Phosphorus Reduction In Runoff Using a Steel Slag Trench Filter System

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Introduction

Excessive concentrations of phosphorus (P) can cause deterioration of surface waters by eutrophication. Previous research has demonstrated that P sorptive industrial byproducts loaded into structures placed into hydrologically active drainage have the ability to sequester dissolved P from targeted areas. The objective of this study was to evaluate the performance of a steel slag trench filter system developed for P reduction in runoff under field conditions.

Materials and methods

The experimental design for the study was a 2 x 2 factorial with factors of filter material (6 mm steel slag or 13 mm washed river gravel) and triple superphosphate fertilizer (P applied or no P applied) replicated within irrigation zones covered with 'Astro' bermudagrass [Cynodon dactylon L. (Pers.)] mowed at 38 mm. Each irrigation block consisted of four plots that were 6.1m wide with a uniform 5% slope that measured 24.4 m long. Four plastic containers (volume = 178 L each) were placed in a 5.2 m $\times$ 1.2 m trench dug in the middle of each plot perpendicular to the slope to accommodate filter materials. Runoff caused by either natural rainfall or irrigation was collected for comparison of P concentrations before and after filtration. Flow rates were determined using ultrasonic depth detection devices as runoff flowed through calibrated Parshall flumes. To test the impact of P fertilizer on P runoff, 49 kg ha-1 super triplephosphate (0-46-0) was applied as granules on half the plots on September 22, 2011, March 29, 2012 and August 14, 2012. The other half plots were not fertilized with P.

Photo 1. Metal plates and shingles conduct raw runoff into filter tubs

Photo 2. Automatic Sampler and Ultrasonic Sensor

Table 1. Phosphorus (P) concentrations in runoff from fertilized and unfertilized treatments and proportion of P removed from the gravel and slag treatments.

Event	Precipitation	P concentration		P removed	
		Fertilized	Unfertilized	Slag	Gravel
		mg L^{-1}		(%)	
10-Mar-12	natural	2.24*	1.55	42.83*	1.50
19-Mar-12	natural	1.91*	1.58	35.65*	0.60
23-Mar-12	simulated	1.01	0.94	30.40*	0.10
11-Apr-12	natural	13.11*	0.92	25.38*	-0.12
14-Apr-12	natural	8.63*	1.19	22.80*	0.35
23-Apr-12	simulated	4.60*	0.56	24.57*	-0.20
29-Apr-12	natural	6.68*	0.69	25.42*	1.13
15-May-12	simulated	3.29*	0.80	23.63*	0.65
28-May-12	natural	2.53*	0.76	31.33*	1.63
15-Jun-12	natural	2.00*	1.02	29.05*	-0.03
26-Jun-12	simulated	1.43*	1.05	18.53*	0.10
9-Aug-12	simulated	1.59*	1.16	22.40*	0.48
25-Aug-12	natural	7.36*	1.76	17.87*	1.13
30-Sep-12	simulated	2.11*	1.18	17.32*	-1.95

*Fertilized treatment is significantly ($P < 0.05$) different than the unfertilized treatment or the slag treatment is significantly ($P < 0.05$) different than the gravel control.

Results

From March through September 2012 a total of 14 runoff events were studied. Approximately 269 g of dissolved P entered into the steel slag filter systems and 19% of all dissolved P was removed. The three largest runoff events accounted for 81% of the dissolved P that entered the steel slag filter systems and 74% of the dissolved P removed by the systems. Statistical comparisons (ANOVA; $P < 0.05$) of each runoff event indicated that the P concentrations in runoff filtered through steel slag were significantly lower than the P concentrations in runoff filtered through gravel in all 14 events. Runoff filtered by steel slag contained from 17% to 43% less dissolved P than runoff filtered through the inert gravel control. The P concentrations in runoff from the fertilized treatment were always significantly greater ($P < 0.05$) than the unfertilized treatment except for the 23 Mar event that occurred 214 days after the initial fertilizer was applied on 22 Sep 2011 (Table 1). With one exception, 29 Apr 2012, the difference between P concentrations from the fertilized and unfertilized treatments declined with each runoff event from 12.19 mg L^{-1} in the initial event after fertilizer was applied on March 29, 2012 to 0.43 mg L^{-1}, 133 d and nine runoff events after fertilization. Phosphorus concentrations declined with each subsequent runoff event following fertilization except for 29 Apr (Fig. 1). The proportion of cumulative P removed by steel slag filters was calculated as a percent of the cumulative P that entered the filter [(cumulative P in runoff that entered the slag filters – cumulative P that exited the slag filters) / cumulative P that entered x 100]. The P removed on a cumulative basis decreased from 44% to 19% during the first five runoff events, and the slag consistently removed around 19% during the remaining runoff events (Fig. 2).

