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Selecting a Treatment Technology for Manure Management

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Animal manure has been used for centuries as a fertilizer and a soil builder because it contains nutrients and organic matter. However, as animal production shifts toward fewer but larger operations, the number of confined animals has increased in some geographical locations, resulting in more manure produced than can be assimilated by the available farmland where the animals are raised. If manure is not managed properly, the potential for air, water, and soil pollution become environmental concerns. One way to avoid the negative environmental impacts of manure nutrients is through treatment prior to land application.

This publication provides guidelines to help those considering installing or upgrading manure-treatment systems or technologies on their farms. Specifically, an overview of the basic principles underlying manure-treatment systems and some questions to ask technology providers in order to make an informed selection of appropriate farm technology are presented.

Why Treat Manure?

Questions to consider when evaluating whether to treat manure generated on your farm include:

- Do you have enough land to apply all the manure produced to meet the agronomic needs of crops?
- Is salt accumulating in the soil where manure is being applied?
- Is nitrate or salt in groundwater or nutrient enrichment of surface waters a local concern?
- Do community members complain about your manure application activities?
- Are odors and/or gaseous emissions from your farm a concern to citizens and/or a regulatory authority?

If the answer to any of these questions is yes, then there exists a potential to install manure-treatment technology.

The objectives of manure treatment depend on the needs of a particular farm and applicable regulations. However, some common objectives of manure treatment are:

- stabilization of the manure,
- odor reduction,
- nutrient management,
- proper storage and use,
- pathogen reduction, and
- reduction of gaseous emissions such as ammonia, hydrogen sulfide, and greenhouse gases.

Properly treated manure can result in:

1. Manure with reduced or balanced quantities of nutrients. Manure with balanced nutrients has the potential of minimizing the risk of nutrient pollution of the environment if used as a crop fertilizer.
2. Reduced manure mass and less material to transport and apply to crop land.
3. Reduced concentrations of pathogens and antibiot ics in animal manure.
4. Value added byproducts, such as, energy (heat, electricity), fertilizer, and organic matter that can be used on the farm or sold to provide an extra income source to the farm.
5. Increased costs and labor requirement to manage manure.

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What Technologies Are Available?

Several treatment technologies are available in the open market, and vendors and environmental groups are recommending the use of some of these technologies. Regardless of their names, these technologies use a physical, chemical, or biological process – or a combination of these processes – to treat manure. Therefore, if you have an understanding of the processes, you should be able to understand how the treatment technologies work.

Some of these technologies have been investigated or evaluated by organizations, including government agencies, universities, corporations, and farmers, to test their suitability for use on farms. In general, manure-treatment technologies – or alternative technologies, as they are referred to at times – are evaluated or selected based on their ability to provide the required protection of soil, water, and air resources, i.e., their effectiveness in reducing odors, gaseous emissions, and pathogens and in managing nutrients from animal-feeding operations. In some cases, the treatment or alternative technologies can address several of these requirements, while some address only individual resources or waste constituents. However, long-term success of the treatment systems is still in question. There are concerns about affordability, effectiveness, and long-term environmental and social impacts associated with some of these treatment technologies.

Principles of Manure-Treatment Processes

The basic principles underlying manure-treatment systems or technologies can be grouped into: physical, chemical, and biological processes. Manure-treatment technologies typically include one or a combination of these basic processes.

Physical

The treatment of manure or wastewater can happen by or through application of physical forces. Physical processes include those technologies that involve liquid-solids separation and/or the use of heat and pressure. Liquid-solids separation can be achieved through settling (sedimentation) or by using mechanical methods (e.g., use of screens, centrifuges, or belt presses). Advantages of liquid-solids separation include concentration of solids for separate treatment or reuse, reduction of solids that can settle before treating and storing manure in lagoons, and prevention of clogging of manure pipes. In combination with chemicals, liquid

Figure 1. Examples of manure separators used in liquid-manure handling

-solids separation can be used to remove nutrients from manure. Other physical methods include drying, incineration, pyrolysis, combustion, and gasification.

