Alternative Technologies/Uses for Manure

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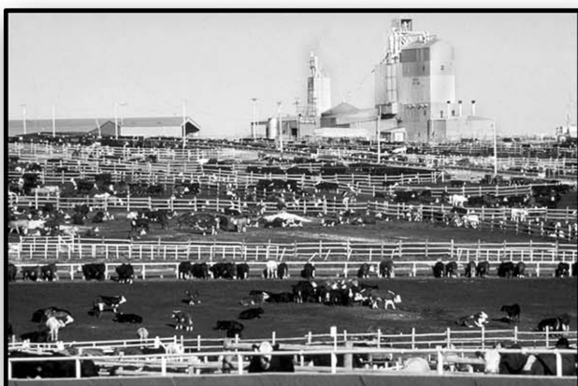

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CONTENTS

INTRODUCTION

Alternative Technologies/Uses for Manure is a compilation of alternative uses for manure from animal feeding operations (AFOs). This document serves as a reference concerning the use of alternative technologies to address situations where the overapplication of manure to croplands can cause excess nutrients to enter surface waters and ground water through runoff and other hydrologic processes. These excess nutrients can cause numerous water quality impacts. Utilization of these technologies may assist operators in meeting National Pollutant Discharge Elimination System (NPDES) permit requirements. The amount of information available and current level of implementation vary widely for the technologies/uses presented in this report.

Current Trends in the Livestock Industry

As a result of domestic and export market forces, technological changes, and industry adaptations, the past several decades have seen substantial changes in America's animal production industries. Despite support from the U.S. Department of Agriculture (USDA) for sustainable agricultural practices, these factors have promoted expansion of confined production in the following ways:

- Increase in the number of animals per facility.
- Growth of production facilities in existing and new livestock sectors.
- Integration and concentration of the livestock industry.
- Geographic separation of animal production and feed production operations.
- Concentration of large quantities of manure and wastewater in some watersheds.

Overapplication of Manure, Litter, and Wastewater

Traditionally, manure, litter, and wastewater produced at an animal feeding operation is applied to croplands and pastureland to take advantage of their nutrient value as fertilizers. The consolidation of the animal agriculture industry has resulted in the production of more manure derived nutrients than are needed to meet crop nutrient needs in some regions of the country. In these areas, nutrients that exceed crop needs and the soil's assimilation capacity can enter surface and ground waters through runoff and other hydrologic processes. Excess nutrients can lead to eutrophication and other water quality impacts.

Why Consider Other Utilization Options?

Due to the imbalances in the animal livestock industry, manure and wastewater from animal feeding operations have the potential to contribute pollutants such as nutrients, organic matter, sediments, pathogens, heavy metals, hormones, antibiotics, and ammonia to the environment.

Nearly 40 percent of the Nation's surveyed waters are too polluted for fishing or swimming. According to the1998 National Water Quality Inventory, approximately 60 percent of this pollution in rivers and streams and 45 percent in lakes comes from agricultural sources. An estimated 376,000 livestock operations confine animals in the United States, generating approximately 128 billion pounds of manure each year. Concentrated animal feeding operations (CAFOs) are the largest of these livestock operations and are regulated under the Clean Water. Alternative technologies/uses of manure may be the only practical methods to address this problem.

Manure Utilization Requirements

The USDA/EPA Unified National Strategy, issued March 9, 1999, includes a national performance expectation that all AFOs should develop and implement technically sound, economically feasible, and site-specific Comprehensive Nutrient Management Plans (CNMPs) to minimize impacts on water quality and public health.

Compliance with this performance expectation will be a requirement for those AFOs defined or designated as CAFOs and issued NPDES permits; compliance will be voluntary for all other AFOs. Other utilization options are one of the six components to be included in a CAFO's CNMP where the potential for environmentally sound land application of wastes is limited.

Contents of *Alternative Technologies/Uses for Manure*

This document is a compendium of technologies and uses that provide a snapshot picture of available manure use alternatives. The options discussed in this document describe uses for manure from animal feeding operations in lieu of land application for crops. It is based upon available information for the more common technologies and is not intended to address all potential options.

The first section of this document briefly discusses the treatment technologies that are used to convert the manure to a more stable product before a farmer uses the options presented in this document and exports the livestock's manure. The types of treatment technologies presented are physical, chemical, and biological.

The second section of this document presents two types of manure use options:

- Conversion to value-added products. Manure is converted into products that can be used as fertilizers, soil amendments, or feed additives. This document discusses the following technologies for conversion to value-added products:
  - Composting
  - Pelletizing
  - Livestock feed additive
- Conversion and use as an energy source. The energy generated from manure can be used for on-farm heating, on-farm electricity generation, and electricity that can be sold to a power company. This document discusses the following technologies that convert manure into an energy source:
  - Combustion (gasification and cofiring)
  - Biological conversion (anaerobic digestion)
  - Chemical conversion (methanol)

For each alternative use discussed, this document details the following information:

- Technology name and description
- Incentives for using this technology
- Technical and social barriers
- Cost information
- Has the technology been applied?
- Where has it been applied?
- Specific company information
- Other information

The last section of this document presents innovative and emerging uses that do not fit into the categories mentioned above. Because information in this final category is sparse, this section only briefly describes the use options and lists a contact name and/or company, if the information could be found.

The appendix at the end of this document presents specific organizations that can assist with obtaining and using alternative technologies. The organization, contact information, and the organization's website are listed, if available.

TREATMENT TECHNOLOGIES

The purpose of a manure treatment process is to convert the manure to a more stable product. Treatment processes fall into three categories: physical, chemical, and biological. The treatment process may be designed to (Prince Edward Island, 2000)

- Solve odor problems
- Recover nutrients or energy from the manure
- Kill pathogens and weed seeds
- Increase the fertilizer value
- Reduce the volume
- Decrease the pollution potential of the manure
- Prepare the manure for export

Physical Treatment

It is sometimes desirable to separate the solid and liquid portions of livestock manure. Solid separation converts the waste into a product that can be sold off the farm, given that a market has been developed (Huebner, 1999). A short discussion of exporting manure follows this section.

Solid separation may be desired for the following purposes:

- To reuse manure solids for bedding or refeeding
- To improve the treatment efficiency of vegetative infiltration areas and leach fields
- To use the liquids for flushing
- To reduce the volume of waste to be hauled

Centrifuges increase the effect of gravity by spinning the manure at high speeds. Centrifuges are small and can produce a substance consisting of 15 to 40 percent solids. The equipment requires routine maintenance (OSU, 2000).

Advantages:

- Centrifuges are a proven technology.
- Centrifuges produce a dryer material.

Disadvantages:

- Costs associated with a centrifuge are high and can not be fully recovered from the sale of the final product.
- It may be difficult to process large quantities with the use of a centrifuge.

Fresh liquid manure can be transferred to a *covered concrete tank*, where the solids are separated by settling. Conventional manure pumps are then used to agitate and remove the solids. Finally, the liquids are transferred from the concrete tank to an uncovered earthen manure storage (Prince Edward Island, 2000).

Advantages:

- Low-cost open storage, which has low nuisance potential, can be used for large volumes of liquids.
- Smaller volumes of highly concentrated manure, which contains the most offensive odors, can be placed in covered storage.

Disadvantages:

- The effectiveness of the covered concrete tank method of separation for odor control has not been quantified.

Drying or dehydration is used to reduce the volume of manure by encouraging the water to evaporate, thereby concentrating the solids. Dehydration is used primarily for odor control. Drying systems must be covered to protect them from rainfall, and supplemental heat or forced air is needed to encourage rapid evaporation (Ohio, 2000; Prince Edward Island, 2000).

