

**Alternative Waste Management Technologies
Summary of Available Resources**

Prepared by
James E. Hannawald
Resource Conservationist
Natural Resources Conservation Service

October 1999

Executive Summary

This report is a summary of available new alternative technologies for animal waste management. A preliminary literature search revealed little in new technologies for animal waste management. With the support of the National Nutrient Team and the NRCS liaisons we were able to contact researchers and others interested in waste management.

The report is divided into three sections, "Treatment, Utilization, and Other Management". Most of the projects are on some type of treatment that ultimately results in land application of the waste as a source of fertilizer. There are a few projects looking at new uses for the manure. Burning and pelletizing the manure are examples of alternative uses. However, we need to look at these technologies closer since they tend to concentrate the phosphorus in the final product. I did find two projects (South Carolina and Oregon) where the researchers are looking at methods of removing the nutrients from the manure. The nutrients then could be custom blended into a more appropriate fertilizer mix for final land application. In most cases I used the researchers description of the project.

It is apparent that the industry is still relying on the final use of any animal waste to be land applied as fertilizer.

Peter Wright, Animal Waste Specialist at Cornell University has a paper titled "Manure Treatment of Existing and Proposed Manure Handling Systems" Proceedings from Nutrient Management Planning: Competitive Agriculture in Harmony with the Environment", Niagara Falls, Ontario March 24-26, 1999. This paper is an excellent reference that summarizes manure management alternatives presently available. It has been included as Appendix I.

Ben Huebner, staff member of Senator Leahy's Office prepared a report for the Vermont Alternative Dairy Manure Management Technology Working Group titled Current and Future Dairy Waste Management Technologies and Practices. These technologies are appropriate for other livestock operations and not just dairy. This report is included as Appendix II. It can also be found on our ITC web site.

This project should be continued in order to keep up to date on what is being done and what some of the results are from the research. It has been suggested that we develop some type of matrix of the projects.

I'm working with Chuck Lander, Dave Moffitt and Bob Kellogg on a formalized paper utilizing this report dealing with the current relationship of the geographic concentration of animal operations with land application of manure and how these new technologies may affect the land resource problems.

Table of Contents

Introduction	1
Alternative Treatment	3
Alternative Utilization	8
Other Management	11
Appendix I	14
Appendix II	38

Introduction

This report is to identify new technologies for animal waste management. A literature search revealed that most of the literature was about existing technologies. We also began a search of the Internet looking for new technologies for animal waste treatment. We had better luck in this arena. With the support of both the National Nutrient Team and the NRCS liaisons we were able to contact researchers and others interested in waste management. As word got around that this work was in progress we began to get more inquiries about it. Overall I feel we had a good response to our requests. This report is a summary the responses that we received as well as the sites that we found on the Internet. There is a short summary of each project including a contact person, Internet and email addresses if available All the data has been forwarded to Bengt Hyberg for input into the economic analysis currently underway. Documents and support information has been saved and will be available upon request.

I first tried to divide this report into three sections, "Storage, Treatment, and Utilization". Since we found very little relating to new technology in Storage it was dropped and I added the "Other" section. Several states such as Alabama and Iowa have very good Internet sites that explain and describe the various alternatives available for animal waste management. These sites will assist a producer in planning a system for their operation. These examples are in the "Other Management" section. The Appendix I is a paper presented by Peter Wright, Animal Waste Specialist at Cornell University "Manure Treatment of Existing and Proposed Manure Handling Systems" Proceedings from Nutrient Management Planning: Competitive Agriculture in Harmony with the Environment", Niagara Falls, Ontario March 24-26, 1999. This paper does a good job summarizing manure management alternatives available to us as of today. He details each management system and includes an economic analysis. Appendix II is a report prepared by Ben Huebner, staff member of Senator Leahy's Office for the Vermont Alternative Dairy Manure Management Technology Working Group titled Current and Future Dairy Waste Management Technologies and Practices. Many of the projects in this report are appropriate for other livestock operations and not just dairy. Many of the technologies in this report also came up in our search.

