

How to Select an Alternative Manure Treatment System

Kelly Zering¹

This paper and presentation are intended to provide a brief review of the economics of manure management and some steps for pig producers to take in selecting alternative manure management systems.

Review of the Economics of Manure Management

Economics is the study of the optimal use of resources to maximize the welfare of people. Application of a few fundamental economic models to manure management issues provides some guidance for regulatory design. The March/April 1999 edition of the *NC State Economist* provides some additional background on those basic economic models. (That publication can be viewed on the Internet at:

<<http://www.ag-econ.ncsu.edu/publications/economist.htm>>.)

Principles arising from those models include:

- a. The value of environmental and economic benefits derived from any change in manure management must equal or exceed the cost. Otherwise, society is worse off.
- b. There should be no less costly method of achieving the environmental and economic benefits than the change in manure management. Otherwise, society could have the same benefits at lower cost.
- c. Imposing higher costs on farms in one region (as opposed to a country or a market) will reduce supply from that region. Prices will change little if at all. Quantity produced will fall. The reduction in quantity will be achieved through liquidation of some farm enterprises.
- d. Imposing higher costs on farms across the country or across most of the market will reduce supply. Prices will rise and quantity supplied will fall. Again, the reduction in quantity will be achieved through liquidation of some farm enterprises.
- e. Reducing income and investment from farming in a community or region acts through multiplier effects to reduce income, employment, tax base, tax revenue, and tax funded services.
- f. Cost share, tax credits, tax deductions, favorable utility rates, and revenues from discharge permit trading programs are some methods of providing financial assistance to farmers to make changes. Financial assistance may be required to achieve benefits without imposing undue costs on a small number of farmers and rural communities.
- g. Changes should only occur on those farms where the environmental and economic benefits clearly outweigh the costs. Priority should be given to those farms where the

¹ Kelly Zering is an extension specialist and associate professor in the Dept. of Agricultural and Resource Economics at North Carolina State University. This paper was presented at the North Carolina Pork Conference in Fayetteville on January 12, 2000.

ratio of benefits to costs is greatest. Programs should be designed to minimize the impact of the change on the farms and communities affected.

Review of Farm Level Economics of Alternative Manure Management Systems

Farmers decision-making can be characterized as profit maximization. The quantities of commodities that they produce and the quantities of inputs that they use in production are selected based on expected profit. Animal manure contains a range of nutrients and hence has some intrinsic value. Low concentration of nutrients in manure and the price of chemical fertilizer can cause the cost of manure handling and application to exceed the value of the nutrients as fertilizer. In other words, manure can create a net cost of disposal for the farm.

Costs of using manure as a crop fertilizer may include storage, transport and land application. Where the marginal cost of using manure as a crop fertilizer is high, farmers may incur manure treatment costs. Costs of using manure as a fertilizer increase with the distance transported. Distance transported increases with larger hog farm size, lower crop yields, and lower proportion of surrounding land available for manure application. . Where manure is very costly to use as fertilizer, farmers' incentive is to dispose of manure at minimum cost. Improper disposal can result in environmental damage and/or costs to neighbors. Regulatory constraints limit farmers' profit maximizing decisions with the intent of preventing improper disposal.

Farmers often operate as price-takers in highly competitive markets. They have little control over the price they receive for their products or the price they pay to purchase production inputs.

Technical constraints incorporate a range of variables that are specific to each farm site such as:

- the volume, composition and concentration of manure produced at the farm,
- soil type, crop selection and yield potential,
- climate,
- the availability and skill level of labor and management,
- location (proximity to neighbors, waterways, and markets for by-products),
- and farm size (land available for spreading).

Each farm is somewhat unique and so no manure management system design is likely to suit all.

What Problem(s) is the Alternative System Intended to Correct :

Each farm has unique circumstances such as land area, soil type, climate, proximity to neighbors, roads, and waterways, lagoon loading rate, as well as labor and managerial capability. The first step in selecting an alternative manure management system is a clear assessment of the problems that the alternative system is intended to correct. Examples of problems may include odor impacts on neighboring property, excessive nutrient load for the land available, excessive liquid accumulation and difficult lagoon management,

excessive sludge accumulation, and general difficulty in complying with the Certified Animal Waste Management Plan (CAWMP). Other types of problems may include a change in regulations that requires a change or a change in pig marketing arrangements that requires a change in manure management.