Advantages:

- Dry manure does not support the growth of microorganisms or insects.
- Dry manure can be used as a soil conditioner in basically the same way that composted manure is used.

Disadvantages:

- Costs associated with moisture removal are high and can not be fully recovered from the sale of the final product.

Filtering and screening systems use a filter or screen to hold solids as the liquid passes through. The technique usually involves the use of gravity, vacuum, or pressure.

Examples of filtering and screening systems:

- Liquid-solid separators, which use stationary and vibrating screens to remove solids from flushing water (OSU, 2000).
- Sand drying beds, which use gravity to carry the liquid down through the sand while the solids form a cake on top (OSU, 2000).
- Vacuum filters, which use cloth or wire screens to hold the solids as the liquid is drawn through (OSU, 2000).
- Presses, which use cloth or wire screens to hold the solids as the liquid is pushed through. A screw-press separator can cost up to $25,000. A screen separator might cost between $5,000 and $15,000 depending on the type of separator (University of Minnesota, 2000).

Freezing has been used to aid in dewatering manure, improving settling and filtering (OSU, 2000).

Incineration is an extension of drying. Manure is converted to an ash requiring application or disposal. Self-sustaining incineration requires a waste of approximately 30 percent solids. Wetter manure with lower solids content requires supplemental fuel to continue incineration (OSU, 2000).

Settling uses gravity to separate the solids from the liquids. Livestock manure is placed in a still basin to allow solids to settle to the bottom. The separation process can take as little as 30 minutes. Solids must be removed regularly to maintain the treatment efficiency of the settling system and to recharge the storage capacity (OSU, 2000).

Examples of settling systems:

- Septic tanks installed ahead of leach fields
- Settling basins used with vegetative infiltration areas

Chemical Treatment

Manure can be chemically treated to improve solids removal, kill microorganisms, eliminate odors, and limit the spread of disease. Adding coagulating agents such as ferric chloride, alum, lime, and organic polymers can greatly improve the dewatering characteristics of manure. Coagulants bring manure solids together so they will settle more quickly. Bringing the small particles together also improves the removal of solids by filtration. Care should be taken when handling coagulants because some are corrosive and others are extremely slippery if spilled (OSU, 2000).

Manure can also be treated chemically by raising the pH to about pH 12 for 30 minutes. This treatment kills most of the microorganisms living in the manure, which eliminates odors and limits the spread of disease. Lime is typically added to raise the pH of livestock manure. A limitation of using lime is that ammonia is immediately lost from the manure. Lime should never be added to manure that is located in a poorly ventilated or confined location (OSU, 2000).

Biological Treatment

Biological treatment uses naturally occurring microorganisms in manure to change the properties of the waste. Examples include biodrying, anaerobic digestion and anaerobic lagoons, and aerobic lagoons.

Biodrying of manure is accomplished by recycling dry compost. It has been proposed that the heat generated in the aerobic decomposition could be used to dry the manure/compost mix with forced air (Hannawald, 1999).

Advantages:

- Odor, volume, and weight are reduced.
- Equipment for solids handling is available on most farms.
- Storage of solids is safer environmentally than liquid storage.
- Materials may be marketed.

Disadvantages:

- Costs of operation may be high.
- Material handling may be excessive.
- Additional amendment may be required.
- Winter operation may require closed buildings.

Anaerobic digestion, which is the decomposition of manure in an oxygen-free (anaerobic) environment, is used in on-the-farm *anaerobic digesters* and *anaerobic lagoons*. Digesters breakdown the manure into a biogas that can be collected and used for fuel or energy. Anaerobic lagoons can be covered to collect gas. Un-covered anaerobic lagoons are usually 100–times larger than anaerobic digesters (OSU, 2000). Refer to the section on anaerobic digestion for more information.

Advantages:

- Digesters reduced odors during treatment of manure.
- Biogas recovered from digesters can be used as an energy source.

Disadvantages:

- Digesters require daily attention.
- Digester biogas is flammable and must be handled with care.

Aerobic lagoons stabilize the manure by adding oxygen. Aerobic digestion is a one-step process, in which microorganisms use the bacteria to convert manure to carbon dioxide and water. This process takes between 1 to 3 months. Aerobic lagoons are 10–times smaller than anaerobic lagoons. Aerobic bacteria are sensitive to the lack of oxygen, and must be aerated and mixed regularly to prevent the lagoon from going anaerobic, which results in strong odors (OSU, 2000).

Advantages:

- Aerated and mixed lagoon limits odors.
- Aerobic lagoons are smaller than anaerobic lagoons

Disadvantages:

- Aerobic lagoon have a high energy requirement.
- Aerator requires routine maintenance.

Export

Farmers may sell or give away excess manure or litter to be used for its nutrient value on other farms, lawns or gardens, nurseries, reclaimed strip mines, revegetated landfills, or highway right-of-way. Prior to exporting animal waste from the farm, one of the waste management practices or treatment technologies described earlier may be applied.

The technical and social barriers associated with export include demand, transportation, handling costs, and nutrient needs at the intended site of application versus nutrient content of the manure.

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CONVERSION TO VALUE-ADDED PRODUCTS: COMPOSTING

Description

Composting is the aerobic decomposition of manure or other organic materials in high temperatures known as the thermophilic temperature range (40–65 degrees Celsius or 104–149 degrees Fahrenheit) (UNL, 1998). During this process, waste and organic matter are allowed to decay in a pile. Because oxygen is necessary for composting, the pile should be turned regularly to incorporate oxygen and to ensure composting of the less decomposed material at the edge of the pile (Purdue, 1996b). This process is complete when the pile does not reheat after turning (Purdue, 1994). Compost, the resulting product, is an odorless, low-moisture-content, fine-textured material that can be used in bulk as a fertilizer or bagged and sold for use in nurseries and gardens and for potting media (UNL, 1998). Composting can be completed within several weeks.

Manure can also be composted through in-vessel composting, a process that is used to more fully control composting. In this process, an optimum mix of organic waste, moisture, and bulking agent is aerated in a vessel. In-vessel composters are typically housed in a building to reduce odors and control moisture (OSU, n.d.).

Compost can be an excellent source of nitrogen, organic matter, and other types of nutrients. While the nitrogen in compost is not as readily available as the nitrogen in manure, the availability of potassium, phosphorous, and micronutrients from compost is similar or higher than from manure. Compost can be applied more uniformly and with better control because it is fine textured and it contains less water than manure. Composted material can also be stored and applied when convenient (UNL, 1998).

The basic factors that influence the rate and efficiency of composting are temperature, water content, the carbon to nitrogen (C:N) ratio, aeration rate, and the physical structure of organic materials (particle size). Recommended and preferred values for these factors can be found in Table 1.

Temperature is the most common indicator for determining how composting is progressing, because elevated temperatures are necessary for killing pathogens and weed seeds in manure (UNL, 1998). The optimal composting temperature is 135 degrees Fahrenheit. Although the inside of the pile typically reaches this temperature, the outside of the pile does not. Therefore, the pile must be turned to ensure that all of the material will be composted (Purdue, 1994).

Moisture is an important factor that must be maintained for optimal composting. At higher moisture levels, voids are filled with liquids and aeration is hindered. As a result, drying is sometimes necessary to obtain the optimal moisture content and ultimately increase the composting efficiency (Purdue, 1994). Adding a bulking agent can also reduce moisture (UNL, 1998). At low moisture levels, microbial activity is hindered.

