## Manure Utilization and Treatment Technologies

### Land application

Land application, which is used as a terminal receiver for untreated manure and many treatment technologies, is discussed in detail in other curriculum lessons.

### Byproduct recovery

Many systems are being developed that process the manure nutrients derived from separated solids and biomass or sludge into value-added byproducts. Raw and composted manure and mortalities have been processed to such value-added byproducts as fertilizer, animal feed, and crab bait.

Animal manure and mortalities can be mixed with other organic materials or waste products and processed by extruding, drying, and pelletizing prior to dry storage as a feed or fertilizer. For example, fermentation and preservation systems for converting poultry mortality mixed with sweet potato waste into value-added products are also being studied. Turkey litter is being processed to produce a cattle feed ingredient, and deep-stacked poultry litter processed to enhance its value as a cattle feed ingredient. Deep-stacked poultry litter is also being evaluated as a protein supplement for animal feed. Details on some of these byproduct recovery technologies and systems follow.

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### Composting

Composting is a natural aerobic process that stabilizes a variety of organic matter ranging from forest litter to horse and cattle manure. It is one of the major recycling processes by which materials return to the soil in the form of nutrients available for future use.

More recently, engineered systems that convert manure from livestock and poultry into compost have become popular. Some of this popularity has been based on the concept of converting manure from a financial liability into a value-added marketable product. Examples abound in which compost is being produced from manure and other waste materials at a profit, but other examples can be cited in which compost production and marketing have not been successful enough to justify costs. In Korea, swine manure that does not exceed the maximum allowed moisture content is composted at a large cooperative facility without additions. A large rotor revolves and travels through a bin-like structure to aerate and continuously move the compost from the input section to the output section where the compost is bagged. Marketing of the bags with colored representations of plants that would benefit from this composted product has been successful.

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**Benefits.** When animal manure is composted, the available organic matter is stabilized to the extent that it is no longer readily decomposable and no longer subject to further anaerobic decomposition with its associated odors. Well-composted animal manure has the odor of humus and is most acceptable for land application in locations where fresh manure would be objectionable. Volume reduction ranges from 25% to 50%, depending upon the initial material. Because of the heat produced during composting, well-controlled composting results in the destruction of both pathogens and weed seeds. If dead animals are used, some ingredients, such as feathers, teeth, and bone fragments that resist composting, may be removed by mechanical screening if

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necessary.

The extent to which N is conserved in the composting process depends largely on the carbon-to-nitrogen (C:N) ratio in the feed material. If the feed has a C:N ratio of 30 or above, little N loss occurs. If the ratio is less than 30:1, as is the case if manure is the principal ingredient, ammonia release tends to raise the ratio. If the ratio is 20:1, N losses can be as high as 40%. Carbon-to-nitrogen ratios above 30:1 generally result in nearly complete N conservation that may require a longer time to reach completion because the N is a limiting nutrient.

Composting is most frequently adopted by livestock producers who have a market for the finished product. That market may be nearby garden or nursery supply outlets, landscaping services, or contractors establishing lawns or landscaping after a construction project has been completed. Cities frequently use compost to establish and maintain parks and other recreational areas. The advantages of compost over fresh manure are the reduced odor, fly attraction, pathogen and weed seed concentration, and according to many horticultural studies, a better plant response due to the addition of stabilized organic material that builds better soil tilth. The disadvantages are the additional processing cost and the need to remove and manage a large amount of solids in the manure management system. Thus, like other alternative or advanced treatment technologies, composting is not compatible with all livestock operations. A thorough analysis of the advantages and disadvantages for an individual site is important.

**Temperature.** Aerobic fermentation releases a considerable amount of heat during the composting process. The composting material retains this heat, and elevated temperatures result. However, high temperatures are essential for the destruction of pathogenic organisms and weed seeds. Decomposition also proceeds more rapidly in the thermophyllic range than at lower temperatures. The optimum temperature is around 60ºC (140ºF).

**Moisture content.** Moisture is necessary for microorganism growth, but excessive moisture displaces the air that is necessary for microorganism growth. The ideal moisture content for composting is between 40% and 60%; the upper limit somewhat depends upon the material being composted. If the material contains straw, it may be possible to operate successfully well above 60% moisture, because straw retains its strength at higher moisture contents and still allows air to freely move through the pile. Waste paper, in contrast, becomes very soggy at 60% moisture and packed with sufficient density to exclude air. Thus, a compost pile containing waste newsprint needs to have a lower moisture content.

