Development of Phosphorus Filtering Systems for Environmental Protection

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Objectives:

1. *To test steel slag material for its dissolved P–reduction potential in both active and passive filtering systems.*
2. *To determine approximately how much runoff P from a mature bermudagrass site is due to natural causes (rainfall, soil, plant material) and how much can be attributed to synthetic fertilizer.*
3. *To identify standard expectations for use in evaluating phosphorous sorbing materials (PSMs).*

Eutrophication, a serious reduction of oxygen in surface waters, is most often a result of nutrient loading and has become a major environmental concern. Although nitrogen (N) is often the limiting nutrient for eutrophication of marine waters, phosphorus (P) is the most likely nutrient to cause eutrophication of fresh water. The objectives of this study were to determine the effectiveness of steel slag, an industrial byproduct of steel manufacture, for its ability to remove dissolved P in runoff, to determine the amount of P in runoff from bermudagrass that is a result of natural causes and the amount that is a result of fertilizer, and to help identify standards and expectations for comparison of P sorbing materials used as P filters in the field.

Laboratory studies and field studies of individual P sorbing materials, mostly industrial byproducts, were conducted to characterize each product´s potential for use as a runoff P filter. Sieved steel slag was determined to have good P sorption capacity and high hydraulic conductivity, and performed well in a ditch filter designed to capture P from a combination residential and golf course watershed. Therefore, a plot study was designed to further test the product. The study was constructed at the OSU Turfgrass Runoff Research Site. The site consists of 24 identical 20 x 35 ft. bermudagrass plots on a 5% slope. Half of the plots drain down the 35 ft. slope into filter trenches and half drain into runoff collection troughs. Each filter plot has a runoff collection plot directly below it. The filter plots are used to determine the concentration of P that enters the filter and the concentration that exits the filter. The runoff collection plots are used to estimate how much runoff occurred from the filter plot above it during a natural rainfall or irrigation event.

The first runoff collection occurred on 11 March 2012 from a natural rainfall event. Additional runoff events

Figure 1. The OSU Turfgrass Research Runoff Site following construction of the filter system in the middle of each plot.

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Figure 2. Relationship between P concentrations in runoff and days after fertilizer treatment (DAT).

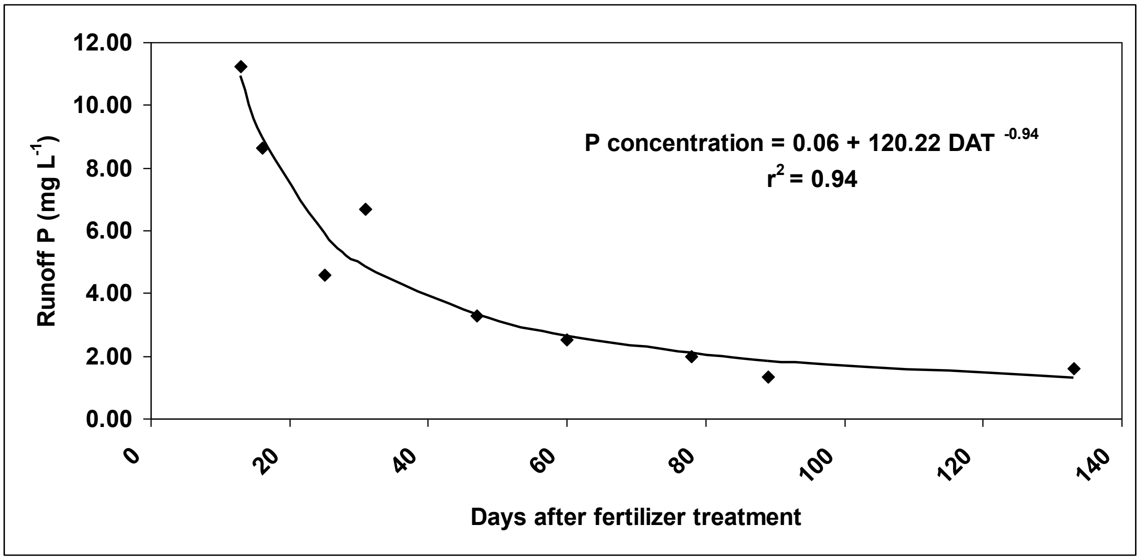

Table 1. Comparison of P concentrations in runoff from fertilized and unfertilized plots and proportion of P removed by gravel and slag filters.

