UofA UNIVERSITY OF ARKANSAS
DIVISION OF AGRICULTURE
Cooperative Extension Service

Agriculture and Natural Resources

University of Arkansas Swine Manure Demonstration Project

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Introduction

The Arkansas Water Quality Inventory Report for 1994 lists the expansion of confined animal production as a special state concern. The report indicates that in the areas of animal production, the reduced water quality attributed to agriculture is primarily due to elevated nutrient and pathogen concentrations. The report also mentions an increased incidence of high nitrate concentration in wells and springs in areas of concentrated animal operations.

Modern swine rearing facilities often have large numbers of animals and a relatively limited land base for manure application. Utilization of the manure in a manner that minimizes odor and optimizes nutrient utilization is an increasing concern. Manure is a valuable resource as an alternative source of fertilizer nitrogen (N), phosphorus (P) and potassium (K) to maintain soil productivity. In fact, improving ground cover tends to reduce runoff volume and erosion. However, application rates greater than crop needs have been shown to result in nitrate (NO_3) movement through the soil into ground water and can also result in excessive soil test P levels, leading to increased phosphorus concentrations in runoff water. This can be a problem, since phosphorus is normally the limiting nutrient for eutrophication in freshwater systems. In addition, odor and nutrient problems can both be increased by excessive nutrient buildup in lagoons/holding ponds if manure solids are allowed to accumulate over a number of years.

Arkansas was the twelfth highest swine producing state in the nation at the initiation of this project. Of the 2 million swine produced annually, the vast majority are raised on farms with liquid manure handling systems. On these farms, the animals are housed in total confinement facilities where the manure is handled with the addition of supplemental water. Water is typically used to flush the manure from the barn into storage/treatment basins until it is land applied to supply the nutrient (nitrogen) needs of a forage crop. While this approach has the advantages of production economics, animal health, beneficial use of the manure for crops and environmental preservation (with proper management), there are a couple of points of concern.

Soil Phosphorus Concerns

The first concern in swine manure management is related to the phosphorus content of the manure. Typically, the manure is applied based on the receiving crop's nitrogen requirements. As a result, more phosphorus is applied than the crop will normally utilize (around fivefold), thereby resulting in a phosphorus buildup in the soil. The phosphorus content of surface soil can directly influence the loss of phosphorus in runoff (Daniel et al., 1994), which can reduce surface water quality. Runoff losses from manure are a particular concern in regions where confined animal operations exist in proximity to surface water bodies sensitive to phosphorus inputs (Daniel et al., 1994). Because of this concern, some states have established subjective

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threshold soil phosphorus levels, or phosphorus risk indexes, intended to ensure continued crop production while not producing eutrophic inducing runoff.

While phosphorus-based application rates would in theory reduce this risk, they would also greatly increase the required land application area, and require the purchase of commercial nitrogen and potassium fertilizers to maintain current forage production. Both results present problems. On many farms, the required additional acreage is not readily available. Continued operation would require transporting the manure to more distant application sites. The additional distance to the land application sites, if available, would increase the required time to apply the manure, which would increase the difficulty of proper manure management and the likelihood of point-source discharges from the ponds. Furthermore, the additional commercial fertilizer cost could lead to under-fertilization of pastureland in many cases. The low fertility condition could potentially result in a reduction in ground cover and an increase in erosion and loss of sediments enriched in phosphorus. In addition to these environmental concerns, manure application rates to meet crop phosphorus needs could adversely affect economic pork production due to increased manure transportation costs during application. This in turn could have significant economic impacts on the state economy.

Another approach to addressing soil phosphorus buildup concerns is to reduce the phosphorus levels in the manure. Doing so would still supply the crop's nitrogen needs, while reducing the amount of phosphorus available to potentially degrade surface water quality.

Manure Solids Concerns

A second point of concern is the difficulty of handling manure solids that fall from suspension and settle during storage. The majority of swine manure is stored in holding ponds that may be preceded by settling basins. The holding ponds are earthen storage structures that are designed to hold 120 to 180 days of manure between land applications. Settling basins are earthen basins designed so that 50 to 70 percent of the solids settle out as liquid manure flows through on its way from the animals to holding ponds or lagoons. Settling basins are typically designed to store 45 to 90 days of manure solids. There are some farms that store the liquid manure in concrete pits. All of these storage structures are designed for the manure to be agitated prior to land application so that both the solid and liquid fractions are removed.