In evaluating the problem(s) to be corrected, farmers must identify the cause of the problem. For example, if an odor problem exists, is the source of the odor the lagoon, the spraying of effluent, the buildings, or some combination of these sources. Replacing the lagoon may not solve the problem if the lagoon was not the source. Furthermore, the manager should determine whether the technology or the management of the technology is at fault. The use of expert evaluators such as the NPPC's On-Farm Odor/Environmental Assessment program may help farmers clearly identify the problem.

Before proceeding to selection of an alternative manure management system, it is important to consider other options for addressing problems. Other options may include changing the diet of the pigs. Increased phase feeding, amino acid supplementation, phytase supplementation, and reduced "safety margins" of minerals and metals are among the diet changes that can substantially affect manure management. Other changes may include changes in facilities such as flooring, ventilation, and type of feeders and waterers. Changes may also include increasing the sprayfield area receiving effluent, changing the crops receiving effluent, planting trees to create visual buffers and alter air movement, installation of "windbreak walls" or "washing walls", and changing management practices to reduce problems.

Criteria to Consider in Selecting an Alternative System :

Important criteria may include the following.

1. Regulatory acceptability: no system is feasible unless it can be approved under current regulatory procedures.
2. Land requirement: how much land is required to receive nutrients from all by-products of the system including liquids, separated solids, sludge, and biosolids? Is this land available on the farm or on neighboring farms willing to sign an agreement?
3. Labor and managerial requirement: how much labor and management of various skill levels is required to maintain and operate the system? Is this labor and management available on the farm or through service contract?
4. Risk/reliability under adverse conditions: how will the system perform when the electricity fails, when extremes of temperature, precipitation, and wind occur, when equipment breaks down, when foreign objects enter the system, when labor is absent, et cetera? What contingency plans or features are in place to make the system safer.
5. Liquid accumulation and effect of heavy rainfall: extreme variation in precipitation is a characteristic of the climate in Eastern North Carolina. How will the system handle periods such as September, 1999?
6. Susceptibility to spills: how susceptible is the system to spills due to failed pumps, plugged or broken pipes, dam failure, human error, or weather extremes? What safety or backup features are part of the system to minimize the frequency of spills or the damage done by spills?

7. Seasonal performance: how does the system perform across different seasons? Many treatment components rely on microorganisms to digest organic matter. These systems may have much lower treatment rates during cold seasons. Ice formation may be another seasonal consideration on some components.
8. By-products volume and value/market: Some systems produce separated solids and/or sludge or biosolids and propose to market those products off the farm. Careful consideration of the storage and handling of those byproducts and a frank evaluation of the actual market (quantity and price) for the by-products is required. Will that market exist for the life of the facilities and if not, what is the alternative outlet for the by-products?
9. Compatibility with existing building design: will the system work with the existing building design and if not what retrofits are required? Will the retrofits have an impact on pig health and performance and/or worker health and satisfaction?
10. Odor: How will the system affect odor at the property line, from the buildings, from storage facilities, from handling and land application?
11. Nutrient fate/form and concentration: how will the system affect the quantities to be land applied of nitrogen and phosphorus and other nutrients of concern? Where do the separated quantities of nutrients go?
12. Fate of pathogens: what is the fate of pathogens and where do they go in this system?
13. Initial investment, annual costs and benefits: finally, what are the initial capital requirements and annual costs and benefits of this system? Are these costs added to the costs of the existing system?

Compatibility of the system with other enterprises on the farm and potential benefits to the pig enterprise are additional criteria to be evaluated. This list of criteria will be augmented according to criteria developed by the North Carolina Department of Environment and Natural Resources' (DENR's) lagoon risk assessment working group over the next few months.

Since many of the alternative technologies are highly experimental and unproven on pig farms, another criteria may include the warranty provided by the technology supplier. To what degree can the vendor guarantee the promised operation of the technology? If it fails, to what degree can they accept the liability? In the event of the vendor's bankruptcy, what guarantees and financial protection are left in place for the farm? A faulty manure management system can jeopardize the entire investment in the farm through permit violations and liability claims.

Assessing Costs and Benefits of Alternative Systems :

Costs include initial investments to modify or replace existing systems less any cost share or tax credits received. Annual costs of the system will include amortization of the initial investment net of cost share plus recurring expenses such as electricity, supplies, royalties, repairs, maintenance and service agreements, labor and professional oversight. Annual costs may be reduced by tax credits, cost share, utility price reductions, and low interest credit. Annual benefits may include savings in any of the categories listed previously plus receipts from sales of by-products, or savings generated by use of by-products on the farm. Benefits may also include improvements in pig performance and increased crop revenue on land released from sprayfield requirement. Reduced fines,

legal expenses, and management time spent on conflict resolution are other benefits to be considered.

