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## **Effectiveness of Silage Leachate Treatment with Vegetative Filter Areas**

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**Abstract.** The silage leachate from bunk silos can have a pH of 4, a five-day biochemical oxygen demand (BOD<sub>5</sub>) of 12,000 to 90,000 mg/l, and an ammonia level of 700 mg/l. It can have high nutrient values of nitrogen, phosphorus, and potassium. The high concentrations of BOD<sub>5</sub>, acid, and ammonia in the leachate cause the septic odors, vegetation burn, and fish kills that create real environmental problems. Because the amount of leachate is partially dependent on rainfall it is very difficult to design a system that contains all of the effluent. A system to collect the concentrated low flow, while allowing the rainwater-mixed higher volume (but lower concentration flow) to be treated in a grass filter area has been installed on a number of farms. This type of system is often proposed for the over 600 farms in NY that are complying with the general CAFO permit. This paper documents the actual pollution reduction from the low flow collection- high flow bypass to vegetated filter system.

Three bunk silos were sampled during runoff events during the summer and fall of 2003. BOD<sub>5</sub>, ammonium, total phosphorous, ortho-phosphorous and total solids were measured. The sites include two farms where actual rainfall events were sampled and one site where irrigation equipment was used to measure the reduction in varying degrees of saturation of the filter area. The pollutographs show a substantial decrease as the initial soil moisture of the filter area decreases. The reduction in flows, and pollutants are shown. The pollutant reductions range from 1% to 100% depending on the existing moisture conditions, the amount of precipitation, and the contaminant.

**Keywords.** Silage Leachate, Vegetative Filter Areas, and Runoff Treatment

## Introduction

Silage leachate is an environmental problem on many farms. The expansion of dairy farms and the change from forage storage in tower silos to storage in bunk silos has accelerated. The silage effluent or juice can have a pH of 4, a five-day biochemical oxygen demand (BOD<sub>5</sub>) of 12,000 to 90,000 mg/l, and an ammonia level of 700 mg/l. (Graves 1993) It can have high nutrient values of nitrogen, phosphorus, and potassium also. The high concentrations of BOD<sub>5</sub>, acid, and ammonia in the juice cause septic odors, vegetation burn, and fish kills that create real environmental problems. Losses from bunk silos can be as high as 15% of the nutrients in the harvested feed. This could be as much as 3.2 kg (7 lbs) of phosphorous per cow per year. Concentrated Animal Feeding Operation (CAFO) planners need to address the effluent from these bunk silos.

Since the amount of leachate is partially dependent on rainfall, it is very difficult to design a system that contains all of the effluent. The amount of juice from silage peaks quickly after harvest and then decreases to a trickle over time. (Savoie 1993) The amount and concentration of the effluent can be variable from season to season and from day to day depending on crop maturity and harvest conditions. Collecting all the runoff from an uncovered bunk silo can be done, but the amount of storage needed is usually unreasonable, since all the rainfall that runs off also needs to be stored. When it rains, the precipitation creates runoff and dilutes the silage juice.

A practical way to address this issue is to collect the concentrated low flows while having a mechanism so that the higher volume but lower concentration of pollutants mixed with rain water is treated in a grass filter area, grassed waterway, or wetland. Allowing rainfall driven higher flows to bypass the leachate collection storage system makes the storage of the higher concentrated effluent more palatable to the producer, while still protecting the environment. (Wright 1993)

This alternative system has been adopted and a conservation practice standard was developed by the NY NRCS. (NRCS Standard) This system has been installed on some farms and is often proposed for the over 600 farms in NY that need to complying with the general CAFO permit. This system is also being used on Animal Feeding Operations (AFOs) as they voluntarily comply with developed Comprehensive Nutrient Management Plans (CNMPs)

The actual pollution reduction from these systems has not been documented. It is important to quantify the treatment potential of these systems in order to have confidence in their application on farms. This information is needed by agencies and consultants who advise farmers to improve decision-making regarding effective pollution reduction practices.

## Objectives

The goal of this project was to evaluate silage leachate low flow collection, high flow vegetative treatment systems to determine their effectiveness in reducing the pollution potential from bunk silos.

## Methods

Three bunk silos with low flow collections and high flow bypass to a vegetative filter and with cooperating farmers were selected for evaluation and sampling. The sites consist of two farms in central New York where actual rainfall events were sampled. Samples were obtained at

various intervals during runoff events at each of these two sites. The third site was in northern New York at Miner Institute. At this site, irrigation equipment was used to obtain three measured runoff events under varying antecedent moisture conditions.

Sampling locations at each site consist of: the effluent entering the low flow storage, the high flow entering the vegetated filter area, and flows leaving the filter area. The concentration and mass of BOD<sub>5</sub>, nitrogen and phosphorus was determined at each stage of the system. Samples and volume measurements were taken during rainfall and/or irrigation events. Samples were obtained as natural storm events progressed at the two CNY sites. The coordination and timing to be at the site when runoff began necessitated several trips to each site. For each site, samples were taken more frequently at the beginning of the event to define the rise in the hydrograph as well as to quantify the concentrations of BOD<sub>5</sub>, N, and P in the first flush of runoff.

The project and sampling effort on the two CNY sites occurred from August to September in 2003 to document the fall corn silage harvest and subsequent leaching. In Northern NY at Miner institute, 3 irrigated events were performed in June, July and September in 2003. The first two dates were selected to document fresh haylage storage, while the September event was when corn silage was being harvested.

The irrigation was accomplished by utilizing surface water collected in a recent lagoon excavation, pumping it over 500 feet with a 5 horsepower portable pump, through 5.1 cm (2 inch) lay flat hose to two sprinklers in the bunk area and 4 sprinklers in the vegetated filter area. Only a portion, 762 m<sup>2</sup> (8,200 ft<sup>2</sup>), of the bunk area was wetted near the low flow collection. The high flow was sent to a 7.6 m (25 foot) length of perforated pipe and distributed across a portion, 274 m<sup>2</sup> (2,950 ft<sup>2</sup>), of the vegetative filter area. This portion of the filter area was segregated from the rest of the filter area with 30 cm (12 inch) aluminum flashing trenched into the sod to contain the flow. The ratio of wetted bunk area to filter area was about 2.8 to 1. This is similar the 3 to 1 ratio called for in the NRCS standard. A weir was constructed at the lower end of the filter area so that flow measurements could be recorded and samples could be collected.