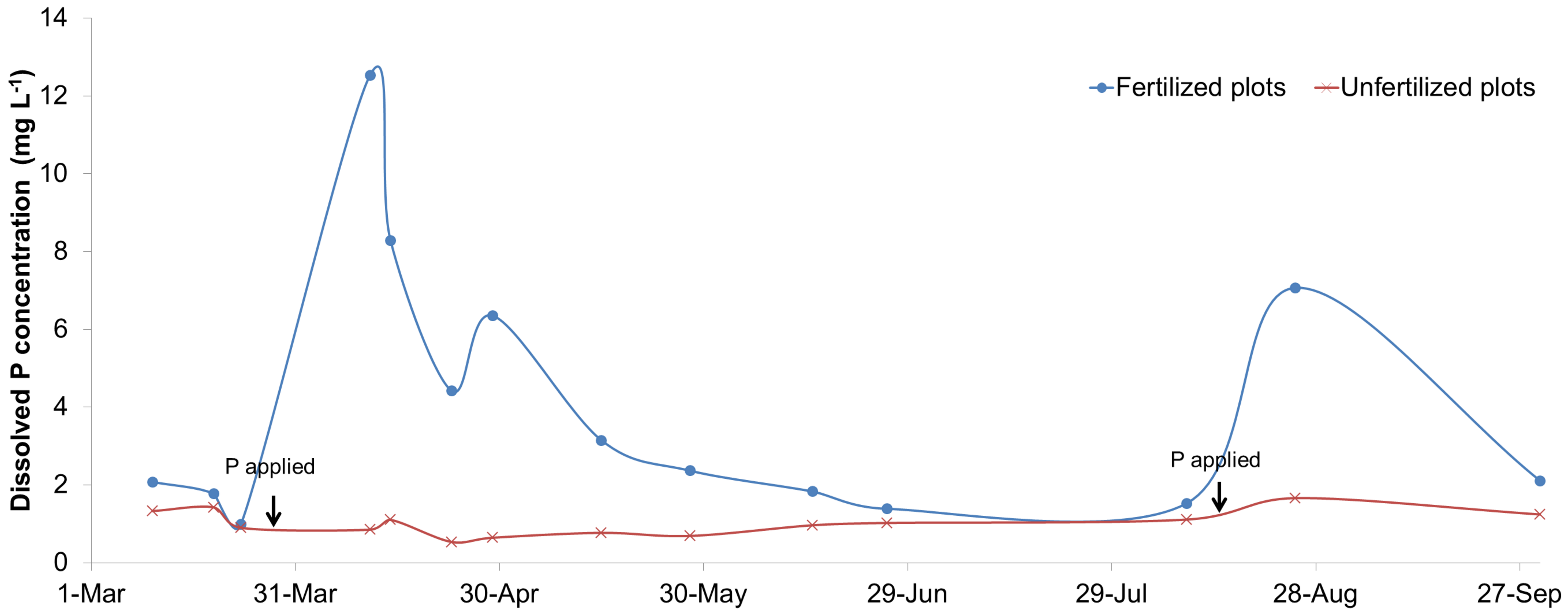

Figure1. Dynamics of dissolved phosphorus (P) concentration in natural and simulated rainfall runoff between fertilized and unfertilized plots on dates from 11 Mar through 30 Sep 2012.