**Aeration and turning.** Aeration is necessary during thermophyllic aerobic digestion in order to produce a high-quality compost and to avoid nuisance conditions during composting. Aeration can also be used to overcome an initial moisture content that is too high.

If a compost pile becomes anaerobic as indicated by odors or by a temperature drop during the first 7 to 10 days, then turning is required. No matter how anaerobic a compost pile may become, frequent turning and aeration will handle the situation.

**Inocula.** Throughout the history of engineered composting processes, the development and marketing of inocula and enzymes to aid the composting process have steadily increased. If the initial waste materials to be composted were sterile, a scientific basis would exist to support the addition of microorganisms. Since that is clearly not the case with manure composting and because composting processes throughout the world operate successfully without microbial or enzyme additions, it must be concluded that inocula or other additives are not essential in the composting of waste materials, including animal manures.

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## Vermicomposting

Vermicomposting is a process where earthworms and microorganisms convert organic materials into nutrient-rich humus called vermicompost. The resulting vermicompost can be used as a soil amendment similar to conventional compost.

Removing the solids from a waste stream before a lagoon for vermicomposting or composting reduces lagoon loading and thus the potential of odor and ammonia volatilization. It also reduces the amount of land required to apply the lagoon liquid. Nutrients and organics diverted from the lagoon are stabilized by the vermicomposting process, making it easier to find off-farm uses for the product.

Methods for growing earthworms range from extremely simple techniques such as boxes and outdoor windrows to complex automatic systems with continuous flow reactors, overhead gantries, and automatic collection of castings or metabolic byproducts. In all of these systems, fresh organic manure is frequently applied to the surface of the worm beds where the worms concentrate. The fresh manure must be carefully added to maintain aerobic conditions and avoid excessive moisture. Following the vermicomposting process, the worms are separated from the castings or compost product. The worms are needed for the vermicomposting process and have high value for animal and aquaculture feed.

Vermicomposting of dewatered swine manure is currently being conducted on a farm in North Carolina that uses the manure solids recovered from a solid separator. The manure solids are applied to worm beds that are maintained in an enclosed greenhouse facility. After a period of processing, the final product is odor free and has excellent physical properties for use as a plant growth medium. The vermicompost product is quite consistent throughout the year because the composition of the manure does not change during the year and greenhouse use eliminates extreme environmental fluctuations.

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## Energy conservation

Alternative or advanced techniques for converting manure to energy result in the conservation of valuable manure constituents and reduction of odor and ammonia volatilization. The direct combustion of dry manure as a fuel source for a small electric generator could be an alternative. Anaerobic digestion has been used with beef, dairy, swine, and poultry manures to produce methane gas, which farm owners may use to produce electricity for on-farm use or sale to an electric utility. The resulting hot water also has energy value. The last section provides a case study that discusses a covered, in-ground anaerobic digester for waste treatment and energy recovery.

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## Animal protein byproduct recovery

As animal agriculture becomes increasingly integrated with more large-scale production units in geographically concentrated areas, animal protein byproduct recovery and utilization will become a higher priority. These animal byproducts are rich in C, N, P, and minerals. Environmental and public health regulations, economic scenarios, and technology availability are the main forces that govern the utilization of these byproducts. To solve present and future problems with animal agriculture byproduct utilization, technology research and development must be a priority. However, the social issues that accompany these technologies must always be considered.

## Mortality utilization

The proper disposal of mortality continues to challenge the livestock and poultry industries because of its implications for bio-security and public health, environmental safety, and public relations. Many of the current disposal options potentially risk environmental safety, contribute to groundwater and surface water contamination, cause odors and pests at disposal sites, and increase the risk of spreading pathogenic organisms.

The waste generated from normal poultry and swine farm mortalities is substantial. Normally, about 100 pounds of mortality is generated per 1,000 broilers raised to market and 500 pounds of mortality per 1,000 turkeys raised to market. Although these mortality mass figures are low, a broiler or turkey grower must commonly dispose of over 10 tons of mortality per flock each year. Considering all of the poultry produced in the United States, about 650,000 tons of poultry mortality must be managed per year. The swine industry must also manage an enormous amount of mortality carcasses because the annual mortality mass generated per sow is about 40 pounds. When the national production of swine is considered, over 180,000 tons of dead pigs must be managed in the United States. Using this waste product to produce value-added byproducts is an excellent alternative to other waste degradation treatment processes.