There are some anaerobic treatment lagoons in the state. Lagoons, in contrast to pure storage structures, also have a biological treatment component. The treatment consists of the biological decomposition of up to 85 percent of the manure solids into primarily methane and carbon dioxide. The nitrogen in the organic matter is converted into the ammoniacal forms. In Arkansas, lagoons are designed to have a liquid storage volume of 180 days and an undigested solids (about 15 percent of total solids) storage volume of five or more years. With proper management, the lagoon is pumped down to the treatment volume every 180 days without agitation. The volume required for treatment and the accumulated solids are not removed. About every five years, the accumulated solids should be removed by dredging or agitation and pumping.

For all of these structures, if the solids are not removed they will build up over time and reduce storage capacity. The reduced capacity can greatly increase the required pumping frequency to maintain adequate freeboard in the storage structure. The increased pumping frequency often results in land applications on saturated soils or immediately prior to rainfall events. Both are situations that increase the potential for nutrient-laden runoff to negatively impact water quality. In severe cases, if a pump-down does not occur, overflows will cause point-source discharges. In addition, the increased manure solids concentrations increase the potential for offensive odors.

Lack of education and proper equipment prior to the late 1980s and early 1990s contributed to holding ponds and settling basins being managed as lagoons with only water being pumped, thereby leaving the solids to accumulate. This resulted in a significant portion of the settling basins and holding ponds in Arkansas having significant amounts of solids buildup and inadequate holding time.

Since 1993, educational efforts have made producers aware of the design and management differences of holding ponds and lagoons. The educational efforts have also presented the recommended agitation and solids removal practices. As a result, progress is being made on many farms to avoid the lost storage capacity. However, it was anticipated that this progress would be greatly enhanced by demonstrating pumping and agitation equipment in operation.

Demonstrating proper solids management by documenting nutrient and solids stratification and storage volume retention and the effect of agitation will provide the information necessary to present the benefits and promote the implementation of solids management.

Shared Organizational Concerns and Cooperation

The concerns listed above are shared by many organizations. Among them are the University of Arkansas, the Arkansas Department of Pollution Control and Ecology, the Arkansas Soil and Water Conservation Commission, the Natural Resources Conservation Service, the Arkansas Pork Producers Association, Tyson Foods, Inc., and Cargill Pork. The

shared concerns have resulted in a close working relationship that expresses itself in the annual environmental training that permitted swine producers attend and support for this demonstration.

As a measure of the University of Arkansas' concern about economic and environmentally friendly pork production, it constructed (with specially approved financial support from the state) a modern swine farm. The objective for the farm is to be a long-term model of the environmentally friendly management of animal nutrition, manure and odors. This farm is a commercial-sized operation that has multiple long-term uses. These include animal production and nutrition research, student education, producer education and as a model for proper facility design and management. In addition to standard manure management components, four additional holding basins to facilitate separate manure collection from pigs receiving different diets were constructed utilizing funds from an EPA 319 Technology Transfer Grant. The additional holding basins were needed to avoid mixing of manures from different feed demonstrations. The separate manure collection system was designed and installed at this farm during construction. The standard settling basin and lagoon combined with the additional holding basins are instrumental in the research and extension components of the University's swine farm.

General Project Description

To address the phosphorus and manure solids concerns discussed above, this demonstration project had several components on three different farms. The first component was at the University swine farm where phytase feed trials and manure applications to half-acre monitored runoff plots were conducted to demonstrate the effect of phytase-amended feed on animal performance and phosphorus runoff. The second component was demonstration of the impact of grazing cattle on phosphorus movement. The third component used the new manure storages on the University farm and the older manure storages on two privately owned farms to demonstrate that it is possible to properly manage manure solids with currently available equipment.

Phytase Demonstration

There are several BMPs that can reduce phosphorus runoff from fields fertilized with swine manure. Approaches include decreasing the amount of phosphorus in the manure by decreasing the amount fed to swine or by improving dietary phosphorus availability. This can be done by reducing the unavailable dietary phosphorus by adding the microbial phytase enzyme to the feed to break down phytate-bound phosphorus in corn and soybean meal. Phytase is an enzyme which degrades phytate to release phosphorus and other nutrients, making them more available to the animals. Therefore, the use of phytase in animal feeds reduces the need to add supplemental phosphorus to the feed. As a result, the total amount of phosphorus excreted in the manure, and potentially available for runoff, is reduced.