Samples were analyzed at the Cornell CALS Nutrient Analysis Laboratories for pH, TKN, NO<sub>x</sub>, NH<sub>4</sub>, TP and Ortho - P. Samples were also sent to a commercial lab for these analysis, as well as BOD<sub>5</sub>. A Quality Control and Quality Assurance (QC/ QA) Plan was put into place to document the sampling, handling, and testing of the samples.

### ***Farm TB Description***

Farm TB is located in the Finger Lakes region of New York State. It is a 1,200-cow dairy that has a stock of 700 heifers and 180 calves on the 2,200-acre farm. All the forage is stored on site in a 10,656 m<sup>2</sup> (114,700 ft<sup>2</sup>) bunker covered with plastic. Some piles of spoiled silage are on the pad and portions of the concrete bunk floor are cracked. The schematic shown in figure 1 is representative of the silage leachate low flow collection/high flow treatment in a vegetative filter area system.

### ***Farm FE Description***

FE Dairy, a family farm founded in 1863, has 550 cows with replacement heifers and is located in the Finger Lakes region of central NY. Their bunk silo is very well managed with corn and haylage harvested at optimum moisture contents, clean bunk faces with little spoilage, and very little silage on the empty bunk area.

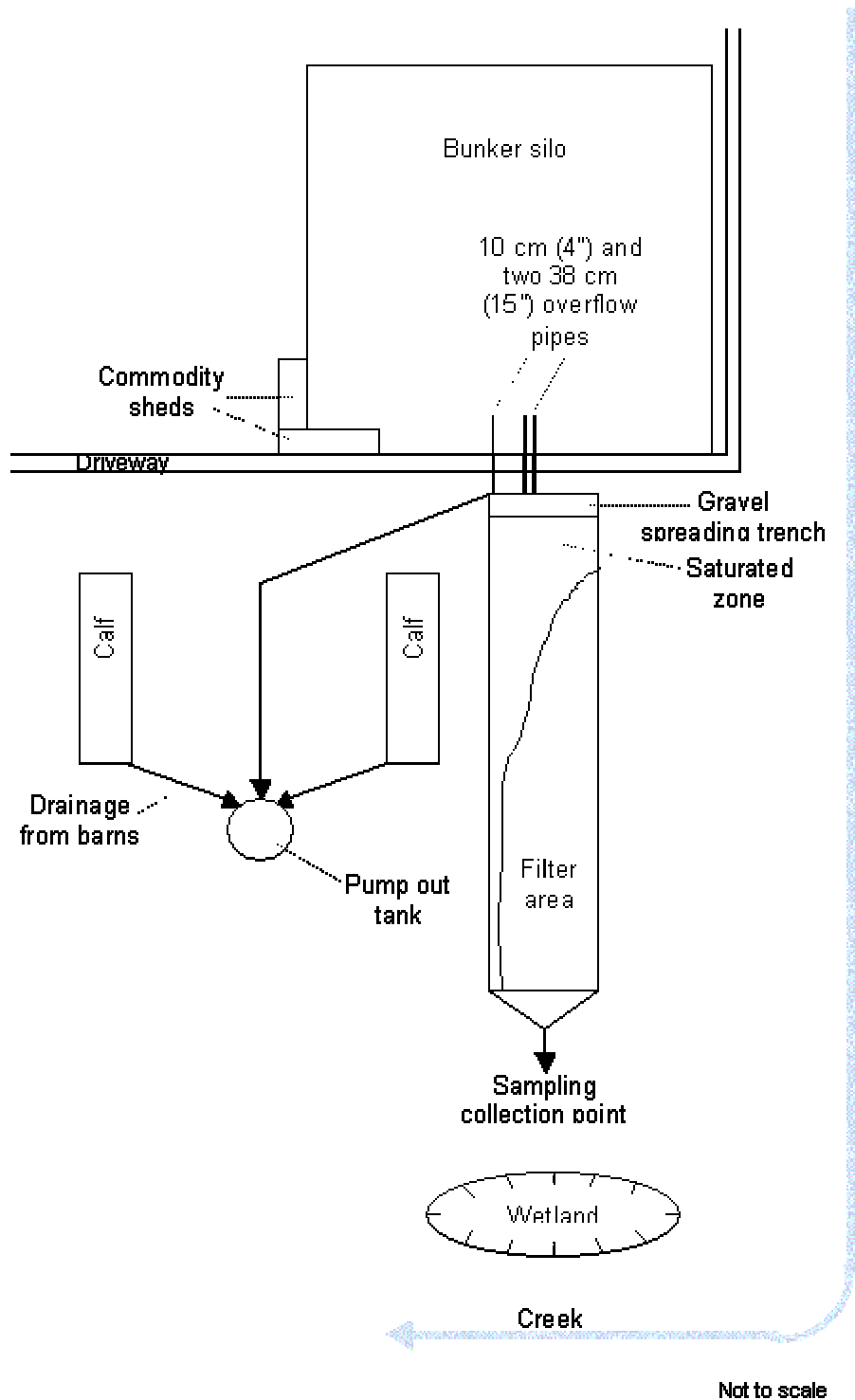


Figure 1. Schematic of bunk and filter area at farm TB. The pump out tank contains the low flow collection from any silage leachate. Vegetative filter area receives any high flow. Grading of the filter area is imperfect resulting in only a portion of the filter area being utilized. The saturated zone is from the 0.89 cm (0.35") rainfall on 8/29/03 where 0.64 cm (1/4") fell in about five minutes.