There were a few projects looking into alternative uses. Sometimes it was hard to determine if they were looking at a new use or really just some form of treatment so the manure could be used as a fertilizer. The ones that came up the most were burning poultry litter for energy and pelletizing the manure to make it more transportable. We need to look closer at these technologies since they both tend to concentrate phosphorus in the residue. However, some are suggesting the addition of nitrogen to better balance the nutrients to the crop needs. The bulk of the projects deal with the treatment of animal waste. Composting came up most often as an alternate treatment. Several states have manure transport programs set up. For example, Maryland and West Virginia have programs that help address the transfer of poultry litter to other areas. It was surprising that alternative uses such as using manure as a feed supplement to cattle did not show up. Agricultural Research Service scientists have several projects where they are looking at the effects of dietary phytase and high available phosphorus corn. The practice of adding phytase to feed has been shown to be an effective means of reducing the amount of phosphorus excreted. A couple of these are in the Other Management section

Several respondents indicated that this type of report should go on the Internet. This could be another future project that would encourage Internet interaction. Another issue that surfaced and may warrant further investigation was the issue of odor. There are numerous researchers and companies looking in ways of reducing the odor. A couple of these have been added in the Other section.

This report contains those projects that we have been able to gather over a brief time period. This animal waste management technology is new and dynamic. There are new concepts all the time. This project should be an on-going one in order for us to keep up to date on new developments, since the subject is important to the livestock and poultry industries and it is evolving.

Alternative Treatment

University of Georgia

Bioconversion of Broiler Poultry Litter

The Biological Resource Engineering Laboratory (BREL) is the central location for research on the biological conversion of renewable resources and waste materials into value-added chemicals and other products. The primary objectives of BREL are to add economic value to under utilized food, agricultural, textile, and paper resources in the state of Georgia through Bioprocessing and By-Product Recovery. Research endeavors include the fermentation of carbohydrate wastes such as bakery waste and poultry litter. BREL has facilities for the maintenance of both anaerobic and aerobic microorganisms. Metabolic engineering is routinely practiced with collaborating faculty.

About 1.2 million ton of poultry litter are removed from Georgia poultry houses each year. This project explores the use of poultry litter as a substrate for the production of fermentation products. Studies have used *Bacillus thuringiensis* serovar japonensis strain buibui to produce bioinsecticidal protein in solid and liquid fermentations. The protein produced in solid substrate fermentation is being quantified, and insects are used to evaluate the strength of the bioinsecticide product. Major hurdles have included the identification and removal of chemical growth inhibitors in the litter and to quantify the amount of protein produced in solid substrate fermentations.

Contacts:

<http://www.bae.uga.edu/dept/faculty/eiteman/brel/index.html#BREL> : Poultry Litter

Tom Adams tadams@bae.uga.edu

Barbara Greyson bgreyson@bae.uga.edu

In-House Composting of Layer Manure

A manure management system, which utilized in-house low temperature composting, was tested in an experimental layer house at the University of Georgia. This system involved layers at commercial densities, depositing their manure onto deep stacked materials located directly beneath the cages. Weekly turning of the litter facilitated composting with the layer house. Tests were conducted over a one-year period using wood shavings and shredded paper products as a bedding material. Temperatures were monitored daily and compost monitored on a periodic basis. During a one year period approximately 3400 kgs of wet weight manure was deposited into a single test box (1.2 m wide, 2.4 m long, 0.6 m deep) which originally contained 150 kgs of bedding material. After a one-year period a 62% and 50% reduction in weight was observed in the woodchips and shredded paper products, respectively. A 35% reduction in organic matter was observed prior to final composting of the manure mixture. The dry weight analysis of the compost removed from the house was 1.3%, 6.5% and 3.5% for N, P₂O₅, and K₂O, respectively. The compost removed from the house is currently going through further composting for a 75 day period.

