East River Watershed

Phosphorus, Ammonia, and Suspended Solids Concentrations in Runoff Water Above and Below a Barnyard Grass Filter Strip in Brown County, Wisconsin

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ABSTRACT

Runoff from barnyards and other animal confinement areas is a source of pollution to streams, lakes and groundwater. Grass filter strips are designed to filter runoff water from barnyards in order to reduce the amount of pollutants entering surface and/or groundwater. This study addressed the ability of a filter strip to reduce phosphorus, ammonia, and suspended solids concentrations in barnyard runoff. Runoff could only be collected below the filter strip during high intensity events because runoff often does not reach the bottom of the filter strip during low intensity events. The filter strip was somewhat effective in reducing pollutant concentrations. Suspended solids concentration was reduced significantly. Ammonia and dissolved phosphorus concentrations were reduced, but not significantly. Total phosphorus concentration increased.

INTRODUCTION

Barnyards and other livestock containment areas were identified as significant sources of pollution to surface waters in the East River Watershed located in northeast Wisconsin (WDNR 1993). Barnyard runoff management systems are combinations of management practices which work together to prevent or reduce water pollution caused by barnyard runoff (Lindquist 1987). Grass filter strips are installed below barnyards as the last step in a barnyard runoff management system.

Bubenzer, Converse and Patoch (1988) defined grass filter strips as follows:

> "A grass filter strip is an area of permanent vegetation developed to receive barnyard runoff and to reduce the pollution potential of the runoff water through the filtration of solids in the surface runoff and through the infiltration of water and nutrients into the soil where they can be used by plants, transformed within the soil system, or adsorbed onto the soil particles."

The effectiveness of a grass filter strip in reducing pollutant concentrations is dependent upon many factors such as season, rainfall amount and duration, concentration or dilution of the pollutants, and the condition and management of the filter strip. Additionally, little field data is available documenting the amount of pollution that can be reduced by passing barnyard runoff through a filter strip.

OBJECTIVE

The purpose of this study was to determine the effectiveness of a grass filter strip, as designed by the USDA Natural Resources Conservation Service in northeastern Wisconsin, in reducing suspended solids and nutrients in barnyard runoff.

Specifically, this study compared concentrations of total phosphorus, dissolved phosphorus, ammonia, and suspended solids in barnyard runoff above a filter strip with concentrations of the pollutants in the runoff after flowing through the filter strip.

METHODS

Barnyard and Filter Strip

The grass filter strip selected for this study was located on a dairy farm within the East River watershed in Brown County, Wisconsin. The soils at the site were mapped as Manawa silty clay loam and Kewaunee silt loam (Link 1974). Kewaunee silt loam has moderately slow permeability (0.63-2.0 in./hr.). Manawa silty clay loam has slow permeability (0.20-0.63 in.\hr.)

The farming operation and filter strip selected for this study was representative of the average dairy farm in Brown County. It had the following characteristics:

- filter strip was four years old
- herd consisted of 70 dairy cows
- single owner/operator farm
- all components of the runoff management system were intact and reasonably well managed
- the system consisted of a concrete settling pad and gravel spreader
- filter strip had a 2% slope
- filter strip was 101 X 20 feet in size

All components of the filter strip were described in a barnyard runoff management publication by Lindquist (1987). Barnyard runoff was held on a concrete settling pad for a short time to settle out solids. Runoff leaving the settling pad flowed through wooden pickets into a concrete outlet box. A hole in the outlet box allowed the runoff to exit the barnyard and enter a level gravel spreader. Runoff from the gravel spreader seeped evenly onto the grass filter strip (Fig. 1).

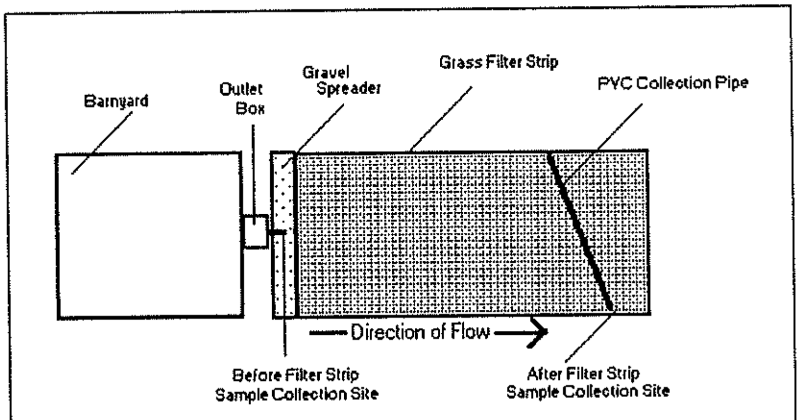

Fig. 1. Layout of filter strip components and locations of the runoff sample collection sites.