## Miner Institute Farm Description

The William H. Miner Agricultural Research Institute dairy operation is located in New York's Champlain Valley. Since its creation in 1951, the principal function has been, and continues to be, the economic improvement of agricultural operations through research, education, and demonstration. Miner Institute conducts research programs that apply basic science to contemporary problems confronting the dairy industry. Utilizing the onsite Holstein dairy farm Miner Institute demonstrates the latest innovations in crop and dairy production so that regional producers and allied industry may understand the on-farm application of new technologies. Currently they are milking 150 animals, with a total herd size of just over 300 dairy animals. Forage is being stored in their 2787 m<sup>2</sup> (30,000 ft<sup>2</sup>) bunk in anticipation of a herd expansion.

## Results

Gathering data from actual rainfall events on the two farms in CNY proved problematic. Predicting when significant rainfall would occur, even using online Doppler radar, proved to be frustrating. The irrigated site worked well. The irrigation system consistently supplied 1.5 cm (0.6 inches) per hour in the bunk area, and although the distribution was variable in the filter area the irrigation rate averaged 1.3 cm (0.5 inches) per hour. The irrigation was interrupted on the 6/18 event, when the hose was broken by truck traffic. The irrigation event on 7/16 followed a light rain, which was insufficient to create a good runoff event.

A summary of the reductions as the bunk effluent went through the low flow collection and high flow vegetative filter are shown in table 1. During low rainfall events no water escapes from the filter areas so the treatment is considered 100% effective. During higher rainfall events the soil moisture content has a significant impact on the amount of reduction of both flows and potential pollutants. The increase in total solids during the June event was likely do to the failure of the weir at the lower end of the filter area and the muddy water produced as the flashing and sod dam were rebuilt to catch samples again.

**Table 1. Percent reduction from bunk effluent to filter outlet.**

Site and date	Precip. cm (inches)	Moisture content of the soil	Flow	BOD <sub>5</sub>	NH <sub>3</sub>	NO <sub>x</sub>	TP	OP	TS
Miner									
6-18-03	5.1 (2)	43%	1.65	24	76	62	36	27	-2
7-16-03	5.1 (2)	28%	59	79	77	62	72	57	82
9-16-03	5.1 (2)	21%	96	98	97	96	97	96	98
FE									
8-29-03	0.25 (0.10)		100	100	100	100	100	100	100
9-19-03	0.23 (0.09)		100	100	100	100	100	100	100
TB									
8-29-03	0.89 (0.35)		99	99	99	99	99	99	99
9-13-03	0.36 (0.14)		100	100	100	100	100	100	100
9-15-03	0.25 (0.10)		100	100	100	100	100	100	100

The low flow collection on each system was adjustable. In each case the farm had set the amount to be collected at a very low level so that almost any measurable flow would go into the vegetative filter area. In all cases, even with the light rain events at the CNY farms, essentially all the runoff discharged to the vegetative filter areas. The low flows from the collection tank at Miner institute and from one non-rain event on farm TB are shown in table 2. On 9/19/03, Farm TB had harvested corn silage at 27% solids. This condition resulted in a flow of 0.09 liters per

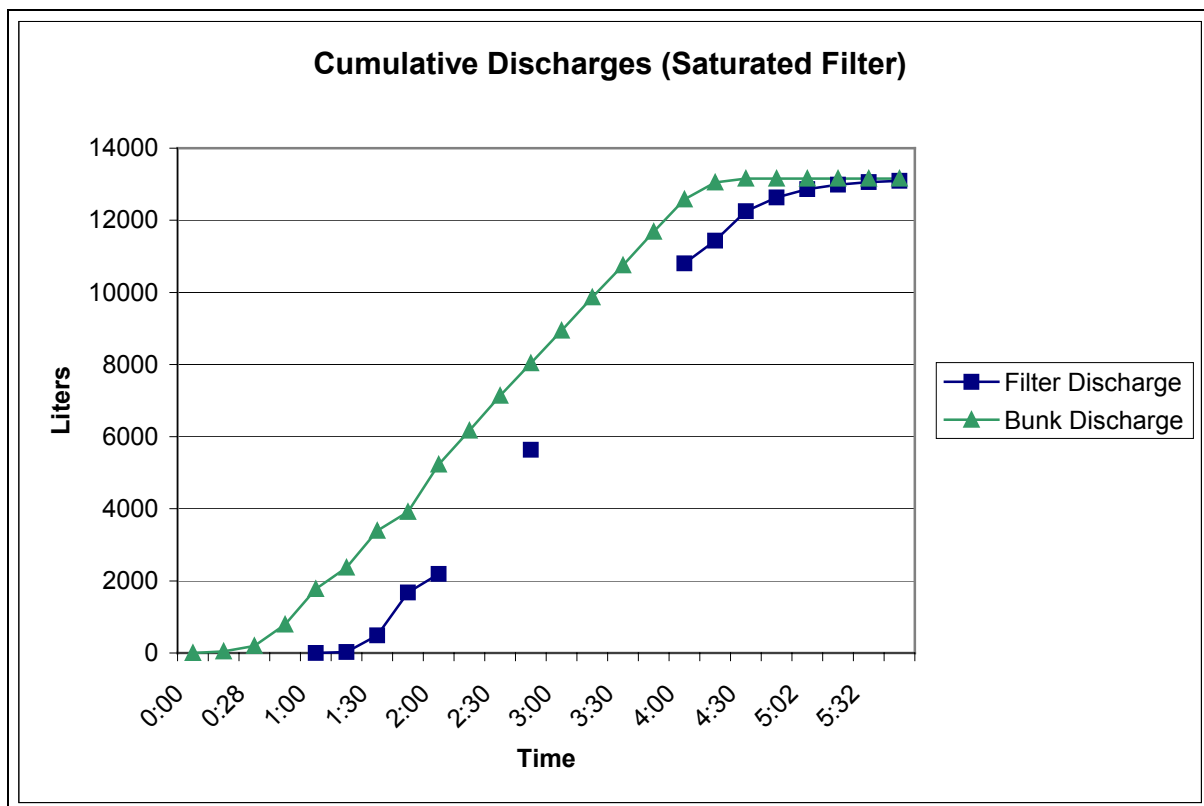
second (1.4 gpm), which consisted of the high concentrations as shown in table 2. Miner Institute emptied their 3500 liter (930 gallon) low flow collection tank 3 times during the summer of 2003.