The C:N ratio is important for ensuring that the necessary amounts of carbon and nitrogen are available for microorganisms, which use carbon as an energy source and nitrogen as a source of nutrients. If the C:N ratio is less than 20:1, nitrogen will escape as ammonia; if there is too much carbon, the rate of decomposition can decrease (Purdue, 1994). The ideal ratio is about 30:1 (OSU, n.d.). It is important to maintain the optimal C:N ratio to prevent nitrogen loss and to ensure rapid composting (Purdue, 1994).

Aeration is important for maintaining composting. As a result, compost is typically piled into 5– to 8–foot-tall windrows that are turned at 1– to 60–day intervals. Compost can also be aerated by forcing air through a large rotating drum in which the compost rolls for 2–10 days. Particle size is also an important factor in composting. The rate of degradation is greater with smaller sized particles because these particles have a greater surface area, which provides microorganisms with more sites to degrade (Purdue, 1994).

Table 1. Recommended Conditions for Rapid Composting

Factors	Reasonable Range	Preferred Range
Temperature	110–150 °F	130–140 °F
Water content	40–65%	50–60%
C:N ratio	20:1–40:1	25:1–30:1
Oxygen concentration	5%	5–15%
Particle size (diameter)	⅛–½ inch	depends on the material

Source: UNL, 1998.

When deciding whether composting is the best option for a livestock operation, producers should consider the advantages, disadvantages, and feasibility of composting, in relation to their operation and waste management needs (UNL, 1998). In addition, the advantages and limitations of both types of composting processes should be considered when deciding which type of composting to use.

Incentives for Using This Technology

Composting can reduce manure volume and weight, which improves handling, and transform it into a more stable nutrient form. In this more stable form, nutrients are less likely to be transported in runoff and leaching (Purdue, 1996b). Composting can reduce manure odor (OSU, n.d.) and kill weed seeds, fly larvae, and pathogens (UNL, 1998). It also improves the moisture retention of light soils and the pore volume of heavy soils (Purdue, 1994). Another benefit of the composting process is that it generates heat, which can be collected for later use (Purdue, 1996b; ARS, 1998).

Advantages of in-vessel composting include the vessel's small size, limited or no odor from the compost building or finished compost, and a dry end product that can be piled, spread, or bagged (OSU, n.d.).

Technical and Social Barriers

Disadvantages of composting include odors, loss of nitrogen and other nutrients, slow release of available nutrients, enough available land for composting, diversion of manure or residue from cropland, processing time, cost of handling equipment, and developing a successful market for compost. Runoff, leaching, and hydrolysis all affect the level of nutrient loss to the environment during composting (UNL, 1998). This loss of nutrients might discourage composting use.

In-vessel composters have limitations because they need energy to stir and aerate the compost, a building to control odor and moisture, and careful monitoring of the compost pile. Ammonia is also lost during in-vessel composting as it is in regular composting (OSU, n.d.).

Cost Information

The costs of composting depend on the livestock operation and its manure management needs. The composting facility at Purdue University's research farm uses a 1.3-acre site near the Purdue dairy barns. The Purdue dairy herd is made up of 400 animals that produce about 9 tons of manure solids a day. When the composting site is at capacity, there is room for 13 rows of composting material; each row is approximately 5 feet high, 10 feet wide, and 250 feet long. The site development costs for this composting project were approximately $4,600, which included labor; bulldozing a slope, berm, and retention pond (to capture rainfall runoff); and adding riprap, an overflow pipe, and a perimeter fence. The major startup cost was purchasing the windrow turner, which cost $19,400. The windrow turner allows for faster turning of the compost pile and ultimately a better product. Other costs included a carbon dioxide tester, thermometer, and pH meter, purchased for $1,020. The operating costs of the facility since 1995 have averaged approximately $4,500, which includes labor, site maintenance, and equipment depreciation (Purdue News, 1998).

Has the Technology Been Applied?

Composting has been widely applied on farms as a form of manure management. It has also been applied as a form of waste management for food scraps, shredded waste, yard trimmings, wood chips, and other types of waste.

Where Has It Been Applied?

Composting has been applied to manage manure at livestock operations throughout the United States, Canada, and other countries. It has also been applied in homes and schools to manage waste other than manure, specifically food scraps and yard waste.

Other Information

For more specific information about composting as it is practiced with different types of livestock, refer to *http://ianrwww.unl.edu/pubs/wastemgt/g1315.htm*. Information about composting, proper methods of composting, and precautions that should be taken during the process can be found at *http://www2.ctahr.hawaii.edu/oc/freepubs/pdf/AWM-1.pdf*. For more information about in-vessel composting, refer to *www.tamu-commerce.edu/coas/agscience/res-dlc/dairy/dlc-dair.html* or *www.tamu-commerce.edu/coas/agscience/res-dlc/poultry/dlc-poul.html*.

Specific Company Information

A number of companies offer composting services and equipment. Refer to the Internet or phone book for local composting companies, agricultural research extensions, chambers of commerce, and soil and water conservation districts.

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CONVERSION TO VALUE-ADDED PRODUCTS: PELLETIZING

Description

Pelletizing, also known as extrusion, converts fresh manure to a dry, pathogen-free, easy to handle, finished product that can be used as a fertilizer, soil amendment, feed additive, or energy fuel (USPEA, 1998). The manure is compacted at high temperatures and pressures, then compressed in a die to form pellets.

Incentives for Using This Technology

- Where local soil nutrient contents are high, pellets can be sold for use elsewhere to significantly reduce nutrient runoff into local rivers (Antares Group, Inc. et al., 1999).
- Pelletizing provides farmers with an animal waste option (USPEA, 1998).
- Pellets can be used on-site or be sold off-site to fertilizer or fuel markets (USPEA, 1998).
- On-site pelletizing systems allow farmers to process and use animal waste on the farm (USPEA, 1998).
- Because the pellets take up a much smaller volume than in their initial form, they can be easily stored and transported (Fletcher, 1999).
- Poultry manure pellets can be applied on farms using conventional fertilizer spreaders and planting equipment (AgriRecycle, 2000).

Technical and Social Barriers

Although pellets can be marketed in large quantities, their marketability is limited by insufficient markets, low market values, and high transportation costs. Several companies, however, are developing technologies to make the product more marketable. These technologies involve conserving the nutrient qualities of the raw litter through processing or enhancing the nutrient qualities of the products. It is currently assumed that market prices for such products will be high enough to cover the costs of these operations (USPEA, 1998).

There are several areas in which the technology can be improved. Currently, pelletizing operations of poultry litter are hindered by its high moisture content and abrasive qualities, which can result in high equipment maintenance costs. On-site pelletizing is expensive because it requires a litter drier, which is a large and expensive component. Densification technologies need to be developed to process higher-moisture feedstocks, avoiding the need for pre-drying (USPEA, 1998).

Cost Information

Some general cost information is specified in the preceeding section.

Has the Technology Been Applied? Where Has It Been Applied?

One example of how pelletization can be used is AgriRecycle, of Springfield, Missouri, which processes raw manure into a high-grade, pasteurized, pelletized organic fertilizer. Recently, AgriRecycle joined with Perdue Farms in Delaware to develop a multipurpose facility that will include numerous technologies (pelletizing, composting, etc.) to turn poultry waste into products.

Specific Company Information

Perdue-AgriRecycle officially introduced its MicroStart60™ to the agricultural community and marketplace on July 20, 2000, at Perdue Farm's micro nutrient facility in Sussex County, Delaware. MicroStart60™ is the brand name for the pelletized fertilizer to be produced at the site by Perdue-AgriRecycle. The partnership is part of Perdue's effort to address environmental concerns posed by excess poultry litter. The facility, which is to be completed in the spring of 2001, will pelletize surplus chicken litter into a pasteurized fertilizer product that can be transported to nutrient-deficient regions in the United States and abroad. More information can be obtained from AgriRecycle Inc. at http://www.agrirecycle.com/ or from Perdue Farms Inc. at http://www.perdue.com/ (Perdue News, 2000).