Recycling mortality carcasses as feed nutrients offers many advantages, such as recovering resources efficiently, minimizing nutrient emissions into the environment, and defraying waste treatment costs. Preventing spoilage and controlling pathogenic organisms by stabilizing waste products through direct acidification/pickling has been used as an alternative to fermentation for many years. On-farm preservation methods such as freezing, lactic acid fermentation, or acidification with phosphoric acid increase the storage potential of mortality carcasses, thereby reducing the transportation costs, by up to 90%, associated with daily pickup and transfer to a recycling facility. However, the high-energy costs, capacity limitations of freezer operations, and technical difficulties associated with biological fermentation have limited the acceptance of these technologies. The recent successful utilization of feed-grade phosphoric acid and equipment to preserve mortality has renewed interest in on-farm mortality preservation and storage technology. Widespread implementation of this automated technology is expected to significantly increase the proportion of mortality carcasses that are stabilized on the farm by direct acidification, and therefore, are available for conversion into feed nutrients.

## Producing nursery potting materials from animal byproducts

The results from over 20 studies indicate that animal waste components can be beneficial additions to the nursery potting substrates used to grow ornamental crops. These components can substitute for nutritional additives such as dolomitic limestone and minor element supplements. In addition, animal waste components tend to increase P tissue levels in crops that are frequently deficient when grown in standard nursery potting substrates.

Animal waste components provide nutrients early in the growth stage and serve the role of starter fertilizers that growers frequently apply. On the other hand, use of these components requires careful management of both nutrient application and irrigation management. Overall, nursery managers who have successfully produced a wide variety of nursery crops with varied container substrates can also successfully grow nursery crops using animal waste components in the potting substrate and benefit considerably from their use.

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## Reducing phosphorus (P) excretion to improve fertilizer use options

Applying livestock and poultry manure to land at agronomic rates for P requires more land because of the much lower animal manure application rates allowed and the fact that P has accumulated in many soils over time. As discussed in the curriculum lessons on animal dietary strategies, animal nutritional strategies are being developed that reduce N and P excretion. These strategies may result in a manure with more agronomically balanced levels of N and P, greatly increasing its possible use as a fertilizer.

## Reducing copper and zinc in swine and poultry diets to facilitate byproduct recovery

In recent years, soil zinc and copper concentrations have increased in some areas where swine and poultry manure have been applied, raising concerns about zinc and copper accumulation in soils to levels that reduce the production of certain crops. Therefore, high levels of copper and zinc in swine and poultry manure may restrict its use as a fertilizer and for other byproduct recovery processes. If zinc and copper intake is exceeded, relative to the animal's requirement, the amount excreted in feces increases. Animal nutritional studies are being conducted to formulate diets in which the mineral levels are close to the mineral requirements, resulting in manures with increased potential for byproduct recovery.

## Constructed wetland systems

Constructed wetlands simulate natural wetlands and have the same general components of landform, water, soil, plants, microbes, plant litter (also called organic matter, or detritus), and fauna. As a result of physical, biological, and chemical processes that take place in wetlands, many pollutants in the water flowing through the system are transformed or inactivated.

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**Wetland system experience.** A literature review funded by the U.S. Environmental Protection Agency (EPA) and by EPA's Gulf of Mexico Program compiled information for 68 different sites using constructed wetlands to treat wastewater from concentrated animal feeding operations (CAFOs). Table 25-2 shows the average treatment performance.

Of the 68 sites identified, 46 were at dairy and cattle-feeding operations, 19 were at swine operations, one was a poultry operation, and two were aquaculture operations. The herd sizes of the dairy and cattle-feeding operations ranged from 25 to 330 head with an average of 85 head. Dairy wastewater often included wastewater from milking barns and from feeding/loafing yards with varying characteristics. Cattle wastewaters typically came from areas where animals were confined. Before being discharged to the constructed wetlands, dairy and cattle manure was usually pretreated or diluted. At the 19 swine operations, the swine manure was collected from solid floor barns and paved lots using flush water or directly from slatted floors in farrowing or nursery barns. In many cases, the wastewater was pretreated in lagoons or by solids separation.