Contact: <http://bae.uga.edu/outreach/aware/thompson.html>

North Carolina

The Animal and Poultry Waste-Management Center at North Carolina State University is overseeing 11 projects evaluating existing waste-management technology. These evaluations will give growers the unbiased information they need to make informed decisions about alternative waste-management technology. The waste-treatment systems being evaluated were selected from 40 proposals submitted to the Animal and Poultry Waste-Management Center. The proposals were selected in late 1996. These eleven projects are:

BioSystems Technology Inc. And RemTec Inc. Procedure
Bion Technologies Animal Waste Treatment System
Polymer-Enhanced Swine-Solid Separation
National Environmental Technologies Inc. Procedure
Newman Environmental Solutions Inc. Aerobic Treatment
Mobil Tangential Flow Separator
Swine Wastewater Dewatering/Composting Facility
Vermicompost System
Ekokan Inc. Animal Waste Management Treatment System
Partial Lagoon Aeration of Swine Waste
Rondali Inc. Animal Waste Management System

Following are examples of the systems being evaluated. The others can be obtained from <http://www.ces.ncsu.edu/depts/agcomm/writing/wredp.htm>

Bion Technologies Animal Waste-Treatment System Evaluation/Demonstration Project

This system has been in place for approximately two years. Waste is first treated aerobically in a bioreactor, then in a long, shallow earthen reactor called an ecoreactor. The ecoreactor serves as a holding cell, where solids are converted to sludge, which can be harvested for use as fertilizer or a soil amendment. Liquid undergoes further treatment in a secondary aerated reactor and is then recycled for pit recharge. Excess wastewater and rainfall is treated in a third aerated bioreactor.

Contact: Dr. John J. Classen, assistant professor, Biological and Agricultural Engineering, North Carolina State University, phone: (919) 515-6800, fax: (919) 515-7760, email: JOHN_CLASSEN@NCSU.EDU.

Polymer Enhanced Swine Solids Separation

Separating the solid portion of waste from a swine building and allowing only the liquid portion to enter a waste lagoon is considered desirable because fewer nutrients end up in the lagoon and the solid waste may be more easily converted to a value-added product. This

project is an evaluation of a system designed to separate solid and liquid waste. The system employs a rotating screen separator, while separation is enhanced with the addition of nontoxic, food-grade cationic polymers. The polymers should increase flocculation, the clumping together of solids. While solids may have a number of uses, in this case they are to be fermented, then used as an ingredient in cattle feed.

Contact: Dr. Diana M.C. Rashash, area specialized agent (environmental education), Onslow County, North Carolina Cooperative Extension Service, phone: (910) 455-5873, fax: (910) 455-6767, email: DRASHASH@ONSLow.CES.NCSU.EDU

Conversion of manure

Theo van Kempen is about to start a project that converts hog waste to ethanol and ash at NCSU. We should be seeing more on this in the future. This will be one that we want to keep an eye on the results as it should produce a form of energy as well as a form of phosphorus that could be blended with commercial fertilizer.

Contact: Theo van Kempen Email: T_vanKeempen@ncsu.edu

Maryland

Pelletization of Manure

Perdue Farms Inc. is planning a joint venture with AgriRecycle Inc. to set up a plant that can process 120,000 tons of poultry manure into 80,000 tons of organic fertilizer in a pelleted form that could be easily shipped to areas outside of the production area.