Chemical

Principal chemical processes for wastewater include chemical coagulation, chemical precipitation, chemical disinfection, chemical oxidation, chemical neutralization, chemical stabilization, and ion exchange. Chemicals, in conjunction with physical processes, can be used to remove nitrogen, phosphorus, and heavy metals. Chemicals have also been used to control odors and pH and to remove organic compounds. It should be noted that adding chemicals means adding external material into the manure-treatment system that is not generated on the farm, thereby increasing the volume of the waste stream to be handled after treatment.

Biological

Biological-treatment systems or processes are designed to oxidize dissolved and particulate biodegradable constituents of manure into acceptable end products, and to transform or remove nitrogen and phosphorus. With proper environmental controls, all wastewater containing biodegradable constituents can be treated biologically. Biological processes make use of naturally occurring microorganisms to degrade manure in the presence of oxygen (aerobic) or absence of oxygen (anaerobic). It is important that the characteristics of each biological process be understood to operate biological-treatment-based technologies efficiently.

In aerobic processes-based technologies, oxygen is provided to the manure so that microorganisms can:

- Remove organic matter, often referred to as biochemical oxygen demand (BOD) or chemical oxygen demand (COD).
- Remove nitrogen and phosphorus through biological uptake.
- Manage nitrogen by converting ammonia in the manure to nitrogen gas (through a process called nitrification and denitrification).

Figure 2. Chemical application to manure in storage tanks for phosphorus removal; struvite recovery reactor from manure to recover phosphorus.

Figure 3. Full-scale manure-treatment technologies on farms using manure separation and aeration.

Anaerobic-treatment processes occur naturally in soils or in engineered systems, such as reactors (digesters) or landfills, in environments where there is no oxygen. The major benefits of anaerobic treatment based processes are reduced COD or BOD and solids; production of methane gas – a potential energy source; less energy required compared to aerobic processes; and less biological-sludge production compared to aerobic processes. Anaerobic digestion does not reduce manure's nitrogen and phosphorus content, and has the potential of producing odor and corrosive gases.

Selecting a Technology

The first step in selecting a manure-treatment system or technology is a clear assessment of the problem that the treatment system is intended to correct. Some examples of the problems may be excess nutrients for the land available on the farm, odor impacts on neighbors, manure storage capacity issues, complying with the nutrient management plan, and changes in regulations requiring change in manure management. Use of the county Extension service and consultants in manure management may be helpful in identifying the problem if the farmer is not fully knowledgeable in the subject matter. Also, it is important to identify the primary source of the problem. For example, if an odor problem exists, is the source of the odor the barn, the manure storage pit, land application of manure, or a combination of these activities? Covering the manure storage pit may not be the solution if the manure pit is not the source.

Secondly, it is important to understand how the treatment technology works, and base selection on the ability of the technology to meet the objectives determined in the first step, i.e., provide protection to soil, water, and air quality.

Thirdly, consider all the options available for addressing the problem identified. Options may include changing the diet fed to animals; changing the way manure is handled and managed on the farm; increasing land area for manure application; or planting trees to create visual buffers and alter air patterns (if odor is the problem), as well as to enhance the aesthetic perception of the farming operation. Remember that some manure-treatment systems address several concerns, while others are very specialized, addressing only individual manure constituents.

Figure 4. Manure-treatment options showing aerated ponds, lagoons, manure storage tanks, and solid-manure storage structure.