**Table 2. Low flows from selected sites.**

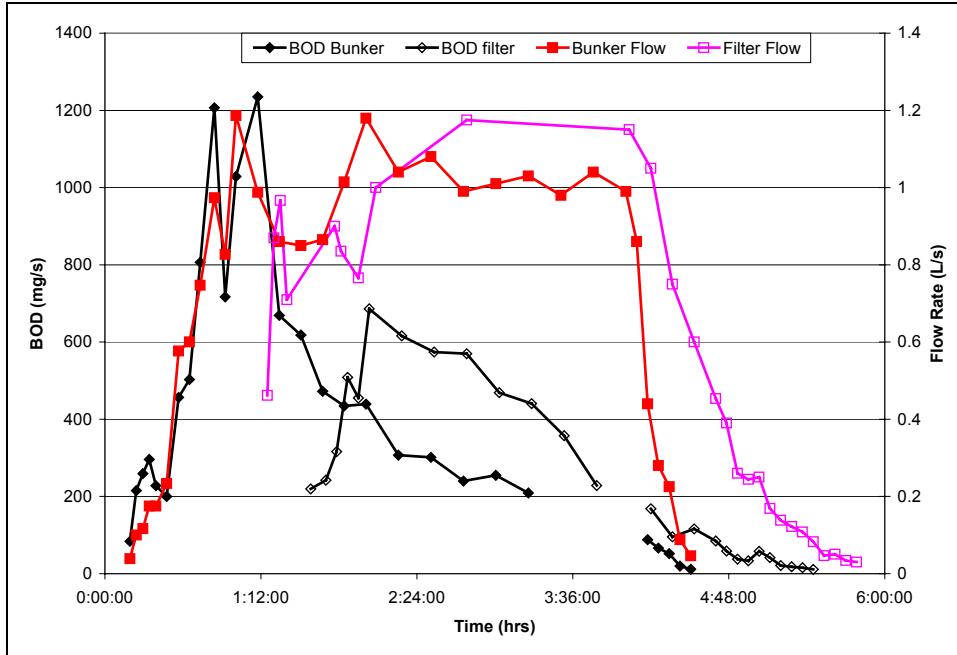
Site and date	pH	BOD <sub>5</sub> mg/l	NH <sub>3</sub> mg/l	Nox mg/l	TP mg/l	OP mg/l	TS %
Miner							
6-18-03	6.7	2280	146	0.18	26	21	0.23
7-16-03	5.9	>600	225	0.51	72	56	0.62
TB							
9-19-03	4.8	>48000	558	9.6	872		8.7

Figure 2 shows the discharges of the bunk area and filter area during the 6/18/03 irrigation event at Miner Institute. Although almost the same flow came out of the filter area as went in it, the filter area was also receiving irrigation water, so some water was infiltrated. The data gaps in the filter discharge occurred as the collected weir failed and then was repaired. The irrigation water on the filter area also served to dilute the bunk flow discharge concentrations. This reduction and time delay of the BOD<sub>5</sub> flow is shown in figure 3.

The existing litter amounts on the bunk floor were collected from 5 randomly selected 0.0929 m<sup>2</sup> (one-foot square) areas in the wetted area before irrigation began. These litter amounts varied from 0.0013 to 0.038 kg/m<sup>2</sup> (0.03 to 0.89 lbs/ft<sup>2</sup>).

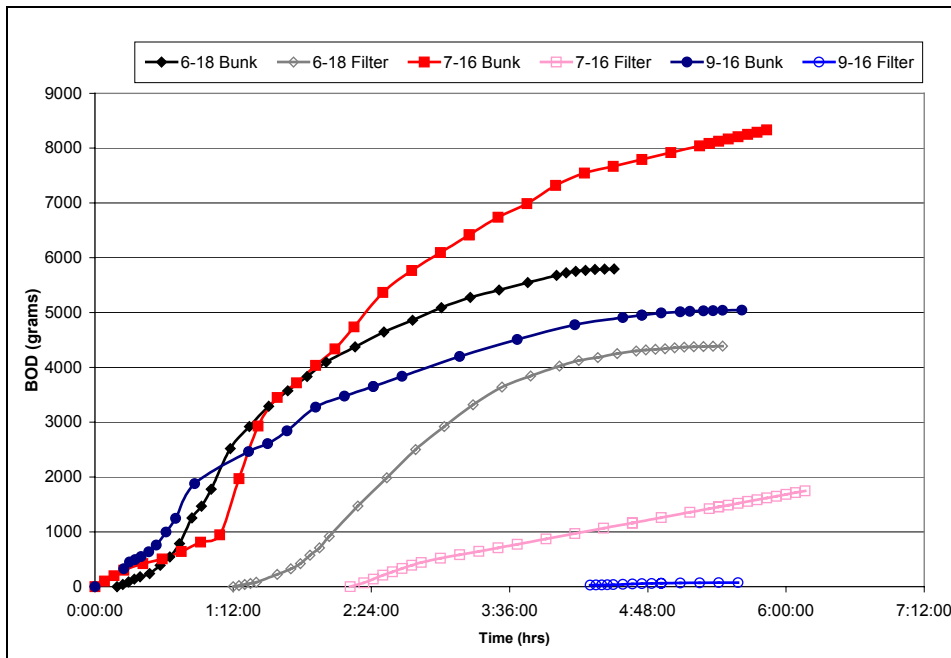


**Figure 2. Cumulative discharge from the bunk area and the vegetated filter area are shown for Miner Inst. on 6/18/03. The soils were initially very close to saturation when the event started.**