Although the percent reductions shown in Table 25-2 are good, the average outflow concentrations are not consistently low enough to allow discharge into surface waters. Instead, the effluent is usually collected and land applied. Because the levels of N and P are reduced, however, less land is required to apply the effluent at agronomic rates.

**Pretreatment requirements.** The high level of organic C, N, and solids in animal manure usually requires pretreatment by lagoons or solids separators. Otherwise, the wetland system can be overloaded with (1) oxygen-demanding pollutants and N that cause wetland plants to die and (2) solids that build up at the wastewater inlet.

**Types of constructed wetlands.** Several types of constructed wetlands can be used to treat animal wastewater and feedlot runoff: surface flow, subsurface flow, reciprocating, and floating aquatic plant systems. In some cases, natural wetland systems are used for municipal treatment, but they are not considered to be constructed wetlands and cannot legally treat animal manure.

Surface flow constructed wetlands are the most commonly used wetlands for treating animal manure and the type that the USDA Natural Resources Conservation Service currently recommends in the technical requirements of the Constructed Wetlands for Agriculture for Wastewater Treatment. The advantages of surface flow wetlands include the (1) ability to efficiently treat the high-strength manure associated with the discharge from animal lagoons and other pretreatment facilities; (2) relatively low construction costs compared with subsurface systems; (3) relative ease of management; and (4) ease of repair and maintenance if problems occur.

Subsurface flow constructed wetlands contain below ground level gravel, rock, or soil media through which the wastewater passes in a horizontal

**Table 25-2. Literature data for 68 different constructed wetlands that treat wastewater from CAFOs.**

| Wastewater Constituent | Average Concentration, mg/l | | Avg Reduction, % |
|---|---|---|---|
| | Inflow | Outflow | |
| 5-day BOD | 263 | 93 | 65 |
| Total suspended solids | 585 | 273 | 53 |
| Ammonium N | 122 | 64 | 48 |
| Total N | 254 | 148 | 42 |
| Total P | 24 | 14 | 42 |

Source: CH2M Hill and Payne Engineering 1996.

direction. The wastewater level remains just below the surface elevation of the porous bed. Subsurface flow wetlands have an advantage in cold climates because treatment occurs below the ground's surface and is thus somewhat insulated from the cold air. In addition, these wetlands have virtually no odors and mosquitoes. When properly designed, gravel-based subsurface flow wetlands efficiently remove biodegradable organic matter and nitrates from wastewater.

A major disadvantage of subsurface flow wetlands is the potential for plugging, which causes water to pond on the surface. The potential for plugging is much higher for livestock systems, which usually contain very high solids concentrations. In addition, the installation cost is typically at least five times more than it is for surface flow wetlands for the same area.

Reciprocating constructed wetlands recurrently fill and drain wetland cells, which promotes the sequential development of aerobic (unsaturated) zones and anaerobic (saturated) zones for nitrification and denitrification to remove N as N gas. The hydraulic retention time (HRT), frequency of reciprocation, reciprocation cycle time, and water depth are important operational parameters for system optimization. Although more expensive than lagoons or surface flow wetlands, reciprocating constructed wetlands may be the least-cost technology for simultaneously removing significant amounts of BOD, nutrients, and odor from pretreated wastewater.

**Wetland summary.** Overall, wetlands by themselves cannot consistently remove sufficient N and P to meet stream discharge requirements. They do show promise, however, for high N mass removal, meaning that much less land would be required for terminal application. Sequencing a nitrification pretreatment component before the wetlands can increase their N removal efficiency. Such systems could provide an alternative to anaerobic lagoons and still provide high levels of N removal with reduced ammonia volatilization and odor. As a result, much less land would be required for terminal application at agronomic N application rates. Preliminary studies indicate that only 10% to 15% ammonia volatilization occurs during summer conditions for constructed wetlands receiving lagoon liquid at the high N loading rate of 25 kg/ha/day.

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## Nitrification and denitrification alternatives

Nitrification is becoming an increasingly important component of total farm management systems for N conservation or removal. Nitrifiers oxidize ammonia to nitrite and then to nitrate N, which is a nonvolative form of N for fertilization. Once in a nitrate form, the transformation to N gas (or denitrification process) requires a source of C and an anaerobic environment. Such conditions are typically found in wetlands, lagoons, or liquid manure storage units.

Nitrifying bacteria compete poorly with heterotrophic microorganisms, particularly in manure treatment systems with high C or organic levels. Nitrifiers need oxygen, lower organic C, and a surface area for growth before sufficient numbers are present for effective nitrification. The results from three studies of nitrification are presented as case studies.