Questions to Ask or Consider When Selecting a Manure-Treatment System

In general, base selection of a manure-treatment system or technology on economics, engineering, regulation, and public reaction as they affect your operation. Some questions that may be helpful in selecting a technology are presented below:

Technology

- Is it necessary to pretreat manure before running it through the treatment system?
- Are any chemicals added to manure to enhance the treatment process? If chemicals are added, what is the fate of the chemicals?
- Will the manure-treatment system or technology operate continuously? What happens when the system shuts off or breaks down?
- Is there enough storage for the manure before and after treatment?
- How does the treatment technology perform over different seasons? Many biological-based systems may slow down during the cold season if temperature is not maintained at the optimum levels for microbial growth.
- How will the treatment technology perform under adverse conditions, such as extreme wind (tornadoes, hurricanes), excessive precipitation, electric failure, introduction of foreign objects or materials into the system, or lack of labor? What contingency plan does the technology have to make it safer under these circumstances?
- How much time per day is required to operate the system?
- What are the operation and maintenance requirements?
- Who will design the system and provide startup assistance and continuing support?
- What is the life expectancy of the equipment?
- Are there any projected byproducts that can generate revenue?

- Has the technology been installed on similar farms? If it has, contact the farmers to find out their experience with the technology. What has been their experience? If they were to do it again, what would they do differently?

- How compatible is the technology with existing buildings and other structures on the farm? If retrofits are required, how easy will they be? How will the retrofits affect the production and health of the animals?

- How much land area does the treatment technology need for installation?

- Is the technology specialized and with limited use?

- Can the technology be easily adapted to future changes on the farm?

Fate of Nutrients, Pathogens, and other Pollutants

- How does the technology affect the nutrients in manure? Are the nutrients reduced or transformed into other byproducts? For example, if phosphorus is removed, where does it go and how much is left in the manure? If nitrogen removal is proposed, what form of nitrogen will result? If nutrients are transformed, into what forms?

- How does the technology affect the value of the manure as a nutrient? Some technologies will convert nutrients into forms that are more available to plants (e.g., soluble phosphorus, nitrate, ammonium).

- Soluble nutrients can be lost to the environment more easily. What quantity of nutrients will be left in the different product streams from the treatment system to be applied to cropland?

- How much land is required to utilize all nutrient streams generated by the treatment technology?

- Is land available on the farm? If the land required is not all available on the farm, where is the land area located for the balance of remaining nutrients?

- Are pathogens reduced by the treatment system? If they are reduced, where do they go?

Other Byproducts and Energy Requirements

- What other byproducts (beyond nutrients recovery) are generated by the technology, and what are their economic values? How much of each of the byproducts is produced, and what is the market for them? Will any of these byproducts require special handling and storage?

- If energy is generated by the system, how much is produced, and can the energy generated be used on the farm?

- Does the treatment system require energy to operate? If so, how much energy will it need, and what are the associated costs?

Technology Provider

- Who is the vendor? Does it have a presence locally or regionally?

- How much experience does the provider have with this technology, and what is its reputation?

- What warranties and post-installation services does it offer? To what degree does it guarantee promised operation of the technology and accept liability if the technology fails?

- Should the vendor go bankrupt, what guarantees and financial protection does the farm have?

Economics

- How much does the treatment technology cost? What is the capital investment and annual operating cost? What is the payback period for the technology?

- What financial help is available to install the technology? Are there any tax incentives associated with the technology?

- Can environmental benefits be quantified monetarily? If so, what is the value?

Regulatory and Environmental Impacts

- How do products of the manure-treatment system or technology impact the environment? How will the technology affect odors generated during normal farming operation and land application?

- Does the technology require permitting before installation? What are the permitting requirements? How will permitting requirements be met?

- Are there federal laws regulating the products from the treatment system?

- How will regulations impact the farm or operation (e.g. nutrient management plan)?

Making a Decision

There is no single technology that is the "best." Each technology and its components have advantages and disadvantages. The best manure-treatment technology depends on personal preferences, available capital and labor, waste sources, soil type, cropping practices, skills needed to use the technology, and a number of other factors. Therefore, in making a selection, evaluate the need for a manure-treatment technology very objectively based on current challenges and planned expansions on the farm.

Also, consider the growth and changes in the community surrounding the farm; for example, how close your neighbors and streams or watercourses are to your livestock center. Other issues to consider include climatic conditions and weather patterns, water-pollution potential, and how changes in regulations governing manure use affect the operation.