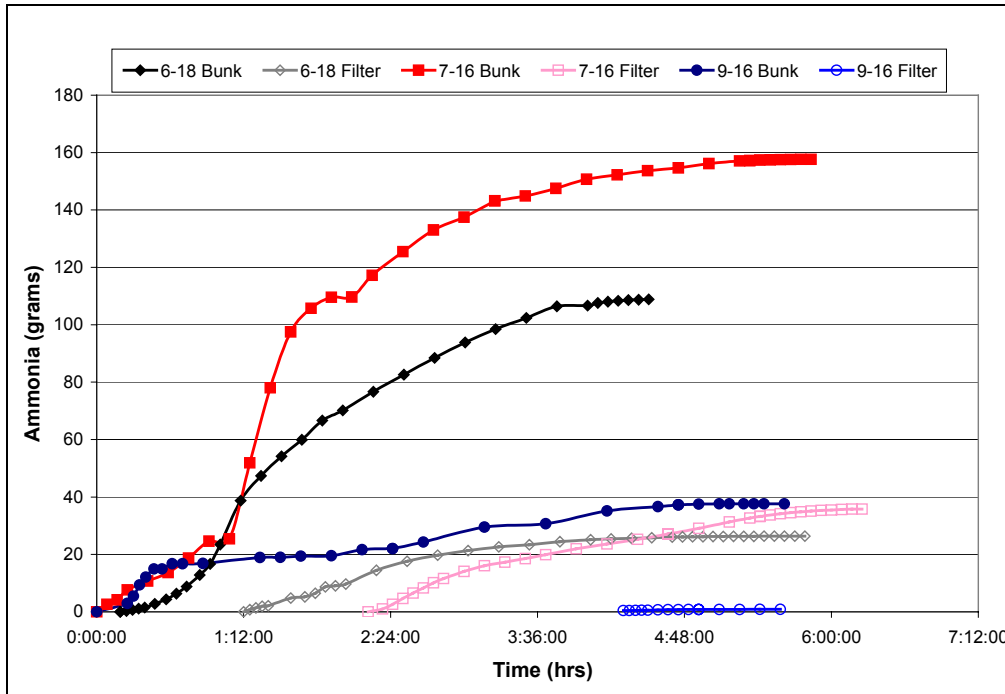


**Figure 3. Discharge from the bunk area and the vegetated filter area is shown at Miner Inst. on 6/18/03. BOD<sub>5</sub> mass flow is shown for each area. The soil was initially very close to saturation when the event was started.**

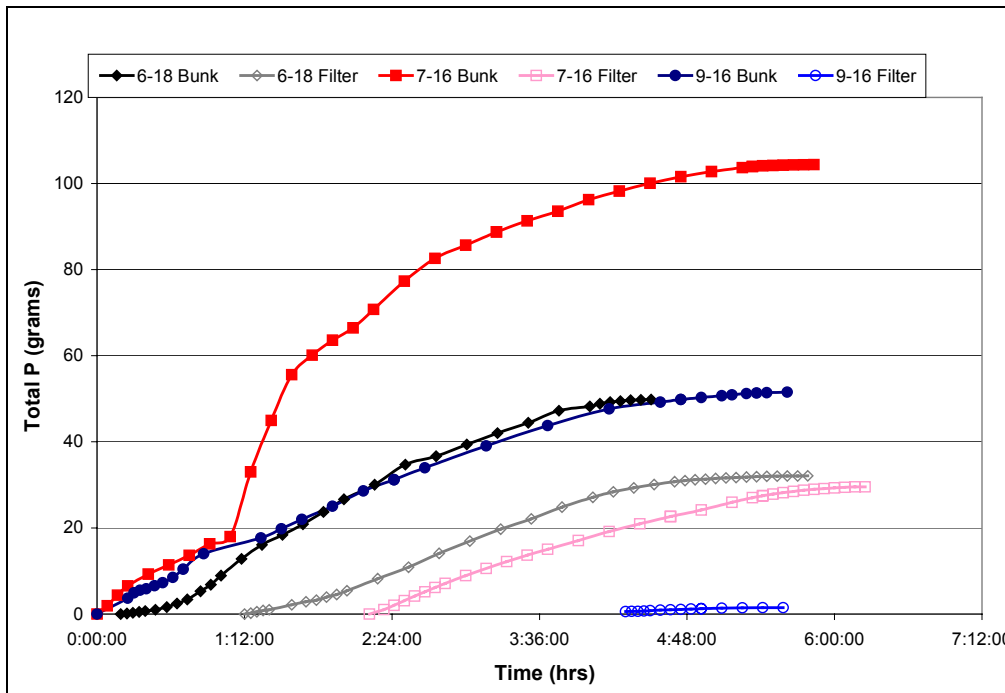
The load reductions as the bunk runoff goes into and through the filter areas for BOD<sub>5</sub>, NH<sub>4</sub>, and TP are shown in figures 4,5, and 6 respectively. For each case, the wetter the soil was in the vegetated filter at the outset of the event, the less treatment occurs.



**Figure 4. Discharge of BOD<sub>5</sub> from the bunk area and the vegetated filter area during each irrigation event at Miner Institute. The antecedent moisture content of the soil in the filter area at the different times greatly influences the reduction in BOD<sub>5</sub>.**



**Figure 5. Discharge of  $\text{NH}_4$  from the bunk area and the vegetated filter area during each irrigation event at Miner Institute. The antecedent moisture content of the soil in the filter area at the different times greatly influences the reduction in  $\text{NH}_4$ .**



**Figure 6. Discharge of TP from the bunk area and the vegetated filter area during each irrigation event at Miner Institute. The antecedent moisture content of the soil in the filter area at the different times greatly influences the reduction in TP.**



Measurements were taken at Farm FE during two rainfall events. Both events did not produce much rain. Although there was a discharge from the impermeable bunk area, there was no discharge from the vegetative filter area. The BOD<sub>5</sub> never exceeded 1,000 mg/l from this bunk.