Cost estimates for technology with a limited history of on-farm operation are extremely sensitive to some of the assumptions that must be made due to limited data. Some of the critical assumptions in projecting costs are listed below.

- a. Expected life of capital investments such as buildings, equipment and earthen structures is an important assumption. The annual amortization per \$1,000 invested at various interest rates and years of life appears in Table 1. Note that at an annual interest rate of 9%, the annual cost per \$1,000 invested can range from \$97 over 30 years to \$1,090 in one year.

Table 1. Annual Amortization Cost per \$1,000 Invested at Various Interest Rates and Years to Repay

Years	Annual Interest Rate					
	6%	7%	8%	9%	10%	11%
	(annual cost per \$1,000 invested)					
1	\$1,060	\$1,070	\$1,080	\$1,090	\$1,100	\$1,110
3	\$374	\$381	\$388	\$395	\$402	\$409
5	\$237	\$244	\$250	\$257	\$264	\$271
7	\$179	\$186	\$192	\$199	\$205	\$212
10	\$136	\$142	\$149	\$156	\$163	\$170
15	\$103	\$110	\$117	\$124	\$131	\$139
20	\$87	\$94	\$102	\$110	\$117	\$126
30	\$73	\$81	\$89	\$97	\$106	\$115

- b. Prices of inputs and outputs are important assumptions. In some cases, actual prices of ingredients can be obtained and secured. In other cases, wide ranges of prices exist in the market so an appropriate local price should be selected. For example, electricity can be priced from \$0.035 per kilowatt-hour (kWh) up to \$0.105 per kWh depending on the location and the service provider. Farmers should select the prices that will apply to that farm to estimate costs and benefits. A farm that can buy electricity at \$0.035 per kWh may find technologies that use more electricity to be relatively more competitive.
- c. Prices for by-products such as separated solids, sludges or biosolids, electricity and heat are very speculative assumptions. In many cases, there is little data and few existing markets for such products. A feed value or a fertilizer value can be imputed for some by-products based on the nutrient content. Whether or not buyers would find the product acceptable and would pay the imputed price remains in question. Prices for electricity sold back to electricity companies are very dependent on local

conditions including state regulations and utility company rules. Where the feasibility of a technology is dependent on a market for the by-products, a guarantee with financial security may be required to justify a long term investment.

- d. Physical flow rates and nutrient concentrations are important assumptions. In some cases, they are based on data from research trials. In other cases, they are projected based on technology vendors' best estimates. Regardless of the source of the number, the actual performance of a system on a farm may produce quite different results. Without several years of experience and data from a large number of systems, it is difficult to know the accuracy of the physical flow rate and nutrient concentration assumptions. In the case of pilot scale evaluation projects, some critical performance data could not be collected. For example, use of an oversized blower and a heater resulted in very high electricity use per gallon treated by a sequencing batch reactor. The vendors project that the full scale system will achieve similar treatment performance with a tiny fraction of the electricity use per gallon treated. That assertion cannot be tested until a full scale system is built and tested.
- e. Numerical values for environmental effects are omitted from the alternative technology budgets in many cases. Insufficient data exists even to project a variety of environmental effects from alternative manure management technology. Examples of unpredicted variables may include odor level, intensity, offensiveness, and frequency at the property line, nitrate levels in shallow groundwater under sprayfields and lagoons, nitrogen levels in surface water, phosphorus levels in surface water, ammonia and other nitrogen compound deposition from volatilized ammonia, pathogen levels in groundwater, surface water, and air, and dust levels in air at the property line. Data of this type can only be collected from full-scale systems operating on a variety of farms for several years.
- f. Cost share, tax credits and deductions, and other government program benefits and costs are omitted from alternative technology budgets. In many cases, it is unclear whether or not benefits will be available and to what level. These costs and benefits may be county specific and should be added when individual farm plans are being developed.

Selected Alternative Manure Management Systems :

A wide range of manure management technology evaluations are underway or have been completed. A few of those are discussed below. The following comments are grouped by the type of technology and the type of technical evaluation that was conducted or is being conducted (pilot scale versus farm scale). A number of evaluations involve components that may be used as add-ons to existing lagoon systems or as components of other manure management systems. Costs are characterized here as low (less than \$1 per hog finished (finishing phase only) above existing lagoon system costs), moderate (\$1 to \$3 per hog finished above lagoon system costs), and high (more than \$3 per hog finished above lagoon system costs).