In this portion of the project, the objective was to demonstrate the effect of adding phytase to the feed. Separate groups of animals were fed either a normal diet or a diet that had phytase and supplemental phosphorus reduced. Animal growth information was collected for both groups of animals. The manure from both groups of pigs was kept separate and applied to separate half-acre runoff plots. In addition, a third runoff plot did not receive manure. A fourth plot received manure from the phytase feed animals that also had aluminum chloride ($AlCl_3$) added to the manure prior to application to the plot. Each plot had its own runoff collector to capture runoff during rain events. The plots also had berms to prevent runoff from either escaping or entering the plot. Figures 1 and 2 provide an aerial view of the university farm and the runoff plots. Manure was applied to the plots three times during the project. After each rain event, the runoff collectors were inspected. If runoff occurred, the volume of the runoff was determined and water samples collected for chemical analysis.

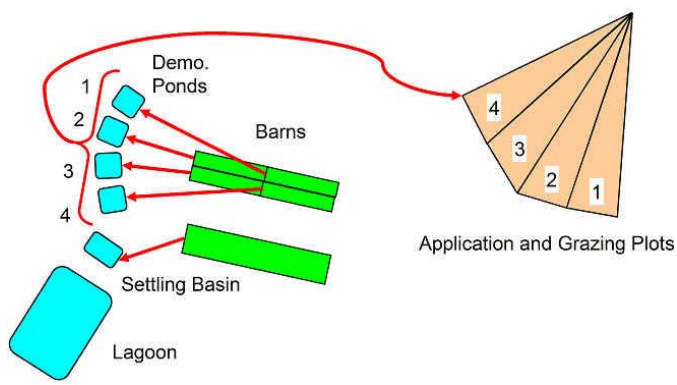

Figure 1. Schematic showing the location of the swine barns, manure storages and the runoff plots. The red arrows show the movement of manure. The runoff collectors are clustered together at the narrow ends of the plots.

Figure 2. Runoff plots 1, 2, 3 and 4 from right to left with the runoff collectors in the foreground.

Analysis of the animal growth information collected indicated that the effects of reduced phosphorus diets with added phytase on performance during the nursery phase indicated that overall performance was similar. However, during the finishing phase, a small reduction in gain and efficiency was observed in pigs fed the reduced phosphorus diet with added phytase. Decreased performance may be due to the fact that reducing available phosphorus in diets based on NRC 1998 recommendations by 0.1 percent and adding phytase may not have provided sufficient phosphorus for rapidly growing pigs. Industry standards are somewhat higher and may be justified to ensure adequate growth.

Comparing the total phosphorus and soluble phosphorus concentrations in Table 1 shows a 24.8 percent reduction in total phosphorus and a 8.95 percent reduction in soluble phosphorus. This indicates that the use of phytase reduced the total phosphorus concentrations while increasing the proportion of the phosphorus that is in a soluble form. Table 2 shows the chemical analysis of the runoff water which indicated that all four plots lost nutrients. The plot where phytase diet manure was applied lost less total and soluble phosphorus than the normal diet manure plot.

Table 1. Phosphorus concentration in holding ponds (mg/L).

ITEM	Normal P	Phytase P	% Reduction
Total P	289.7	217.9	24.8
Soluble P	138.4	126.0	8.95

N = 6 samples per manure source.

Table 2. Mass of nutrients lost from watersheds (lb/A) and percentage of applied nutrients lost (percentage in parentheses).

TREATMENT	Soluble P	Total P	Total N
Unfertilized	0.89	1.26	1.84
Phytase Diet	0.92 (7.2%)	1.12 (3.6%)	1.39 (0.6%)
Normal Diet	1.30 (12.7%)	1.65 (5.4%)	2.38 (1.2%)
Phytase + $AlCl_3$	0.97 (16.5%)	1.31 (4.9%)	2.28 (1.0%)

Cattle Management Demonstration

A third component of the project consisted of a demonstration of the impacts of grazing cattle on land receiving animal manure. To accomplish this, cattle were grazed on the runoff plots in the spring and fall to match the fescue pasture growth in the plots. Adjusting the number of cattle in the plots controlled the amount of forage grazed. Cattle weights prior to and after grazing were collected. In addition, small sub areas of the plots were protected from grazing to allow measurement of forage production.