Sampling Design

Grab samples of barnyard runoff were collected at two locations during each runoff event to compare differences in pollution concentrations. The first sample was collected from runoff leaving the outlet box (Fig. 1). The second sample was collected below the filter strip from the end of a PVC pipe (Fig. 1). The PVC pipe was installed diagonally across the bottom of the filter strip to collect runoff leaving the filter strip. A 3 cm slit was cut length wise out of the PVC pipe and the pipe was placed with the slit flush with the ground (Fig. 2). Runoff moving through the filter strip entered the PVC pipe and was collected at the bottom end of the pipe (Fig. 1).

Runoff samples were collected whenever possible during rain and snowmelt events. Samples were preserved following Wisconsin Department of Natural Resources (1988) "Sample Handling and Preservation Handbook" protocols, and sent to the Wisconsin State Laboratory of Hygiene for analysis. Samples were analyzed for total and dissolved phosphorus, ammonia, and suspended solids.

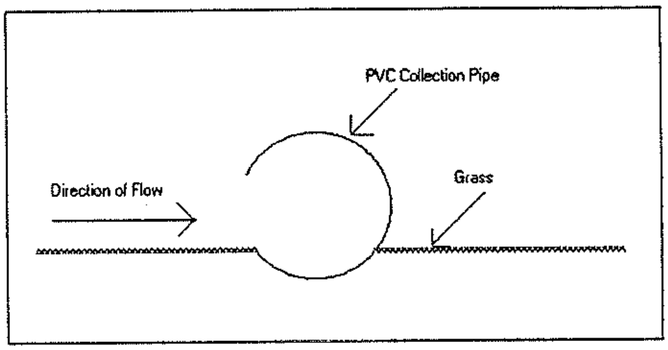

Fig. 2. Crossection and placement of PVC collection pipe.

Rainfall was measured with a rain gauge installed on a fence post near the filter strip or rainfall data was obtained from the National Weather Service.

Data were analyzed using the paired two sample t-test for means to determine if there were significant reductions in pollutant concentrations in runoff that flowed through the filter strip. Also, correlation between the intensity of rainfall events and reduction in nutrient concentrations were determined using the Spearman's rank nonparametric test for correlation.

RESULTS AND DISCUSSION

Sixteen runoff events were observed between July 1994 and May 1995. During nine of the least intense rainfall events, runoff did not reach the bottom of the filter strip. While it was impossible to compare above and below filter strip pollutant concentrations, it was obvious that the filter strip was 100% effective in reducing pollutant runoff from the barnyard during these nine events. This suggests that intensity and duration of rainfall contributes to the effectiveness of the filter strip. Edwards, Owens and White (1983) state that the amount of relatively dry manure remaining on a feedlot will also impact the amount of runoff leaving a barnyard during low intensity rainfalls. Bubenzer, Converse and Patoch (1988) summarized that filter strip effectiveness is reduced during intense rain events when filter strips are flushed of previously deposited pollutants and infiltration of runoff is reduced. For the remaining seven of the sixteen events in which runoff did reach the bottom of the filter strip, concentrations of pollutant runoff were compared (Fig. 3).

Figure 3. Suspended solids, ammonia, total phosphorus, and dissolved phosphorus concentrations in runoff collected above and below a grass filter strip.