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CONVERSION TO VALUE-ADDED PRODUCTS: LIVESTOCK FEED ADDITIVE

Description

Ruminant animals—animals with four chambered stomachs such as cattle—have the unique ability to digest forages, other fibrous materials, and inorganic nitrogen such as urea. Because of this ability, by-products of agriculture and the food processing industry can serve as low-cost, alternative feed sources for these animals. One such by-product is broiler litter (Davis, 1999). Broiler litter is an economical and safe source of protein, minerals, and energy for ruminant animals when it is processed by an acceptable method. Acceptable methods of processing litter for cattle feed include deep stacking, ensiling, dehydrating, and extrusion-pelleting. The web sites listed in the references below contain information on these various methods. Deep stacking is the most common method because it is considered the most economical and the most practical (Carter and Poore, 1996). When litter is stored in deep stacks, heat is produced. This reaction not only eliminates potentially toxic bacteria but also replaces the characteristic ammonia smell of manure with a sweeter aroma (UM-MCE, 1994).

Currently there are no federal regulations controlling the sale or use of broiler litter as a feed ingredient. In addition, there are no state laws specifically regulating the feeding of any animal waste and other by-products. Several states, however, do regulate the commercial market sale of broiler litter as a feed ingredient (Davis, 1999).

Incentives

- Litter is an excellent source of protein, energy, and minerals, especially for brood cows and stocker cattle (Davis, 1999). Increasing the use of broiler litter as cattle feed increases the distribution of these nutrients from poultry producers to beef producers and increases the profitability of beef production (Carter and Poore, 1996).
- The use of broiler litter as cattle feed is an environmentally responsible use of a by-product (Davis, 1999).
- Broiler litter-based cattle feed provides an incentive for proper management of this by-product by both poultry and cattle producers (Davis, 1999).

Technical and Social Barriers

- Feed diets containing boiler litter may trigger public relations problems derived from fear and perception rather than scientific data and accurate information. There appear to be no more health risks to animals or indirectly to humans from properly processed broiler litter than from any other cattle feed (Bagley and Evans, 1998).
- Broiler litter rations should not be fed to cattle producing milk for human consumption and should be discontinued as feed for beef cattle 15 days before slaughter (UM-MCE, 1994).
- Overheating broiler litter (temperatures exceeding 140°F) binds nitrogen. Bound nitrogen decreases digestibility and thus reduces the value of the litter as a feed (Davis, 1999).
- The protein in broiler litter is often in the form of nonprotein nitrogen, which is mostly uric acid. Young ruminants usually do not use this form of protein as readily as more mature beef cattle. Therefore, for best performance, broiler litter should be fed to beef cattle that weigh more than 400 pounds (Davis, 1999).

- Though litter is high in fiber content, it does not effectively meet the ruminants' needs because they need long roughage to properly maintain their digestive systems. Long roughage such as hay should therefore be added to the feed (Davis, 1999).

Cost Information

Broiler litter when processed as feed may have a value of $80 to $120 per ton. One survey showed that producers considered the value of the broiler litter-derived feedstuff to exceed the cost by up to five times (UM-MCE, 1994). As a feed source, broiler litter is worth about four times more than its value as a fertilizer (Davis Jr., 1999).

Application

Broiler litter is converted to feed or fertilizer on the producer's own farm or purchased from a licensed, reputable dealer, ensuring that the quality of the broiler litter is suitable for its intended purpose.

Where Has It Been Applied?

Refeeding of broiler litter has occurred on operations throughout the United States for more than 40 years as an effective way to capture the potential value of the litter (Davis, G. Jr., 1999).

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CONVERSION AND USE AS AN ENERGY SOURCE: GASIFICATION

Description

Gasification is a process that uses heat to convert animal manure, usually poultry litter, into a clean fuel gas form. The two-step, endothermic (heat absorbing) process converts animal waste into a gas of low- or medium-British thermal units (Btu). This form gives the animal manure tremendous flexibility in the way it can be used to produce power. The first step in the process, called pyrolysis, vaporizes the volatile components of the fuel at temperatures under 1100 °F (600 °C) by a set of complex reactions. Fixed carbon, called "char," and ashes are the unvaporized by-products of pyrolysis. Char is gasified through reactions with oxygen, steam, and hydrogen in the second step. A portion of the unburned char is then combusted to release the heat required for the endothermic gasification reactions. There are several different gasification processes available. They include fixed-bed gasifiers, fluidized-bed gasifiers, and low-pressure gasifiers (EREN/DOE, 2000).

Incentives

- Gasification offers the opportunity to convert animal manure into fuel and energy (EREN/DOE, 2000).
- Converting animal manure to useful heat or electricity while meeting environmental requirements for air and other emissions can result in benefits at the local level:
  - Creating new jobs for hauling and at energy facilities
  - Providing new income for facility owners, employees, and hauling companies
  - Providing a new animal manure disposal option for farmers
  - Recycling the fertilizer value of manure in a concentrated ash for use outside the local region
  - Significantly reducing nutrient runoff into local rivers where nutrient concentration levels are too high (Antares Group, Inc. et al., 1999).
- Gasification produces cheaper fuels than can serve as substitutes for expensive fossil fuels (Engström, 1999).
- Gasification converts animal manure into a flexible-use form that can fuel a wide range of power systems, including gas turbines, fuel cells, and reciprocating engines. It also produces fuel in an easy-to-use form for power equipment, while providing a productive alternative to land-application (EREN/DOE, 2000).
- Gaseous fuel is easier to distribute and control than other forms of fuel (EREN/DOE, 2000).
- Coupled with advanced conversion cycles, gasification reduces air emissions per kilowatt hour of electricity produced compared with other methods (EREN/DOE, 2000).
- The ash that is left over from the gasification process is extremely low in nitrogen and high in phosphorus and potassium. This can be of significant economic value, making it possible to export phosphorus fertilizer from regions of phosphorus surplus to regions of phosphorus deficit (Bock, 1999).

Technical and Social Barriers

Because gasification of animal waste is still a relatively new technology, more studies and research will need to be conducted before this method can be applied on the industrial level. Advanced manure-based gasification technologies are, however, rapidly nearing commercialization (Stanton, 1995). Initial conversion of energy factories to use biomass as feedstock can result in above-average short-term expenditures as compared with widely used methods such as oil. In addition, efforts to inform the public of these new technologies and encourage public involvement in new programs are helping to make these methods of energy conversion successful.

Cost Information

Because research and development into biomass gasification continues, cost estimates vary widely. Currently, gasification of litter and other manure waste products becomes economical in light of disposal costs rather than operational costs, although costs are expected to drop below oil- and natural-gas-based feedstocks costs (Antares Group, Inc. et al., 1999; Stanton, 1995). In a case study conducted in Maryland, the state provides a cost-share incentive for transporting poultry litter to fertilizer markets out of the region. Costs to the farmer could be cut in half if the deliveries are to energy facilities, however, according to this study, the primary economic drivers will be a combination of tipping fees for excess litter disposal, the enactment of proposed power production tax incentives, and the recovery of ash value as a fertilizer. Ash sales as fertilizer could have a net income or value to operations of $50 per ton of ash sold (Antares Group, Inc. et al., 1999).

Application

During World War II, Australia and Germany turned biomass into vehicle fuel through gasification (Australian Greenhouse Office, 1999). Today, several companies are developing gasification technology in the United States, aided by cost-share funding from the U.S. Department of Energy's (DOE) Biomass Power Program (EREN/DOE, 2000). In addition to DOE's program, Primenergy (see section on Cofiring) is just one of many companies that is also investigating and applying the technologies of turning animal waste into energy through gasification.