The forage and animal components of the study only evaluated the impact of manure application in the runoff plots fertilized with normal and phytase manure due to cost constraints of forage mineral analysis. In the two watersheds monitored for forage and cattle gain, a high proportion of P and N from the applied manure was taken up by the fescue. Figure 3 also shows that a large percentage of the P taken up by the fescue was consumed by the grazing cattle. However, since almost all of the P and N consumed by cattle goes to tissue maintenance, which is dynamic, the animal's long-term P and N absorption is a small fraction of what is consumed. This means that most of the P consumed by the cattle is redeposited in the manure. Therefore, the most logical practice to remove or utilize excess P and N from a field or farm would be to harvest the forage and feed it in a location with lower P and N concentrations.

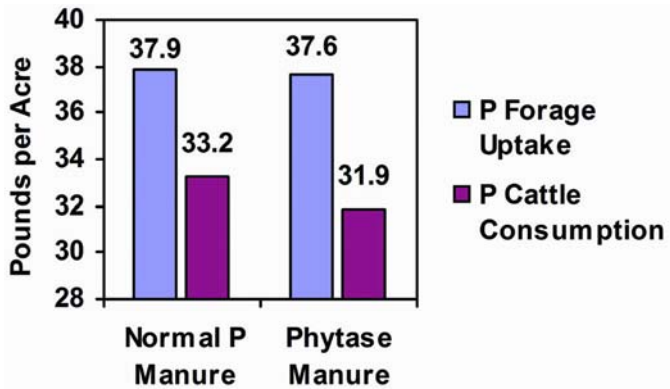

Figure 3. P uptake by the forage and P consumption by cattle grazing for the runoff plots that received normal P manure and phytase manure. All units are in pounds per acre.

Manure Solids Demonstration

The objective of this part of the project was to demonstrate that, using available equipment, it was possible to prevent the accumulation of manures solids at the new University farm and to reduce the accumulation of solids at existing swine farms. To accomplish this demonstration, the University purchased a prop agitator and also hired a custom applicator to manage the manure in its settling basin. On the two commercial farms at the beginning of the project, the owners had just initiated improved solids management practices by obtaining the prop agitator shared between them. On all three farms, periodic measurements using survey and global positioning equipment were used to determine the elevation of the manure solids at multiple locations. Computer software was then used to convert these measurements into surface maps. The same software was used to generate maps to show the areas of accumulation and reduction in manure solids as influenced by agitation over the life of the project. Figure 4 shows a series of the maps generated for the settling basin on the University's farm.