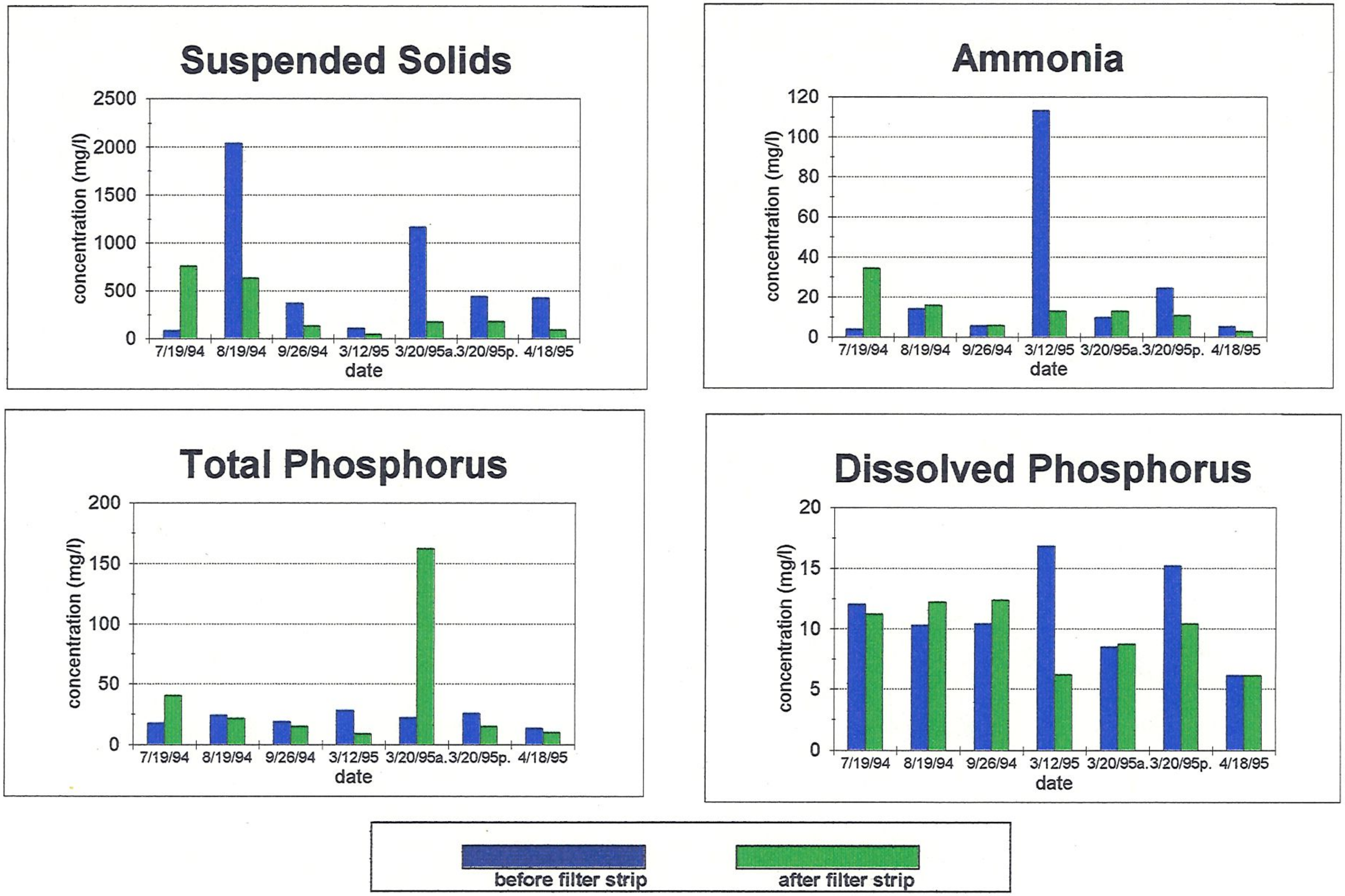

Table 1. Filter strip sample results, mean concentrations, and rainfall intensities in surface water runoff before and after flowing through a grass filter strip. Means are of seven samples.