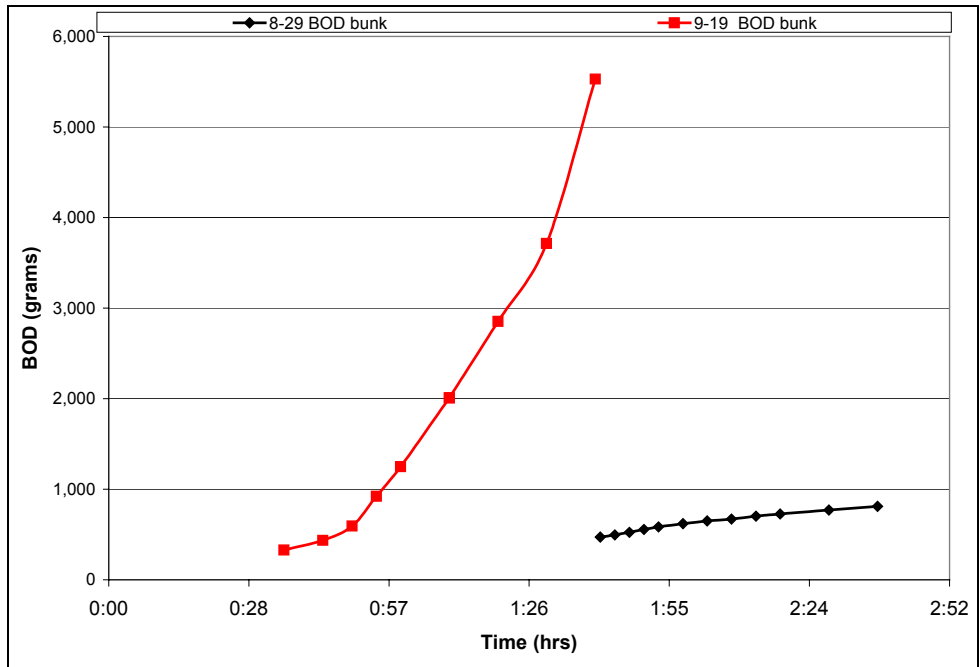


Figure 7 Discharge of BOD<sub>5</sub> from the bunk area of farm FE during two rainfall events. In both cases there was no discharge from the vegetative filter areas.

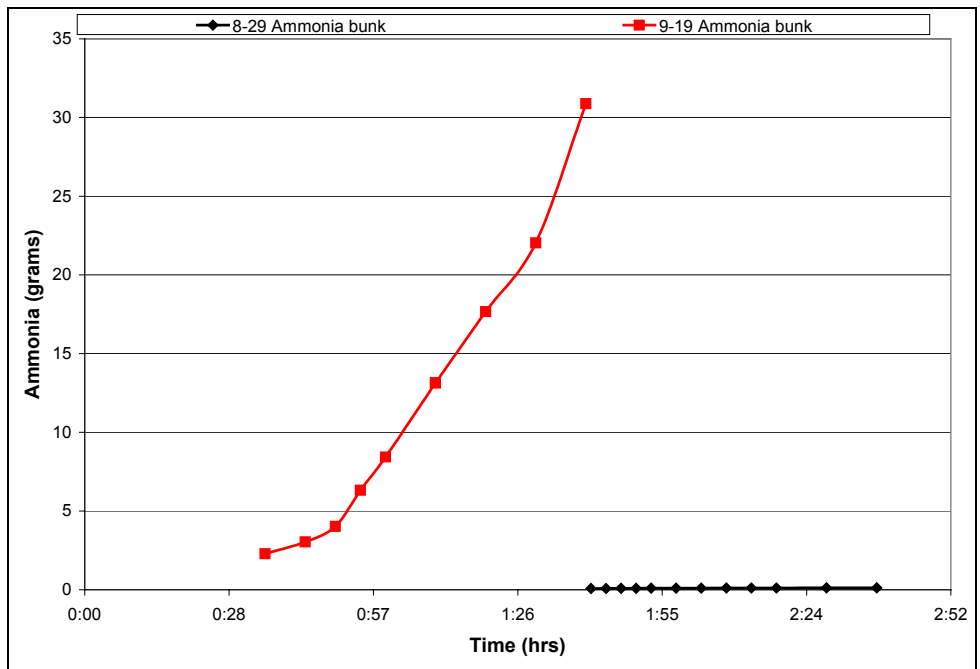
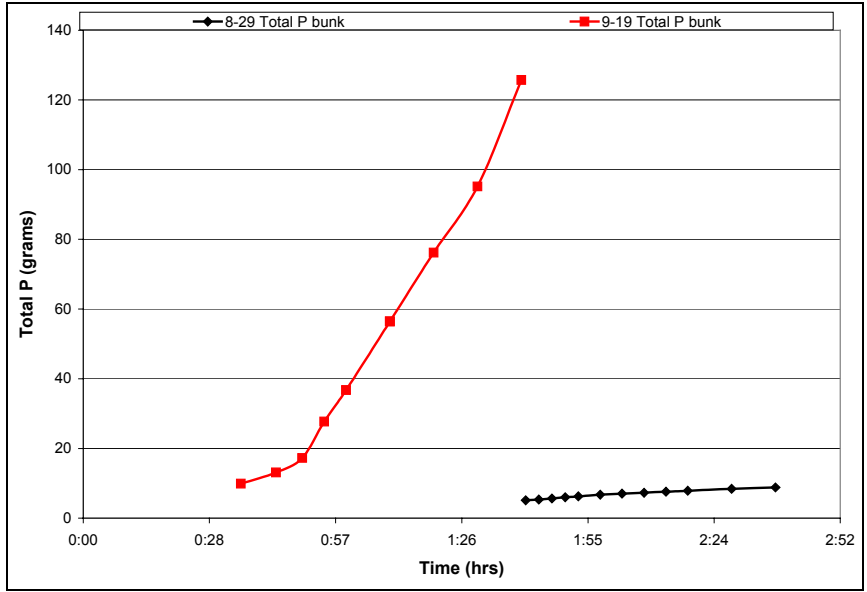
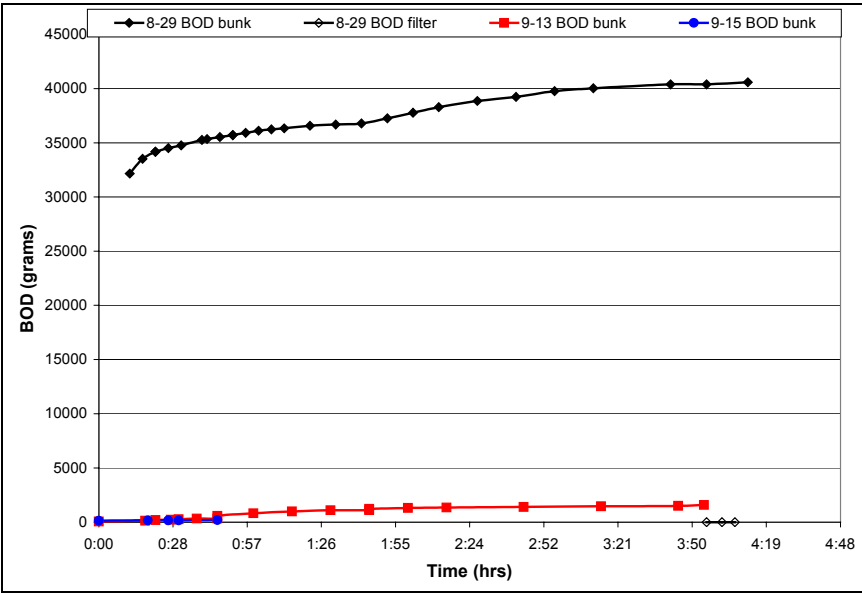