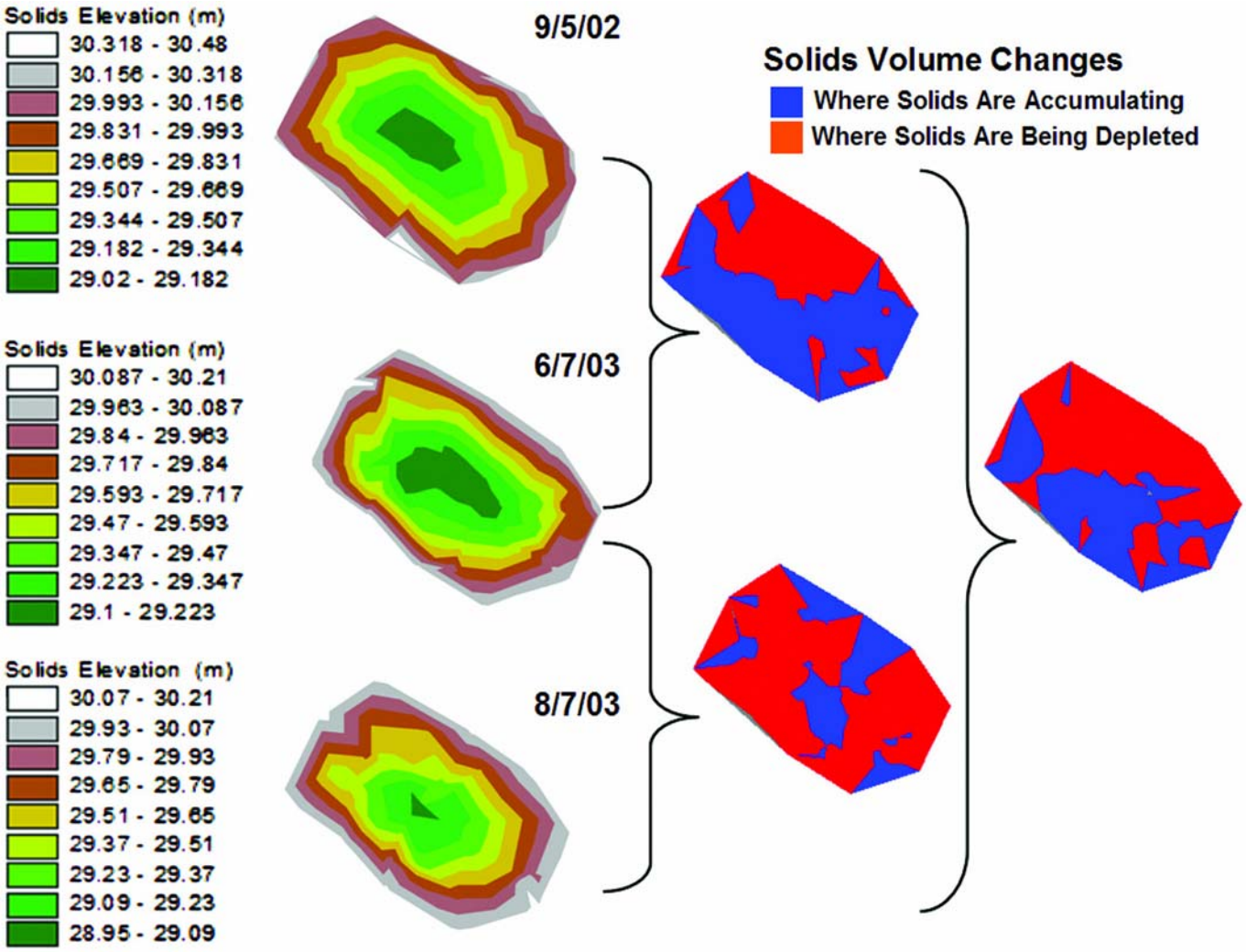

Figure 4. Manure Solids Trends: UA Swine Farm Settling Basin.

At the University of Arkansas farm and the privately owned farms, both prop and pump agitators were effective in mixing the manure prior to pumping, allowing both the manure liquids and solids to be pumped and applied to the fields. However, it was easier to maintain a minimal volume of manure solids at the University farm than it was to reduce the multiple year accumulation of manure solids at the two older farms. However, during the life of the project, they were able to substantially reduce the manure accumulations.

Figure 4 also shows that while agitation can re-suspend solids and allow for their removal, it also has the potential to move the location of manure solids accumulation. For smaller manure storages, this should not be a problem. However, for larger storages, agitators have been known to move the settled solids from near the banks of the storage to the center, resulting in a mound or island of solids in the center of the storage. In some of the larger facilities, it may be possible to use multiple agitators to keep all the water in the storage moving fast enough to keep the solids in suspension. For a few of the largest storages, floating dredges may be the most appropriate option.

This project demonstrated that using commercially available equipment and service it is possible on most Arkansas storages to manage manure solids so that existing storage capacity is maintained and that capacity lost to accumulated solids can be recovered.

Summary

This project demonstrated that the use of phytase in swine feed can reduce the total phosphorus concentration in the manure. However, it appears the proportion of the soluble phosphorus in the manure increases. When applied to demonstration runoff plots, phytase manure resulted in lower phosphorus losses than normal manure. The manure solids management component of the project demonstrated that it is possible to properly manage manure solids with commercially available equipment. Grazing cattle were shown to be effective in consuming significant amounts of P; however, as most of this consumed phosphorus is redeposited in their manure, grazing is not an effective way of removing P from the soil.

Reference

Daniel, T.C., A.N. Sharpley, D.R. Edwards, R. Wedepohl, and J.L. Lemunyon. 1994. Minimizing surface water eutrophication from agriculture by phosphorus management. *J. Soil and Water Conservation* 49 (2): 30-38.

This publication was written as part of an EPA 319(h) project. For the entire project, $300,000 was provided by the Environmental Protection Agency and $226,316 was provided as matching funds.

Printed by University of Arkansas Cooperative Extension Service Printing Services.

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. FSA1042-2M-12-03N

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