Other Information

There is a range of options that accompany gasifier technology. More information on fixed-bed gasifiers, fluidized-bed gasifiers, low-pressure gasification, and technology options can be found on the U.S. Department of Energy's Biopower website at http://www.eren.doe.gov/biopower/projects/.

Specific Company or Organization Information

- **Battelle –** http://www.battelle.org/
  Columbus, Ohio
  Phone: 1-800-201-2011, E-mail: solutions@battelle.org
- **Brightstar Synfuels Co. –** http://www.brightstarsynfuels.com/
  St. Gabriel, Louisiana
  Phone: (504) 642-2500, Fax: (504) 642-2503, E-mail: brightstarsynfuels@worldnet.att.net
- **Burlington Electric Department –** http://www.burlingtonelectric.com
  Burlington, Vermont
  Phone: (802) 658-0300 or (802) 865-7386, Fax: (802) 865-7400, E-mail: http://www.burlingtonelectric.com/questionform.htm
- **Foster Wheeler Corporation –** http://www.fwc.com/
  Clinton, New Jersey
  Phone: (908) 730-4000, Fax: (908) 730-5315, E-mail: info@fwc.com
- **Future Energy Resources Co. (FERCO) –** http://www.future-energy.com/
  Atlanta, Georgia
  Phone: (770) 662-7800, Fax: (770) 662-7807, E-mail: ferco@future-energy.com
- **Heuristic Engineering**
  Vancouver, British Columbia, Canada
  Phone: (604) 436-9317, Fax: (604) 436-9533, E-mail: mlefort@compuserve.com

- **National Renewable Energy Laboratory –** http://www.nrel.gov/
  Golden, Colorado
  Phone: (303) 275-3000, E-mail: nrel_director@nrel.gov
- **PrimeEnergy –** http://www.primenergy.com/
  Tulsa, Oklahoma
  Phone: (918) 835-1011, Fax: (918) 835-1058, E-mail: info@primenergy.com
- **Thermogenics, Inc. –** http://www.thermogenics.com
  Albuquerque, New Mexico
  Phone: (505) 344-4846, Fax: (505) 344-6090, E-mail: thermogenics@worldnet.att.net

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CONVERSION AND USE AS AN ENERGY SOURCE: COFIRING

Description

Cofiring is the simultaneous combustion of a supplementary fuel, such as manure, with a base fuel, such as wood or coal. It is proving to be one of the most promising near-term methods of increasing the use of manure in electricity generation (Tillman, 1999). Several types of boiler technologies have been practiced, tested, or evaluated for cofiring, including wall-fired and tangentially designed pulverized coal (PC) boilers, coal-fired cyclone boilers, fluidized-bed boilers, and spreader stokers (EREN/DOE, 2000).

Stoker-grate firing systems with animal manure have recently and successfully entered the commercial market, typically using a mixture of woodshavings, straw, or both, rather than coal with poultry litter (Antares Group, Inc. et al., 1999). Since fine litter is porous and not suited for fixed- or deep-bed burning without a moving grate, this thin, moving or rotating bed allows the carbon to burn out completely without the fuel crusting or caking as it burns.

Incentives

- Converting animal wastes to useful heat or electricity while meeting environmental requirements for air and other emissions can result in benefits at the local level:
  - Creating new jobs for hauling and at energy facilities
  - Providing new income for facility owners, employees, and hauling companies
  - Providing a new animal waste disposal option for farmers
  - Recycling the fertilizer value of litter in a concentrated ash for use outside the local region
  - Significantly reducing nutrient runoff into local rivers where nutrient concentration levels are too high (Antares Group, Inc. et al., 1999).
- Cofiring increases fuel diversity for utilities (Plasynski et al., 1998).
- Compared with traditional coal firing, cofiring provides an inherently low-cost application that takes advantage of the best qualities of various firing systems (Plasynski et al., 1998).
- Compared with traditional coal firing, cofiring with manure as a supplemental fuel reduces fossil-fuel-derived carbon dioxide emissions. The growing, burning, and replanting of biomass, the original source of manure content, is considered to be nearly CO_2 neutral, when compared to the burning of coal (a source of carbon locked in rocks beneath the Earth's surface). While living, biomass takes CO_2 out of the air, and recirculates it into the air when burned. In contrast, coal results in the addition of carbon into the atmosphere when burned (Plasynski et al., 1998).
- There is little to no loss in total boiler efficiency after adjusting combustion output for the new fuel mixture, which means that the biomass combustion efficiency to electricity would be close to the 33-37 percent range of coal firing (DOE, 2000).
- Studies show that the amount of fossil carbon in the current coal-fired power generating system can be reduced by 15 percent using renewable carbon sources from biomass (EREN/DOE, 2000).

Technical and Social Barriers

Since the cofiring of animal waste is still a relatively new technology, more studies and research will need to be conducted. Even though cofiring has successfully been incorporated into the commercial market in Europe, and is making its way to the United States and other areas of the world, investors are still hesitant. Combustion problems result from the high phosphorus content of animal manure, especially poultry litter. If burned at the elevated temperatures of an incinerator, the litter releases phosphorus, which forms phosphate salts and phosphoric acid. Both of these chemicals react with metal and therefore can cause deterioration and fouling in heat recovery boilers (Primenergy, 2000).

Cost Information

In general, the critical terms in the cost of a cofiring operation are the fuel cost and the capital cost of modifiying the power plant for cofiring with a biomass (Plasynski et al., 1999). Investment levels are very site-specific. Costs are affected by the available space for yarding and storing biomass, installing size reduction and drying facilities, and the type of boiler burner modifications. Investments are typically between $50 and $200 per kilowatt of biomass capacity, with a median ranging from $180 to $200/kW (EREN/DOE, 2000). The financial cost or benefit per pound of manure is not available.

Application

Large-scale power plants have been built in England by the English company, Fibrowatt. These power plants are designed to be cofired with poultry litter and woodshavings, straw, or both (Fibrowatt, 2000). The plants use a stoker-grate firing system designed to maintain moderate firing temperatures to minimize vaporization of potassium and phosphorus. A high internal surface area encourages condensation where suspended ash particles collect. Flu gas exit temperatures are maintained above the dew point to avoid corrosion. Particulates are collected in a baghouse (Antares Group, 1999).

Fibrowatt's power stations obtain poultry litter from nearby broiler poultry farming companies, transport it in tightly covered trucks, and store it at the plant in negative pressured facilities for odor control. The by-product of the process is a nitrogen-free ash, rich in potash and phosphate, which is marketed as an environmentally friendly fertilizer. The chemical makeup of the fuel produces very low levels of gaseous emissions from the chimney. Fibrowatt has developed technologies to reduce these emissions even further (Fibrowatt, 2000).

The state of Minnesota has proposed that Fibrowatt build a plant in Meeker County to address its poultry manure problem (Ward, 1999). Fibrowatt may also build a plant in the Netherlands (Fibrowatt, 2000).

Other Information

More information can be found on these sites:

http://www.eren.doe.gov/biopower/projects/ia_tech_co.htm
http://www.osti.gov/bridge/
http://www.fetc.doe.gov/index-b.html

Specific Company or Organization Information

Fibrowatt Group, London, England: http://www.fibrowatt.com
Phone: (0171) 229-9252
Fax: (0171) 221-8671

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Antares Group Incorporated, T.R. Miles Technical Consulting, Inc., and Foster Wheeler Development Corporation. 1999. *Economic and Technical Feasibility of Energy Production from Poultry Litter and Nutrient Filter Biomass on the Lower Delmarva Peninsula*. <http://www.nrbp.org/>. Accessed December 2000.