Figure 8. Discharge of NH<sub>4</sub> from the bunk area of farm FE during two rainfall events. In both cases there was no discharge from the vegetative filter areas



**Figure 9. Discharge of TP from the bunk area of farm FE during two rainfall events. In both cases there was no discharge from the vegetative filter areas.**

Measurements were taken at Farm TB during three rainfall events. Each event did not produce much rain. The event on 8/29 did produce a minimal flow from the filter area. Only during the rainfall event where 0.64 cm (0.25 inches) of rain fell in about 5 minutes was there any discharge from the vegetative filter area. Measurements of the bunk effluent started after flow began as the sampler got to the site 10 minutes too late. During the other two rainfall events on 9/13 and 9/15 there was a discharge from the impermeable bunk area, but there was no discharge from the vegetative filter area.



**Figure 10. Discharge of BOD<sub>5</sub> from the bunk area of farm TB. Only during the rainfall event where 0.64 cm (0.25 inches) of rain fell in about 5 minutes was there any discharge from the vegetative filter area.**

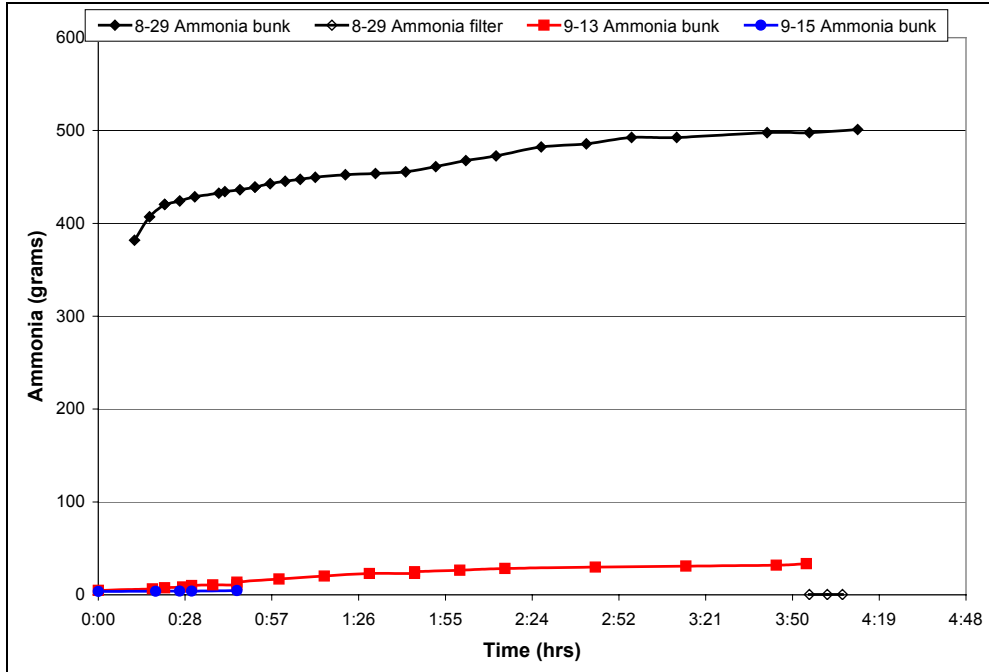


Figure 11. Discharge of  $\text{NH}_4$  from the bunk area of farm TB. Only during the rainfall event where 0.64 cm (0.25 inches) of rain fell in about 5 minutes was there any discharge from the vegetative filter area.

