with calcium (Ca²⁺) to form metastable Ca-P compounds, or P adsorption onto calcite (CaCO₃), have been invoked as one of the major P removal mechanisms in the nutrient-enriched canals and zones of the STAs and Water Conservation Areas (WCAs) in South Florida (Diaz et al., 1994; Dierberg et al., 2002). Soil P fractions support the concept of a central role for Ca-P removal mechanisms because nonlabile P usually comprises a significant percentage of the soil total P (TP) content (Reddy et al., 1998).

While high dissolved Ca²⁺ concentrations are considered to aid in the removal of P from the water column, elevated sulfate (SO₄²⁻) concentrations have been shown to mobilize P stored in soils and sediments as either bound P within organic matter or associated with iron (Fe)-P minerals (Lamers et al., 2002; Smolders et al., 2006). Based on these studies, it may be anticipated that the high SO₄²⁻ loadings to STAs and WCAs would a priori result in mobilization of soil P to the water column. However, anaerobic laboratory incubations of SO₄²⁻-amended soil slurries from one STA and two WCAs did not show a P mobilization effect (Dierberg et al., 2011).

Draining and subsequent reflooding of organic soils also influences wetland nutrient retention, usually resulting in an increase in nitrogen (N) and P fluxes into the water column (Newman and Pietro, 2001; White et al., 2004, 2006). These processes can affect outflow concentrations of a treatment wetland because soil-to-water column fluxes can influence water column constituent concentrations (Reddy and DeLaune, 2008).

The primary goal of this investigation is to compare the P mobilization potential of two prominent biogeochemical processes that occur within STAs: aerobic oxidation of organic matter during episodic dryout periods vs. SO₄²⁻ and Fe reduction during hydrated conditions that occur over longer