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CONVERSION AND USE AS AN ENERGY SOURCE: ANAEROBIC DIGESTION

Description

Anaerobic digestion is the decomposition of manure in an oxygen-free (anaerobic) environment. Two types of systems are available for on-the-farm anaerobic digestion, anaerobic digesters, and anaerobic lagoons.

Anaerobic digesters work in much the same way as an animal's digestive tract; microorganisms breakdown or digest the manure. One of the last phases of digestion is the conversion of the manure into biogas by methane-forming bacteria. Biogas is a combination of methane, carbon dioxide, nitrogen, hydrogen, carbon monoxide, oxygen, and hydrogen sulfide. Between 55 and 70 percent of the biogas is methane, and the remainder consists mostly of carbon dioxide. Usually, the nitrogen, hydrogen, carbon monoxide, oxygen, and hydrogen sulfide are found in trace amounts. The methane in biogas is similar to natural gas, and after scrubbing it can be used to fuel internal combustion engines that run generators and produce electricity (Rozdilsky, 1997).

Anaerobic digestion is not limited to manure products and can be applied at any site that produces organic material. In this report, however, only farm based anaerobic digestion is addressed. The on-farm digester system typically involves an animal facility where manure is produced; a manure-handling system to transport manure to and from the digester; a reactor tank; where anaerobic digestion occurs; and an apparatus for the collection, pretreatment, and use of biogas (Rozdilsky, 1997).

There are several types of digesters, which are made for specific types of manure management situations. The complete-mix digester and plug-flow digester are the most common types of on-farm digesters. Recent advances in this area include the loop digester and the advanced integrated pond system (Rozdilsky, 1997).

- The *complete-mix digester* has an aboveground or belowground tank that uses heat to treat swine or dairy manure with a 3 to 10 percent solid concentration (USEPA, 1997a).
- The *plug-flow digester* uses a below ground tank to hold manure and a gas-tight, expandable top to capture biogas. Plug-flow digesters work only with high-solid-content (> 11 percent), scraped dairy manure and can not be used with other manures. Each day a new "plug" is added, which gradually pushes the old manure down the tank (USEPA, 1997b).
- The *covered lagoon digesters* typically consists of a floating impermeable cover placed over the surface of a manure treatment lagoon. Covered lagoons can be used at both swine and dairy operations. They work best when the manure is handled as a liquid and the climate is temperate to warm year-round (USEPA, 1996).
- The *loop digester* uses a circular design and a fabric cover to collect the biogas. The circular design allows for convective currents to form in the digester, eliminating crusting problems common to plug-flow digesters (Rozdilsky, 1997). A loop digester can operate with 11 to 13 percent total solid slurry.
- The *advanced integrated pond system* uses a submerged canopy to cover a facultative pond. The cover captures biogas. Effluent is discharged to a second pond to be used as a growth medium for algae (Rozdilsky, 1997).

Anaerobic lagoons function exactly like anaerobic digesters with one exception: the lagoons are usually not covered to capture gas. They are much larger than digesters–up to 100 times larger in some cases. Anaerobic lagoons reduce the volume of manure by breaking the manure down in an anaerobic environment. All types of livestock manure can be digested in an anaerobic lagoon (OSU, 2000).

Incentives for Using This Technology

There are five reasons why a farmer or producer might want to install an anaerobic digester (Roos and Moser, 1997).

- Anaerobic digesters reduce unpleasant odors from waste management systems, which are often offensive to surrounding communities. Digesters reduce odors because biogas-producing bacteria consume the odor causing compounds.
- Anaerobic digesters produce a high-quality fertilizer. During the digestion process, nitrogen is converted to ammonia, which is a common component of commercial fertilizer and is easily used by plants.
- The digestion process treats the manure, making it a uniform and predictable product. Digested manure is easy to spread during land application. When it is applied properly, it can reduce the chance of contamination of surface and ground water.
- Heated anaerobic digesters reduce the amount of pathogens in manure, thus reducing the amount of pathogens entering a storage unit or land applied after digestion. Anaerobic lagoons also help reduce the amount of pathogens by allowing time for the pathogens to die off during the digestion process.
- Biogas recovered from anaerobic digesters can be used to generate electricity to use on the farm or to sell to a local power grid. The biogas can be used on site to fuel a boiler, space heater, or refrigeration equipment, or as cooking and lighting fuel. Gas recovered from digesters is approximately 60 to 80 percent methane and has a heating value of 600 to 800 Btu/ft3. Most equipment that uses natural gas, butane, or propane as fuel can be modified to use biogas (Roos and Moser, 1997).

Technical and Social Barriers

The perception among the farming community that anaerobic digesters fail is one of the largest social barriers to acceptance of the technology (Rozdilsky, 1997). Through personal communication or word-of-mouth, many farmers know of some farm with an abandoned digester. This perception has resulted in limited support from the agricultural community and few, if any, technological advances (Roos and Moser, 1997). Anaerobic digesters require high-level management time, and when farmers do not have the skill or time to manage the digesters the systems tend to fail. Farmers are reluctant to use digesters because the operation and maintenance costs are too high compared to the financial returns from energy production. Another reason for digester failure is that producers select systems that are not compatible with their type of manure handling method and the layout of their farm. Poor design and installation also contribute to the failure of digesters (Rozdilsky, 1997).

One of the largest technological problems for anaerobic digesters is sand clogging the digester. Sand bedding material is typically preferred to organic material because it prevents bacteria from growing and infecting the livestock. When farmers use sand as bedding material, their anaerobic digesters have a high probability of failing. In addition, warmer climates are better for anaerobic digesters used to produce biogas; in cooler climates, the production of biogas decreases (Rozdilsky, 1997).

Cost Information

Digesters have high start-up costs. A study of anaerobic digesters used by dairy farmers in Michigan indicated that a typical payback period for farmers with anaerobic digesters is at least 7 to 10 years. Most farmers are not able to make these long-term payments, especially when energy costs are small compared to total operational costs. For farmers in Michigan to consider purchasing digesters the price of energy would have to triple (Rozdilsky, 1997).

The table below provides one example of the cost of an anaerobic digester used on a dairy farm in California. This producer used a plug-flow anaerobic digester to convert waste from a herd of 400 dairy cattle. The digester was installed in 1981. The annual maintenance cost of the digester was estimated at 8 percent of the capital construction cost, or $16,000 for a $200,000 anaerobic digester (Westbioenergy, 1999).

Initial cost	$200,000
Biogas produced	120 million ft^3
Methane in biogas	72 million ft^3
Electricity produced	5 million kilowatt-hours
Value of electricity	$350,000
Digested fiber sales	$138,000
Saving from lagoon clean-out	$135,000
Value of hot water for farm use	$75,000
Operation and maintenance	$160,000
Earning from 16 years of operation	$540,000

Source: Westbioenergy, 2000.

For more cost information, refer to Appendix A of *A Manual for Developing Biogas Systems at Commercial Farms in the United States* (Roos and Moser. 1997). This manual has 22 case studies, including cost and revenue information, of U.S. farm digester sites. The manual is available on the United States Environmental Protection Agency's web site at http://www.epa.gov. Additional economic information is available in a report by Lusk, entitled *Methane Recovery from Animal Manures: The Current Opportunities Casebook*, which is available on the following web site: http://www.osti.gov/bmp/bmphome.html.

Has the Technology Been Applied?