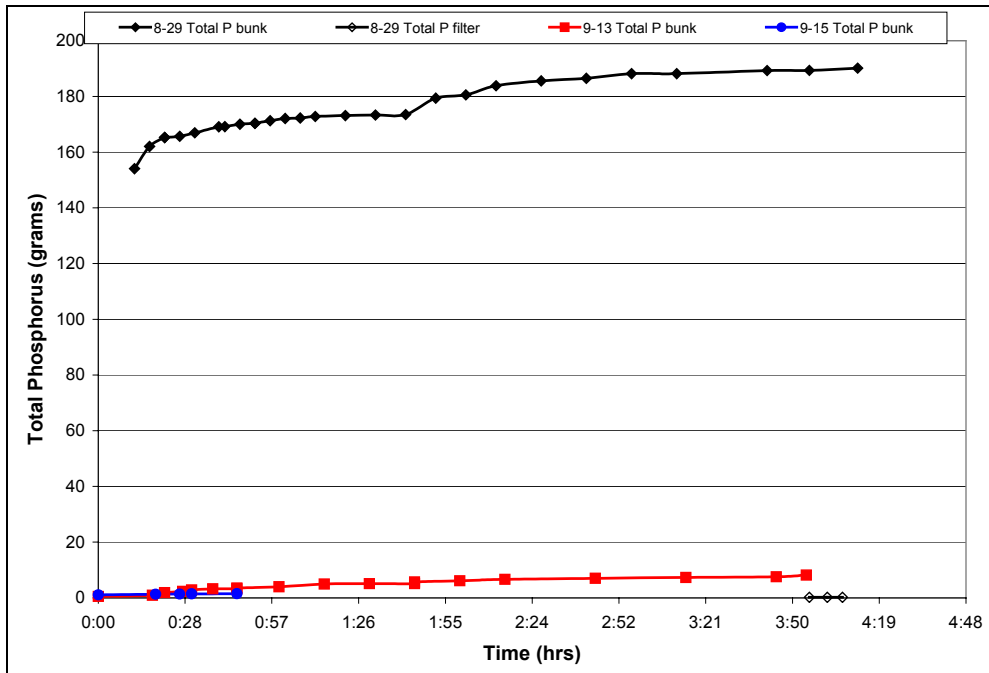


Figure 12. Discharge of TP from the bunk area of farm TB. Only during the rainfall event where 0.64 cm (0.25 inches) of rain fell in about 5 minutes was there any discharge from the vegetative filter area.

## Discussion

In all cases, even with the light rain events at the CNY farms, essentially all the runoff went to the vegetative filter areas as opposed to the low flow collection tanks. Therefore the systems did not catch the first flush of runoff. This was as it should be when the forage or corn is harvested at the correct moisture content. When there is no leachate from the stored silage, the only flows from the bunk should occur during precipitation events. If the filter area is not being continually loaded with leachate it should be able to accept runoff from the bunk with little damage to the plants and little discharge. During the site visits for this project, only once was there a discharge from the stored forage (the 9/19 sample in table 2). When that farm discovered the mistake in harvesting corn silage at 27% solids, they delayed harvesting operations until the solids content of the silage increased to 33%.

Table 1 and figures 4,5, and 6 show that during nearly saturated soil conditions in June the flow, BOD<sub>5</sub>, and P had very little reduction. TS actually increased. Little infiltration occurred and the wetting front moved fairly quickly down the filter area. The increase in TS during the June event was likely due to the failure of the weir at the lower end of the filter area and the muddy water produced as the flashing and sod dam were rebuilt to catch samples again. Nitrogen was reduced 76 percent for NH<sub>4</sub> and 62 percent for NO<sub>x</sub>. The ammonia may have had time to volatilize as it traveled along the filter area. During the September event when the soil moisture was at about 50% of field capacity the reductions of the flow and the potential contaminants were all greater than 96 percent. Infiltration of the bunk runoff was the prime mechanism that achieved this reduction. The soil moisture at the start of the event in July was in between the other two events and the reductions in flow and contaminants also fell in between the reductions from the other two events. This is to be expected from other studies showing greater treatment with drier soils. (Kim 2003)

The litter of spilled silage on the bunk floor varied from site to site and from time to time. This variation could have a large impact on the quality of the runoff. Some farms made more of an effort to keep the bunk floors clean.

Harvesting silage at the proper moisture content will prevent a large part of the problem from concentrated silage leachate. However, bunk silos should be designed to control the outside runoff water as well as the water that collects on the cover to minimize the amount of the clean seepage water, which becomes contaminated. At one site, outside water was continually mixing with the spilled silage on the bunk floor, which resulted in contaminated water flowing to the vegetative filter area. This continual flow of high concentration water saturated one area of the filter and disrupted plant growth.

Grading the bunk so that the surface water and silage leachate can be collected in one spot, where a collection system can be easily installed, and maintained, will reduce the pollution potential. Also providing an appropriate place for waste silage and contaminated snow so effluent from these can be controlled should reduce pollution potential. Runoff flows from some of the sites was observed coming into contact with spoiled silage piles in the bunk. This adds to the potential for contamination.

The effluent distribution mechanisms such as gravel infiltration trenches at the inlet to the vegetative filter areas seldom spread the flow uniformly across the cross-section width of the vegetated filter. Even where the flow was fairly uniformly spread, flows tend to concentrate a short way down the filter area. Vegetated filters, which are narrow in width but longer, are more likely to help distribute and treat the flow.

The lower amounts of rainfall experienced on the two CNY farms produced none or insignificant amounts of runoff from the vegetative filter area. These smaller storms are the type that more

typically occur throughout the year and can cause fish kills on untreated sites. If untreated runoff gets directly into low flowing streams the damage to aquatic life can be severe. Even small precipitation events may create enough runoff from impermeable areas without producing runoff in streams. Thus there is not enough dilution of the bunker runoff to overcome the high BOD<sub>5</sub> of the silage leachate.

Many of the BOD<sub>5</sub> test results came back from the lab as either: < a value, or > a value. The labs (two were used) both had a difficult time estimating the proper dilution levels to get the actual BOD<sub>5</sub> reading with three samples. Using less expensive COD tests may provide better results for evaluating these discharges even though BOD<sub>5</sub> is a more accurate measure of the potential for a fish kill.

## **Conclusion**

Reduction in BOD<sub>5</sub> nitrogen and phosphorus range from only 24% for BOD<sub>5</sub> to 76% for NH<sub>4</sub> during runoff events while soils are close to saturation at the beginning of the event. Yet when the soils are at half of field capacity the reductions are all above 96%. During small rain events the reductions are 100% as no runoff leaves the filter areas.

The concentration of potential contaminants from bunk silo runoff varies significantly. The amount of litter on the bunk floor, the placement of piles of spoiled silage, the flow path of outside clean water, the adjustment of the amount of low flow collection, and the moisture content of the harvested silage are all under management control. Thus, pollution potential could be reduced significantly with improved management guidelines and the implementation of these guidelines.

Sending the highly concentrated low flows of silage effluent to storage for future land spreading while allowing the less concentrated high flows from runoff events to be treated in a vegetated filter system has the potential to reduce pollution significantly. Pollutant reduction in vegetated filter strips will vary depending on existing moisture conditions. Although some discharge will occur in higher flow events on saturated soils, the local fish kills will be eliminated or at least reduced. The overall loading of pollutants will be significantly reduced with the implementation of this system.

## **Acknowledgements**

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