1. A number of evaluations involve partial aeration. Among those completed are Newman Environmental Systems fine bubble aeration and the partial aeration project conducted by Diana Rashash. In tests on a single lagoon, each of these demonstrated a small effect on the lagoon liquid parameters. Costs were in the moderate to low range including amortization of investment in the equipment and the electricity to operate the aerators. The BION system uses aeration in some of its cells but also involves additional earthwork and plumbing. The BION system is currently being evaluated by an NCSU team.
2. Several projects involve solids separation. Dr. Rashash evaluated a Key Dollar separator using various screen sizes and various levels of polymer addition. A helisieve separator was evaluated in the Tangential Flow Separation project by Dr. Westerman and others. The EKOKAN and AWASH projects also included solids separation. A number of current and proposed projects also include evaluation of solids separators. Zhang and Westerman provide a review of engineering studies of solids separation. They find that from 0 to roughly half of TKN, phosphorus and COD can be removed. Costs of separation range from low to moderate to high with costs increasing as efficiency of separation increases and the use of polymers increases. More work is needed to model and estimate the costs of solids storage and land application after separation. Solids separation may relieve the load on an existing lagoon and may increase the land required to receive swine manure nutrients. Separation and possibly further treatment (composting or dewatering) may add to cost and allow less expensive transport off the site. Effects of solid separation on odor levels at the property line remain to be determined.
3. Lagoon covers have been demonstrated in the Barham Agstar project and the Ramsey Farm project. A substantial drop in price of the cover material (to \$0.46 per square foot installed) dropped the cost of covering the treatment component only of a lagoon into the low cost category. Recent increases in petroleum prices may have increased the cost of the cover. Covering only the treatment component of the lagoon will require additional earthwork for existing single stage lagoons and will increase the cost. At the Barham farm separate evaluations are being conducted on use of methane to generate electricity and on the use of methane to heat water for use in farrowing room heat mats. A detailed initial evaluation of the Barham farm is due to be completed as this article is being printed.. An unknown included in the cost estimates is the life of the cover and the other equipment being evaluated there. Benefits may include reduced air emissions from the lagoon and rainwater exclusion from the lagoon in addition to the by-products.
4. Intensive aeration has been evaluated in the EKOKAN and NET projects and in the Sequencing Batch Reactor (SBR) project. Cost of the NET project was very high. The EKOKAN and SBR projects were pilot scale so only projected costs are available. Those projected costs are in the moderate to high range depending on the degree of treatment and the value assigned to by-products. The EKOKAN and SBR projects produce a stream of sludge or biosolids from the aerobic process. These latter two technologies were recommended for full scale evaluation so that better cost

estimates and farm scale performance can be measured. Benefits may include reduced ammonia volatilization, low nitrogen and odor levels in the irrigated water, and a more concentrated nutrient level in the biosolids by-product. Westerman and Zhang reviewed engineering studies of aeration and found that the typical electricity cost to completely treat finishing hogs' manure using aeration was \$14 per pig space per year at \$0.09 per kW-h. This equates to \$5.38 per hog at 2.6 groups per year. They found that \$2.335 per hog finished in electricity costs would be required to attain partial odor control with aeration.

5. Chemical separation of phosphorus was demonstrated in the Tangential Flow Separation system. The cost was in the high range and the process was effective at separating phosphorus from flush water leaving finishing buildings.
6. Constructed wetlands have proven successful in a pilot scale project at reducing (TKN) nitrogen levels in lagoon effluent. Costs are projected to be in the moderate to high range depending on design and loading rate. A farm scale project is under development to further evaluate cost and performance.

Other systems for which less data is available include thermophilic digestion, "high-rise" houses with dry manure handling, hoop structures, and other systems and modifications. A new round of technology evaluations is currently being initiated at the NCSU Animal and Poultry Waste Management Center.

Summary :

Selection of an alternative manure management system includes identification of problems to be corrected, evaluation of alternative systems by a set of criteria, and identification of the system(s) that best fits the needs and circumstances of the farm. The criteria discussed and questions to be answered about alternative systems provide guidance for further research and development of alternatives currently being evaluated.

Farmers should consider a list of criteria in consultation with their technical advisers when selecting an alternative manure management system. Financially assured guarantees should be obtained in cases where the farmer is exposed to large capital investments and liability by installing alternative technology with a limited history of on-farm performance.

References:

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