Farm-based anaerobic digesters have been used in the United States since the 1970s. The first digester was used at a hog production facility in Iowa. During the energy crisis in the mid- and late 1970s, researchers studied the use of small- and medium-scale anaerobic digesters as an alternative energy source. The requirements of larger American livestock operations led to the design of complete-mix digesters; however, the start-up costs were very high. By the late 1970s, researchers were able to reduce the start-up costs of complete-mix digesters. In 1979 the plug-flow digester was developed for dairies in cooler climates. The concept of using a cover to collect biogas was developed in the early 1980s for a hog farm in California. In 1988, a full-scale covered lagoon digester was brought to the east coast and constructed for a dairy in North Carolina (Lusk, 1998).

The complete-mix digester, plug-flow digester for dairy, and covered anaerobic lagoon are the only digesters recognized by the U.S. Department of Agriculture's Natural Resource Conservation Service (Lusk, 1998).

Where Has it Been Applied?

Anaerobic digesters have been used on farms throughout the United States and around the world. They are most commonly used at dairy and swine operations because the manure is more suited for farm-based energy conversion (Lusk, 1998). Digesters can also be used at caged-layer facilities and beef operations (Lusk, 1998).

Specific Company Information

A number of companies sell anaerobic digestion systems. Refer to the Internet or a phone book for local companies, or contact local agriculture research extensions, chambers of commerce, or soil and water conservation districts for more information.

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CONVERSION AND USE AS AN ENERGY SOURCE: METHANOL

Description

Methanol is the simplest alcohol, typically made from natural gas. Wood, municipal solid waste and sewage and therefore manure can also be used to produce methanol, which is called biomethanol when made from these sources (American Methanol Institute, 2000). Though there are no biomethanol plants currently in the United States, technology to produce methanol from biomass is evolving (OFD, 1995). Methanol is a liquid in its normal state, and it burns much like gasoline. Typically, it is used in the manufacture of windshield washer fluid, gasoline fuel additives, formaldehyde, and other chemicals. It has promise as a transportation fuel (OEE, n.d.).

Methanol production is carried out in two steps. First, the feedstock is converted into a synthesis gas stream consisting of carbon monoxide (CO), carbon dioxide (CO_2), water (H_2O), and hydrogen. In the second step, the methanol is manufactured from the synthesis gas. The synthesis of methanol is very exothermic (produces heat), and most plants are designed to use this extra energy to generate electricity needed in the process (American Methanol Institute, 2000).

Incentives

- Converting animal wastes to useful energy while meeting environmental requirements for air and other emissions can result in benefits at the local level:
  - Creating new jobs for hauling and at energy facilities
  - Providing new income for facility owners, employees, and hauling companies
  - Providing a new animal waste disposal option for farmers
  - Significantly reducing nutrient runoff into local rivers where nutrient concentration levels are too high (Antares Group, Inc. et al., 1999).
- The methanol molecule contains oxygen. It burns more completely than the more complex molecules containing carbon found in gasoline and diesel fuel. Methanol fuel and methanol-gasoline blends therefore produce lower levels of carbon monoxide emissions than regular gasoline. Methanol also vaporizes more slowly than the lighter components of gasoline, contributing fewer volatile organic compounds to the air, and thereby reducing smog. Burning methanol as fuel avoids producing many of the toxic compounds that result from gasoline combustion, however, it produces higher levels of toxic formaldehyde (OEE, n.d.).
- Compared with gasoline combustion, the growing, burning, and replanting of biomass, the original source of manure content, is considered to be nearly CO_2 neutral. While living, biomass takes CO_2 out of the air, and recirculates it into the air when burned. In contrast, gasoline, derived from carbon locked in rocks beneath the Earth's surface, results in the addition of carbon into the atmosphere when burned (Plasynski et al., 1998).
- As technology continues to develop in this area, methanol may be cost-effectively produced from renewable resources in the future, giving it a significant long-term supply advantage over nonrenewable petroleum-based fuels (OEE, n.d.).
- Because methanol is a liquid, it can be stored, transported, and used as easily as gasoline and diesel fuel, and more easily than some of the other transportation fuel alternatives (OEE, n.d.).
- As vehicle emissions controls become more stringent, methanol provides viable options for heavy-duty diesel engine manufacturers and operators (OEE, n.d.).

- Use of methanol reduces dependency on non-renewable energy sources while solving problems regarding manure and other energy-rich biomasses (OEE, n.d.).

Technical and Social Barriers

- Further research is needed to develop an optimized dedicated biomass feedstock and to resolve numerous technical issues (OFD, 1995). As of date, no specific technology or research is available for turning animal waste, a subset of biomass, into methanol, though the possibility is optimistic.
- Methanol has a lower energy content than gasoline. More methanol is needed to travel the same distance (OEE, n.d.).
- When ignited, pure methanol burns an almost invisible flame. Adding gasoline resolves this safety hazard (OEE, n.d.).

Cost Information

Current methanol technologies are more expensive than gasoline-based technologies, restricting widespread use of methanol as a transportation fuel. Costs are expected to decrease as technologies are further developed and large scale production becomes possible (OEE, n.d.). Cost information is not available for manure-based methanol.

Application

A project conducted by the U.S. Department of Energy's Office of Fuels Development will show how thermochemical biomethanol plants can be competitive in the United States without subsidies. The analysis will examine how biomass processing can be used alongside existing natural gas methanol plants, and look for opportunities to reduce the costs of initial plants and for ways to build these plants sooner. The technical and nontechnical barriers to biomethanol market entry and growth by fuel manufacturers will also be examined (OFD, 1995). This project may uncover more options toward the development of biomethanol technologies that make use of animal waste.

So far, several industrial firms are interested in developing, implementing, and commercializing biomethanol activities. Further encouragement by cooperative government/industry cost-shared projects will likely lead to demonstrations of successively larger, fully integrated thermochemical biomethanol production systems (OFD, 1995). As these production systems become established, biomethanol production from animal waste should also become increasingly cost-efficient.

Once established as cost-efficient, biomethanol can be used in transportation. Methyl tertiary butyl ether (MTBE) is produced from methanol and blended with gasoline to boost octane ratings, helping to prevent engine knock. At high concentrations, methanol can be used in special factory-produced M85 fuel flexible vehicles, which can run on a mixture of 85 percent methanol and 15 percent gasoline (OEE, n.d.).

To meet more stringent emission standards for vehicles with diesel engines, special methanol engines have been developed that produce lower levels of nitrogen oxides and particulates than comparable diesel engines. In Canada for example, transit buses with methanol engines have been demonstrated in Winnipeg, Manitoba; Windsor, Ontario; and Medicine Hat, Alberta. Several methanol-fueled buses are also in operation in the United States (OEE, n.d.).

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OTHER INNOVATIVE AND EMERGING TECHNOLOGIES USING ANIMAL WASTE

Algae Production: Biotechna Europe Limited and Plant Research International of Canada have developed Photosynthetic Purification® (PPT), a biological technology that grows algae and photosynthetic bacteria from the nutrients in animal waste. PPT produces a crop of microalgae and other photosynthetic organisms that act as a fertilizer and accelerate the natural growing process. The PPT product can be sold at a profit, while simultaneously providing odor control and producing a clean liquid effluent. PPT provides a variety of applications, including a high-protein animal feed supplement (ACFA, 2000a).

Aquaculture: Manure has been used for aquaculture in the Far East for centuries. Studies indicate that while high-protein feed results in higher maximum yields per unit area when compared with manure, high-protein feed costs more. Incorporating manure into high-protein feed results in reduced growth, without reducing feed cost per unit area. Therefore, the best results are obtained from frequent applications of manure alone (ARS, 1998).