Parameter	Filter Strip Sample Location	7/19/94	8/19/94	9/26/94	3/12/95	3/20/95[1] (a.m.)	3/20/95[1] (p.m.)	4/18/95	Mean Concentration	% Reduction
Ammonia (mg/l)	Before	3.83	14.1	5.55	113	9.68	24.4	5.09	25.09	46% reduction
	After	34.3	15.8	5.70	13.0	12.8	10.7	2.81	13.59	
Total Phosphorus (mg/l)	Before	17.3	23.8	18.82	28.1	22.0	25.5	13.5	21.29	45% increase
	After	40.3	21.48	14.98	8.83	162	14.9	10.2	38.96	
Dissolved Phosphorus (mg/l)	Before	12.0	10.3	10.4	16.8	8.5	15.2	6.10	11.33	15% reduction
	After	11.2	12.2	12.4	6.2	8.7	10.4	6.10	9.6	
Suspended Solids (mg/l)[2]	Before	80	2040	364	108	1160	440	424	659 [3]	56% reduction
	After	760	630	132	44	172	180	92	287 [3]	
Rain Intensity (inches/hour)	—	0.1	1.0	0.14	—[4]	0.15	0.13	0.16	—	—

[1] two samples collected during the same rain event
[2] positive correlation between rainfall intensity and the reduction of suspended solids
[3] significant reduction of the mean concentration after the filter strip at 10% confidence level
[4] snowmelt runoff

A significant reduction ($P < .10$) in mean suspended solids concentration was found (Table 1). During six out of seven events, concentrations below the filter strip were lower than concentrations above the filter strip. A positive correlation between rain intensity and reduction in suspended solids concentration was found ($r_s = 0.942$). This correlation indicates that harder rainfalls dilute concentrations of suspended solids in runoff. Part of the concentration reduction may be due to dilution by rainfall.

Mean ammonia concentrations were reduced but not significantly by the filter strip (Table 1). Ammonia concentrations increased below the filter strip in four out of seven events. The reduction in mean ammonia concentrations were strongly influenced by the extremely high (113 mg\l) above filter strip concentration collected on March 12 during the end of a snowmelt event. The reduction in ammonia concentration remained not significant when the March 12 data point was removed from the data set. A very poor correlation was found between rainfall intensity and reduction in ammonia concentration ($r_s = 0.143$).

Mean dissolved phosphorus concentrations were slightly, but not significantly reduced (Table 1). Dissolved phosphorus concentrations were lower below the filter strip during three out of seven events, higher three out seven events and unchanged in one of the seven events. A poor negative correlation was found between rain intensity and reduction in dissolved phosphorus concentration ($r_s = -0.542$).

The mean total phosphorus concentration increased below the filter strip; however, five out of seven samples showed a decrease in total phosphorus below the filter strip (Table 1). The increase in mean total phosphorus below the filter strip was in large part due to the extremely high concentration found below the filter strip on March 20 a.m., early in a rain event. The extremely high value suggests that nutrients already trapped in the filter strip are washed through the strip early in an event. Samples taken at the end of that same rain event (March 20 p.m.) showed a decrease in total phosphorus below the filter strip. A poor negative correlation was found between rainfall intensity and the reduction in total phosphorus concentration ($r_s = -0.428$).

CONCLUSION AND RECOMMENDATIONS

The barnyard and filter strip monitored in this study were maintained in fairly good condition. At no time during the monitoring was there an excessive accumulation of manure on the barnyard. The filter strip was mowed regularly. However, grass clippings were not removed from the filter strip after mowing. Removal of clippings is desirable to keep nutrients already taken up by the plants from leeching back into runoff leaving the filter strip.

The filter strip monitored in this study was somewhat effective in reducing pollutant concentrations in barnyard runoff. Suspended solids, dissolved phosphorus, and ammonia concentrations were reduced by 56%, 15%, and 46% respectively (Table 1). Suspended solids were the only significantly reduced pollutant monitored in this study.

To better understand the dynamics of this barnyard management system, the following monitoring design improvements would be needed: (I) analyze mean concentrations of composite samples by collecting runoff at regular intervals throughout runoff events; (II) record flows to analyze pollutant loadings and account for pollutant concentration dilution by rainfall on the filter strip; and (III) obtain a much larger sample size (monitor more events) to account for the large variability in pollutant concentrations. The large variability in pollutant concentrations may have prevented significant reductions from showing up in this study.

During high intensity event, filter strips do not assimilate all of the runoff water and pollutants from a barnyard management system; therefore, we recommend that barnyard management systems be designed so runoff water from filter strips does not discharge directly to surface water. Filter strip runoff water should be directed to a hay field or grass waterway which will further reduce the concentration and loading of nutrients into surface water.

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