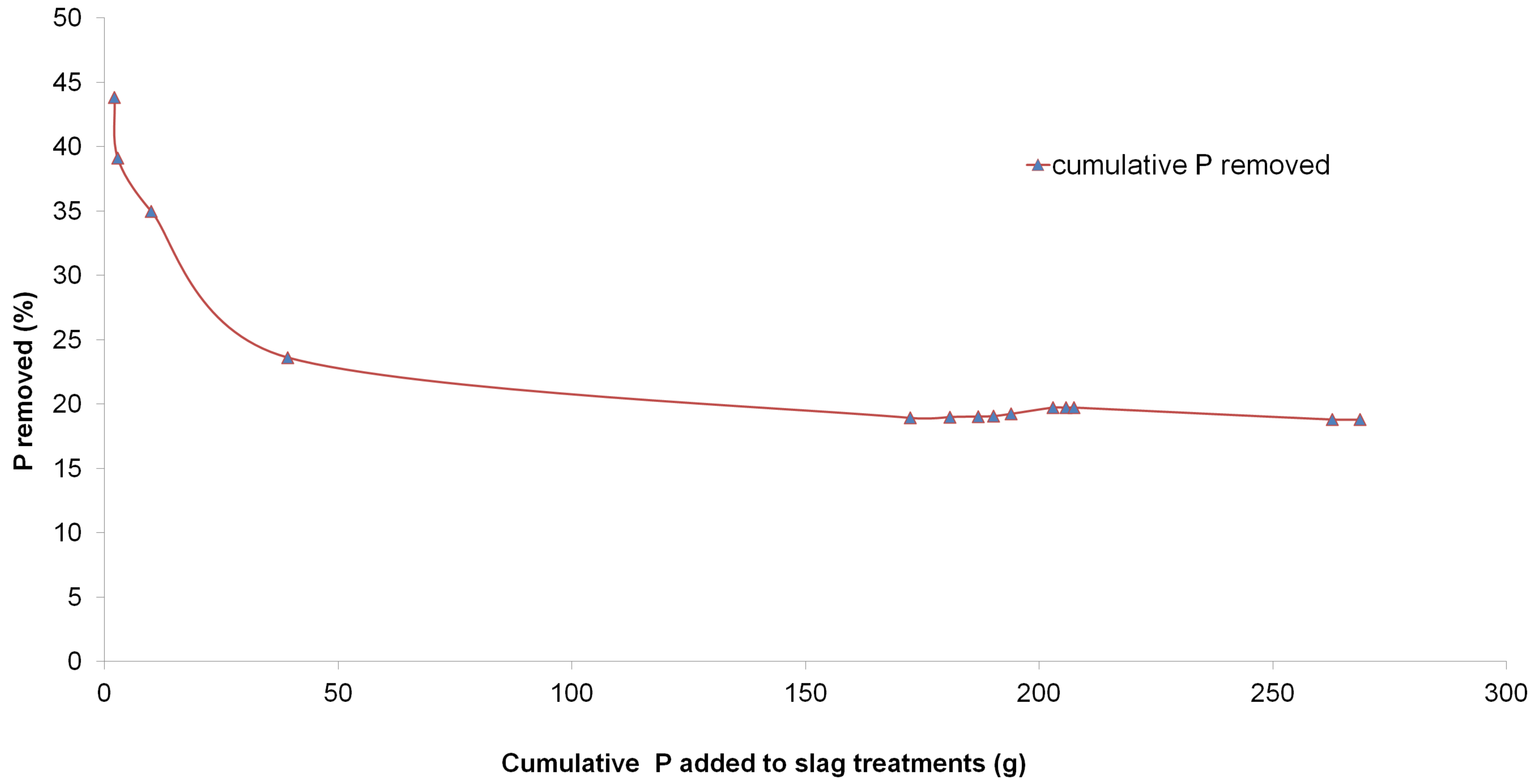

Figure 2. Proportion of cumulative phosphorus (P) [(cumulative P in runoff that entered the slag filters – cumulative P that exited the slag filters) / cumulative P that entered x 100] removed from 14 natural and simulated rainfall runoff events from 11 Mar through 30 Sep 2012.