Bedding or Litter: Livestock waste can be processed into a solid that can be used as bedding or litter. Litter is a mixture of manure, feathers, spilled food, and bedding material. Farmers use litter as an inexpensive fertilizer for cropland because the manure contains nitrogen and phosphorus, two important fertilizer ingredients. A solid-liquid separation system is used to separate the solids in the waste from the liquids (Purdue Research Foundation, 1996b).

Building Material: According to research conducted by Deland Myers at Iowa State University, cow manure can be processed into fiberboard for construction. This experimental fiberboard is best suited for sheds, barns, and other outdoor structures because it is not yet recommended for use in building homes (Belsie, 2000). The fiberboard is not 100 percent manure, and animal processed fiber could be used as a supplement to other fiber that are used to make fiberboard (ISU, 2000). Deland Myers can be contacted at (515) 294-5216.

Flowerpot Ornaments: Jerry Sherrill of Huntingon, Arkansas, molds dried, composted chicken waste into figurines of ducks, turtles, swans, and cats, and he promotes them as flowerpot ornaments that will eventually release their nutrients into the soil. Sherrill calls his invention Crappy Critters (Hannawald, 1999).

Mushroom Cultivation: Composted manure is used for commercial mushroom production (CAST, 1996). Although other types of manure can be used, horse manure is the most widely used in growing mushrooms (Sutton et al., 1999).

Nursery Pots: Litchfield County, Connecticut, is looking at potential markets for the production of nursery pots made from composted manure. After liquid and solids are separated, the solids are composted and then compressed into pots. Contact Kathleen Johnson at Kathleen.Johnson@CT.usda.gov (Hannawald, 1999).

Sealing Ponds and Dams: Although manure has traditionally been used to seal ponds and dams, this process could be adapted to man-made structures. In a process devised in Russia, a slurry of pig manure is applied over the inner base and walls of a dam in multiple, thin coats. The slurry layer is then covered with vegetable organic matter such as leaves, grass, cardboard, or wastepaper. Finally, the two layers are covered with a layer of soil for compaction. The mixture is then left undisturbed for several weeks to allow the anaerobic bacteria to act, after which the dam is ready for flooding (RIC, n.d.).

Soil Reclamation: Composted manure is an effective treatment for various types of land contaminating spills. In Canada, composted manure is used to repair the effects of oil spills, salt spills, or land disruptions from pipeline construction. After application, compost takes approximately 10 years to digest the oil. When manure is composted with phosphogypsum (calcium sulfate), it can be used to clean up salt spills, which can occur when a salt bed is penetrated during drilling and the salt flows out the hole, contaminating the ground. Using composted manure to treat these types of spills cleanses and enriches the soil while also offering a solution to manure disposal problems (ACFA, 2000b).

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APPENDIX: ORGANIZATIONS THAT CAN ASSIST WITH ALTERNATIVE MANURE UTILIZATION TECHNOLOGIES

CTIC – The Conservation Technology Information Center develops public/private partnerships that promote the enhancement of soil and water quality by equipping agriculture with realistic, affordable, and integrated solutions. The web site below offers information regarding farm resource management, such as conservation tillage survey figures and numerous types of agricultural best management practices.

CTIC
1220 Potter Dr.
Suite 170
W Lafayette, IN 47906
Tel: (765) 494-9555
Fax: (765) 494-5969
http://www.ctic.purdue.edu/CTIC/CTIC.html

- **CSREES** – The Cooperative State Research, Education, and Extension Service works to build a global system of research, extension, and higher education in the food and agricultural sciences, as well as related environmental and human sciences. The CSREES mission emphasizes partnerships with the public and private sectors to maximize the effectiveness of limited resources (water, energy, etc.). CSREES programs are intended to increase and provide access to scientific knowledge; strengthen the capabilities of land-grant and other institutions in research, extension, and higher education; increase access to and use of improved communication and network systems; and promote informed decision making by producers, families, communities, and other users of CSREES programs.

  U.S. Department of Agriculture /CSREES
  Washington, DC 20250-0900
  Tel: (202) 720-3029
  Fax: (202) 690-0289
  http://www.reeusda.gov/

  A directory of the land-grant universities that are state partners of the Cooperative State Research, Education, and Extension Service is available at http://www.reeusda.gov/statepartners/usa.htm.

  Other state-specific cooperative extension web sites can be found at http://www.uwyo.edu/ag/ces/other.htm.

  Local county extension offices are listed under "Local Government" in the telephone directory.

- Farm*A*Syst/Home*A*Syst is a program sponsored by the National Resource Conservation Service (NRCS) with the purpose of preventing pollution on farms, ranches, and in the home.

  Farm*A*Syst/Home*A*Syst
  303 Hiram Smith Hall
  1545 Observatory Dr.
  Madison, WI 53706-1289
  Tel: (608) 262-0024
  http://www.wisc.edu/farmasyst/

- **FSA –** The Farm Service Agency of U.S. Department of Agriculture has as its mission to provide efficient and equitable administration of farm commodity programs, farm ownership, operating and emergency loans,

conservation and environmental programs, emergency and disaster assistance, domestic and international food assistance, and international export credit programs.
FSA's national web site is located at http://www.fsa.usda.gov/pas/default.asp.

The addresses of local FSA offices can be found at http://www.fsa.usda.gov/edso/.

- **NACD –** The National Association of Conservation Districts is the national organization for 3,000 local conservation districts across the country. Conservation districts are local units of government responsible for the soil and water conservation work within their boundaries. The districts' role is to increase voluntary conservation practices among farmers, ranchers, and other land users.

  NACD
  509 Capitol Court, NE
  Washington, DC 20002-4946
  Tel: (202) 547- 6223
  Fax: (202) 547-6450
  http://www.nacdnet.org/

  A directory of conservation districts by state is located at http://www.ftw.nrcs.usda.gov/district.html.

  A directory of local soil and water conservation districts is located at http://www.nacdnet.org/resources/cdsonweb.html.

- **NARC&DC –** The National Association of Resource Conservation and Development Councils represents more than 300 local resource conservation and development councils nationwide. The NARC&DC serves as an advocate and assists local councils to identify and take action on issues and opportunities to improve the quality of life and environment in their communities. Local RC&D councils are grassroots community leaders working collectively for conservation and sustainable development.

  NARC&DC
  444 North Capitol St., NW
  Suite 345
  Washington, DC 20001
  Tel: (202) 434-4781
  Fax: (202) 434-4783
  narcdc@rcdnet.org

- **NASCA –** The National Association of State Conservation Agencies is a coalition of state conservation agencies across the country that provide guidance and funding for conservation districts. They operate numerous state environmental, sediment control, and soil erosion prevention programs.

  NASCA
  19979 Tidewater Trail
  Tappahannock, VA 22560
  Tel: (804) 443-2484
  http://nascanet.org/

- **NASDA –** The National Association of State Departments of Agriculture is a nonprofit association of public officials representing the commissioners, secretaries, and directors of agriculture in the 50 states and 4 territories.

  NASDA
  1156 15th St., NW
  Suite 1020

Washington, DC 20005
Tel: (202) 296-9680
Fax: (202) 296-9686
http://www.nasda-hq.org/

A directory of state departments of agriculture is located at http://www.nasda-hq.org/nasda/nasda/member_information/Csd.htm.

- **NRCS –** The Natural Resources Conservation Service of USDA is the federal agency that works with the public to conserve natural resources on private lands. NRCS relies on many partners to help set conservation goals, work with people on their land, and provide assistance. Its partners include conservation districts, state and federal agencies, NRCS Earth Team volunteers, agricultural and environmental groups, and professional societies.

  NRCS Conservation Communications Staff
  PO Box 2890
  Washington, DC 20013-2890
  http://www.nrcs.usda.gov/