When changing, expanding, remodeling, or rebuilding an operation, consider alternative or management options that are more efficient and cost effective, e.g., different kinds of housing, various types of handling equipment, and disposal alternatives. Note that a new technology may require changes in manure handling and equipment.

To make a change worthwhile, processes need to be cost effective, labor efficient, environmentally friendly, and reliable year-round. Thus, the technology will be valuable if it improves the efficiency and productivity of the operation and if the environmental benefits derived from the technology equal or exceed the technology's installation and operation costs.

It is also important to verify performance claims made by technology providers. Ask for data and an explanation of how the claims of the percentage removals or reductions were calculated. Make sure that calculations meet the goals previously established for the technology. Data to support the performance of the technology must be collected within appropriate ranges of key operating parameters, such as feed rate, feed characteristics, temperature, reagent dosages, hydraulic-loading rates, etc. It is important to know the operating conditions and typical ranges that are representative of the process, because these must be stated in the performance claim. A verified claim is only valid if the technology is operated within the operating conditions stated in the performance claim.

Glossary

Aerobic process: Biological-treatment process that occurs in the presence of oxygen.

Anaerobic process: Biological-treatment process that occurs in the absence of oxygen.

BOD: Biochemical oxygen demand is the rate at which microorganisms use oxygen in water or wastewater while stabilizing decomposable organic matter under aerobic conditions. During the decomposition process, the organic matter serves as food for bacteria. BOD is used as a measure of the organic strength of a wastewater.

Coagulation: The clumping together of very fine particles into larger particles, caused by using chemicals (coagulants). The chemicals neutralize the electrical charges of the fine particles, allowing them to come close together and form larger clumps. The clumping makes it easier to separate the solids from a liquid stream by settling, filtering, or decanting.

COD: Chemical oxygen demand is a measure of the oxygen-consuming capacity of a wastewater. COD is expressed as the amount of oxygen consumed from a chemical oxidant in mg/L during a specific test. COD results are not necessarily related to BOD, because the chemicals' oxidant may react with substances in the wastewater that bacteria do not stabilize.

Combustion: A complex sequence of chemical reactions between a fuel and an abundance of oxygen that generates heat. Sometimes it is referred to as rapid oxidation. The reaction occurs between 800°C and 1,000°C (1,450°F to 1,850°F).

Denitrification: The biological reduction of nitrate and nitrites to nitrogen gas.

Flocculation: The gathering together of fine particles after coagulation to form larger particles through a process of gentle mixing.

Gasification: The conversion of carbonaceous material into a combustible gas mixture by partial oxidation (controlled amount of oxidant) of the material at high temperatures. The temperature range for gasification of biomass is 800°C to 1,800°C (1,400°F to 3,200°F).

Incineration: A thermal-treatment process in which organic matter is destroyed by burning at high temperatures of 760°C to 1,100°C (1,400°F to 2,000°F) in a furnace producing ash, flue gases, particulate matter, and heat. The combustible fractions of the manure are burned off and the mineral matter is left as an ash.

Nitrification: The aerobic process in which bacteria change ammonia into an oxidized form of nitrogen (nitrites and nitrate).

Oxidation: The addition of oxygen, removal of hydrogen, or removal of electrons from an element or compound. In treatment of wastewater, organic matter is usually oxidized to more stable substances.

Pyrolysis: The chemical decomposition of organic materials by heat in the absence of oxygen. The process creates three byproducts: char, bio-oil, and gas, depending on the temperature and heating rate.

Stabilization: Conversion to a form that resists change. In manure, the stabilization process results in material that cannot be further or easily decomposed, so the rate and state of manure decomposition would not change to cause any nuisance or odors.

Other Resources

North Carolina State University. Revised 2007. *Development of Environmentally Superior Technologies Reports. https://projects.ncsu.edu/cals/waste_mgt/smithfield_projects/smithfieldsite.htm*

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