Event	Precipitation	P concentration[a]			P removed[b]		
		Fertilized		Unfertilized	Gravel		Slag
		------- mg L^{-1} ------			------ % ------		
11-Mar-12	natural	2.24	*	1.55	1.98	*	42.85
19-Mar-12	natural	1.91	*	1.58	0.75	*	35.64
23-Mar-12	simulated	1.01	*	0.94	0.71	*	30.40
11-Apr-12c	natural	11.24	*	0.92	0.38	*	25.38
14-Apr-12	natural	8.63	*	1.19	0.96	*	17.96
23-Apr-12	simulated	4.60	*	0.56	0.63	*	24.55
29-Apr-12	natural	6.68	*	0.69	1.15	*	25.39
15-May-12	simulated	3.29	*	0.80	1.56	*	23.64
28-May-12	natural	2.53	*	0.76	1.63	*	31.34
15-Jun-12	natural	2.00	*	1.02	0.37	*	29.07
26-Jun-12	simulated	1.34	*	1.10	0.79	*	18.54
9-Aug-12	simulated	1.59	*	1.16	0.85	*	22.42
25-Aug-12c	natural	7.36	*	1.76	1.18	*	17.87
30-Sep-12	simulated	2.11	*	1.18	1.78	*	17.30

* indicates a significant difference ($P < 0.05$) between fertilized and unfertilized or slag and gravel treatments

[a] P concentration in raw runoff before filtration

[b] P removed = (P concentration in raw runoff − P concentration in filtered runoff)/P concentration in raw runoff x 100

[c] Fertilizer was applied on 22 Sep 2011, 29 Mar 2012, and 14 Aug 2012

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occurred from natural rainfall events on 19 March, 11 April, 14 April, 29 April, 28 May, 15 June, and 25 August 2012. Additional runoff events from simulated rainfall applied by the in–ground sprinkler irrigation system at the site (rate = 1.2 in/h) were added on 23 March, 23 April, 15 May, 26 June, 9 August, and 30 September for a total of 14 events. The first P fertilizer applied in 2012 was on 29 March and the first runoff event following fertilization occurred 13 days later on 11 April. On that date, the mean P concentration in raw runoff before filtration from the fertilized treatment was 11.24 mg L^{-1} and from the unfertilized treatment was 0.92 mg L^{-1} (Table 1). The plots were not fertilized again until 14 August. On 9 August, 133 days after initial fertilization, a simulated rainfall event caused runoff from the fertilized treatment with a P concentration of 1.59 mg L^{-1} compared with a concentration in the unfertilized treatment of 1.16 mg L^{-1}. In each runoff event following initial fertilization the runoff concentration in the fertilized treatment declined and the difference between the fertilized treatment and the unfertilized treatment became progressively less. Regression analysis indicated a strong ($r^2 = 0.93$; $n = 9$) relationship between P concentrations in runoff from the fertilized treatment and time in days after fertilizer was applied (Figure 2).

The P concentrations in runoff from the fertilized treatment varied considerably depending on the number of days and probably the number of runoff events that occurred after fertilization but the P concentrations in the unfertilized treatments demonstrated little variation among events (Table 1). The steel slag removed significantly more P than the gravel control ($P < 0.05$) and proved to be an efficient filter of P runoff (Table 1).

Summary Points

- P concentrations in runoff from fertilized plots over a 133 day period declined as the number of days after fertilizer application increased.
- P concentrations in runoff from plots that were not fertilized were significantly lower than from fertilized plots and were fairly consistent among runoff events
- Steel slag proved to be an effective filter of P runoff compared with a gravel control and removed an average of 26% of the P in the runoff from 14

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