Contact: AgriRecycle Inc., <http://www.agrirecycle.com/>
Perdue Farms Inc. <http://www.perdue.com/>

Hawaii

Modified Deep Litter System

A promising technology developed in Hawaii for nutrient management in small-scale swine operations. The deep litter system is practiced in several environmentally sensitive and land-limited countries in Western Europe (Netherlands) and Asia (Japan, Taiwan). However, several problems arising from the static in-pen composting limited expansion of the technology and practice...the Modified Deep Litter (MDL) waste management system is an innovative alternative to swine waste management. The system incorporates a constant flow, dynamic co-composting of diverted green wastes and other carbon waste materials with the wastes generated by the hogs. The composting process is started in the pens, but is completed outside of the rearing area, eliminating the build-up of heat, parasites and disease in the pens. The MDL system virtually eliminates the nonpoint source pollution potential to

aquifers and surface waters since no water is used for wash down operations. The pay back is the production of a high-value organic soil amendment, shifting the paradigm of livestock wastes from a liability to an important revenue generating resource." [A very clever and innovative feature is the use of a sloping pen, in which the litter and manure moves down by gravity and hoof action to be deposited in a holding and secondary composting channel.]

Anticipated goals:

This concept was demonstrated through an EPA section 319 grant in Kona, Hawaii and is being promoted throughout Hawaii and in the other Pacific Rim territories. Use of this technique is being encouraged by CES and NRCS in Hawaii wherever there is a suitable litter (C) source available.

Contact for further information:

Glen Fukumoto, Cooperative Extension Service, P.O. Box 208,
Kealahou, HI 96750 ph (808)322-2718, fax 2493 gfukumot@hawaii.edu

Oregon State University

Ron Miner has a small project attempting to evaluate the alternatives for capturing nutrients, particularly nitrogen and phosphorus, in a dry granular form with good storage and shipping properties. My thoughts are that this alternative may have particular application in developing countries.

Ron Miner
Bioresource Engineering Department
Oregon State University, Corvallis, OR 97331
Phone: (541) 737-6295
minerj@enr.orst.edu

Minnesota

Turning Manure into Natural Gas, and Pollution-Free Fertilizer

Al Rutan of Rutan Research has been involved for over 30 years with the design and development of methane gas producing equipment. Methane gas occurs naturally in nature under various conditions, throughout the world. Good planning and design are essential to efficient conversion of the potential energy source. There must be a net energy gain.

Schlangens Egg Farm has installed a 9,200 gallon digester, which produces methane and aged, processed fertilizer from their 75,000 bird egg-laying operation in an energy efficient manner. All previous attempts at employing the process of anaerobic fermentation, commonly used in many sewage plants, to a farm application have not been energy efficient. The process involves pumping manure from the chicken barn through a pipe into a heated converted diesel tank located in a building close to the chicken barn. This is where the

digestion process takes place. They are currently experimenting with mixing shredded garbage paper with the slurry materials to thicken for storage, drying purposes.

Contact: Alvin Schlangen spi@albanytel.com
Al Rutan, arutan@mail.mninter.net
Rutan Research,
(612) 870-7461
Toll Free 1-888-663-3737
<http://www.commonlink.com/~methane>

South Carolina

There is an on going research project at the ARS facility at Florence that is looking at the addition of Polymers to precipitate soluble phosphorus from waste water. This could be a potential solution to our P problem.

Contact: Patrick G. Hunt, Soil Scientist, Research Leader (843) 669-5203 ext 101.
Email: hunt@florence.ars.usda.gov

Arkansas

Research work at the Poultry Production and Product Safety Unit (<http://www.uark.edu/~usdaars/>) includes laboratory studies to evaluate the effects of various compounds added to poultry litter on soluble phosphorus, the products that are formed between these compounds and phosphorus, as well as ammonia volatilization. Test plots are also used to test the efficacy of various litter amendments to reduce or prevent phosphorus runoff. In addition, one compound, alum, has been shown to be an effective poultry litter amendment to reduce phosphorus runoff, decrease ammonia volatilization from litter, and improve the fertilizer value of the litter.

Contact: Philip A. Moore, Jr. (USDA/ARS, Fayetteville, Arkansas) 501-575-5724
philipm@comp.uark.edu

New York

Resource-recovery waste treatment concepts" that was developed for domestic sewage treatment have been shifted to agricultural wastes such as dairy cow manure. Presently, anaerobic digesters are being operated on dairy and poultry wastes, and the resulting residue is processed for stable fiber recovery and a soluble nutrient-rich liquid that is used in a hydroponic alternative. Important fundamental concepts from this research are significant quantities of clean, renewable energy, protein independent farming and zero pollutant discharge systems that have no ultimate disposal problems, with little or no negative impact on the environment.

