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Phosphorus retention in lab and field-scale subsurface-flow wetlands treating plant nursery runoff

Sarah A. White[a,*], Milton D. Taylor[b,1], Joseph P. Albano[c], Ted Whitwell[a], Stephen J. Klaine[b]

[a] *Department of Environmental Horticulture, Clemson University, E-143 Poole Agricultural Center, Clemson, SC 29634-0319, United States*
[b] *Clemson Institute of Environmental Toxicology, 509 Westinghouse Rd., PO Box 709, Pendleton, SC 29670, United States*
[c] *U.S. Department of Agriculture, Agricultural Research Service, U.S. Horticulture Research Laboratory, 2001 South Rock Road, Ft. Pierce, FL 34945, United States*

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ABSTRACT

Constructed wetland systems built to handle nutrient contaminants are often efficient at removing nitrogen, but ineffective at reducing phosphorus (P) loads. Incorporating a clay-based substrate can enhance P removal in subsurface-flow constructed wetland systems. We evaluated the potential of crushed brick, a recycled building product, and two particle sizes of a palygorskite–bentonite industrial mineral aggregate (calcined clay) to sorb P from simulated nutrient-rich plant nursery effluent. The three substrates were screened for P sorbing behavior using sorption, desorption, and equilibration experiments. We selected one substrate to evaluate in an 8-month field trial to compare field sorption capacity with laboratory sorption capacity. In the laboratory, coarse calcined clay average sorption capacity was 497 $mg\,kg^{-1}$ and it sorbed the highest percentage of P supplied (76%), except at exposure concentrations >100 $mg\,L^{-1}$ where the increased surface area of fine calcined clay augmented its P sorption capacity. Subsurface-flow mesocosms were filled with coarse calcined clay and exposed to a four and seven day hydraulic retention time treatment. Phosphorus export was reduced by 60 to 74% for both treatments until substrate P-binding sites began to saturate during month seven. During the eight month experiment, the four and seven day treatments fixed $1273 \pm 22\,mg\,kg^{-1}$ P and $937 \pm 16\,mg\,kg^{-1}$ P, respectively. Sequential extractions of the P saturated clay indicated that P could desorb slowly over time from various pools within the calcined clay; thus, if the calcined clay were recycled as a soil amendment, most P released would be slowly available for plant uptake and use. This study demonstrated the viability of using coarse calcined clay as a root bed substrate in subsurface-flow treatment wetlands remediating phosphorus from plant nursery runoff.

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1. Introduction

Excess nutrients in surface waters are an acute concern both locally and globally because of the potential for deleterious impacts to humans and the environment (Nosengo, 2003; Owen et al., 2007). Scrutiny by local, state, and federal environmental agencies as a result of increasing concern about water quality preservation and improvement is leading to the formation of new water quality criteria for previously unregulated agricultural non-point source contributors (Headley et al., 2001; Taylor et al., 2006). For example, the United States Environmental Protection Agency proposed numerical limits on nutrients in Florida surface waters in 2009. These proposed criteria include limits for total nitrogen, total phosphorus, and chlorophyll A, and would be applied to three new classifications of Florida water bodies (U.S. EPA, 2010). Even slight increases in nutrient concentrations entering water bodies can increase the rate of eutrophication. Effects of increased eutrophication can range from slightly increased primary productivity, from both phytoplankton and aquatic macrophytes, to expanding dead zones in estuaries, bays, and seas that are a result of very low dissolved oxygen levels from the excess nutrient loading brought to estuarine areas by rivers (Joyce, 2000; Taylor et al., 2006).

Nutrient runoff from nursery and greenhouse production areas are of concern because these industries are the largest per unit area users of fertilizers and pesticides (Joyce, 2000) and they are currently classified as non-point source contributors in most states. Nursery effluent concentrations can range from 0.1 to 135 $mg\,L^{-1}$ NO_3-nitrogen (N) and 0.01 to 20 $mg\,L^{-1}$ PO_4-phosphorus (P, Alexander, 1993; Headley et al., 2001; Huett et al., 2005; Joyce,

* Corresponding author. Tel.: +1 8646567433; fax: +1 8646564960.
E-mail address: swhite4@clemson.edu (S.A. White).
[1] Present address: Civilian Response Corps-Active, U.S. Department of Agriculture, South Building, 1400 Independence Ave. SW, Washington, DC 20250, United States.

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