> Nitrification is becoming an increasingly important component of total farm management systems for N conservation or removal.

## List of alternative utilization and treatment strategies

Information on the following alternative technologies can be obtained at the following North Carolina State University (NCSU) website: <http://

**EXAMPLE PROBLEM**

**For a 4,000-hog finishing operation, calculate the total land required for a constructed wetland loaded at 15 pounds of total N per acre per day for 270 days of operation per year and for the required terminal land irrigation area based upon a N loading rate of 150 pounds of total N per acre per year.**

**Calculate the total land required for a constructed wetland loaded at 25 pounds of total N per acre per day for 270 days of operation per year and for the required terminal land irrigation area for 400 pounds of total N per acre per year.**

This comparison illustrates a conservative design with minimal ammonia volatilization from a constructed wetland at a low N loading rate and low level of N fertilization with a high constructed wetland loading rate that may result in ammonia volatilization and a high N fertilization rate that may result in increased groundwater nitrate levels. These results can also be compared with land requirements determined by agronomic rates for P.

www.cals.ncsu.edu/waste_mgt/apwmc/reactivities.html>

- Biofilter for Removing Odorous Compounds in Exhaust from Swine Buildings
- The Chemistry and Behavior of Phosphorus in Heavily Manured Soils
- Compositing as a Suitable Technique for Managing Swine Mortalities
- Conversion of Ensiled Poultry, Fish, and Sweet Potato By-Products into High-Value Poultry and Aquaculture Feed Ingredients
- Deep-Stacked Broiler Litter as a Protein Supplement for Dairy Replacement Heifers
- Developing Laboratory Techniques to Predict Nitrogen Release from Organic Wastes
- Development and Demonstration of a Fermentation: Preservation System for Converting Poultry
- Mortality and Sweet Potatoes Into Added-Value Products
- Evaluation of Alternative Constructed Wetland Systems for Swine Wastewater Treatment
- Evaluation of Fluidized-Bed Drying Technology for Recycling Poultry Litter as Bedding Material
- Evaluation of Wetland Plant Species for Use in Constructed Wetlands
- Genetically Engineered Microorganisms for Utilization of Ammonia and Other Nitrogenous Compounds from Animal Manure
- Grass and Riparian Buffer Treatment of Runoff from Land Receiving Animal Waste
- The Long-term Nutritional Value of Wastes for Crop Production
- Management of Animal Wastes in Support of Sustainable Agriculture and Quality of Water Resources
- Maximum Nonhazardous Soil Phosphorus Concentrations from Applications of Poultry House Litter
- Molecular Phylogenotic Survey of Methane-Producing Archaea in Animal-Waste Sludge

- Nitrogen Loss from Intensively Grazed Pastures Receiving Swine Lagoon Effluent
- Optimizing the Proteolytic Degradation of Animal By-products
- Optimizing the Use of Livestock and Poultry Manures as a Co-Substrate and Source of Inorganic Nutrients for the Biodegration of Hazardous Compounds
- The Potential of Thermophilic Anaerobic Fermentation of Biological Methane Production and Odor Control Using Swine Manure as Substrate: A Laboratory Evaluation
- Predicting Nutrient Release From Food and Animal Waste Products
- Production of Amino Acids and Peptides from Feathers and Other Proteniaceous Wastes Using Immobilized Keratinase
- Recovery of Solids from Flushed Swine Manure for Utilization
- Separation of Turkey Litter to Enhance Its Value as a Cattle Feed Ingredient
- A System for Development of Value-Added Products from Swine Manure and Peanut Shells
- The Use of Poultry Litter as a Co-substrate and Source of Inorganic Nutrients and Microorganisms for the ex situ Biodegradation of Petroleum Compounds
- Utilizing By-Products to Clean Air in Swine Buildings

The NCSU Animal and Poultry Waste Management Center continues to evaluate alternative treatment systems. A reference for project updates is given in Appendix A.

Tables comparing alternative treatment technology processes on the basis of constituent removal, constituent conservation, gaseous affluent, and cost are presented in Appendix B.

Producers with an existing system or selecting and implementing a new system can refer to the assessment tool contained in Appendix C. This tool will help them select a manure treatment system or alternative that meets their livestock and poultry production/manure management needs.