One year of "proof-of-concept" efforts have shown that the above concepts are capable of minimizing the waste generated on a dairy.

Contact: W. J. Jewell and T. D. Nock,
[http://www.cals.cornell.edu/dept/aben/AnimalWaste Treatment.html](http://www.cals.cornell.edu/dept/aben/AnimalWaste%20Treatment.html)

Alternative Utilization

Alternative utilization of animal manures and byproducts are needed in areas where the concentration of livestock or poultry present significant environmental risks through land application methods. When you mention alternative uses the following examples are discussed: composting, energy generation uses, blending or mixing of wastes and other materials such as fertilizers to create value added products and animal feeding of wastes. These uses have been around for some time; I tried to find new and different uses for this report.

Georgia

Using Dairy Manure to Fertilize Year Round

At the University of Georgia two forage systems are being evaluated:

- (1) abruzzi rye-clover, minimum till, seeded into bermuda sod in fall, and harvested as haylage in March, temperate corn, minimum tilled into rye stubble - bermuda sod and harvested for silage in July, bermuda hay harvested in summer and early fall; and
- (2) abruzzi rye-clover minimum till seeded into corn stubble and harvested as haylage in March, temperate corn minimum till planted into rye stubble and harvested for silage in July, tropical corn minimum till planted into temperate corn stubble and harvested as silage in November. Each of these systems will be fertilized with irrigated dairy manure (about 600 lb of N/acre/year) and commercial fertilizer (based on soil test recommendations), in both small plots and under a center pivot system.

The overall goals of the project are to develop, evaluate and demonstrate an economically and environmentally sound method of manure utilization and crop production within a high-yield, intensive agricultural system. Much of the project work involves the measurement of nutrient recovery in crops and nutrient movement in the environment, including nutrient uptake and sequestration in the adjacent, reforested riparian zone. If the trend observed for the first crop continues for the other two crops, it could result in an additional 25 to 30 pounds of nitrogen per acre recovered as cattle forage, rather than being released to the environment.

Contact: Larry Newton, Animal & Dairy Science
<http://www.bae.uga.edu/outreach/aware/newton.html>

Riparian Buffer Systems For Utilization of Agricultural Effluents

Methods are needed to utilize nutrients contained in animal manures. Past research has shown that riparian buffer systems are effective in utilizing nutrients contained within swine lagoon wastewater. Buffer systems consisting of an upslope grassed area and downslope riparian vegetation (forest or recommended wetland species) removes both N and P from

wastewater applied by overland flow. These systems have several advantages over upland sprayfield systems. First, odor problems are minimized as compared to spray irrigation of wastewater since the effluent is applied directly to the soil surface. Second, this system utilizes a portion of the landscape not commonly used for agricultural production, and hence does not impact on land area available for row crop production. Third, harvestible grass and timber which are then removed from the site use nutrients contained in the waste. The system is recommended for the landscape portion upslope of wetlands, since it is not desirable or permissible to apply wastewater directly to wetlands.

Contact: Dr. Robert K. Hubbard
<http://www.bae.uga.edu/outreach/aware/hubbard1.html>

Connecticut

Under a Rural Development project in Litchfield County they are looking at the potential markets for the production of nursery pots made from composted manure. After liquid and solids separation the solids are composted and then compressed into pots. Kathleen Johnson would be the contact. Kathleen.Johnson@CT.usda.gov

North Carolina

NRCS is utilizing the AgSTAR program for recovery and utilization of methane gas from animal waste. We currently have two projects in North Carolina with direct involvement and several others around the country with various degrees of involvement.

Project Name: Barham Farm – 4000 Sow, farrow to wean, operation

Description: All waste from this facility is flushed to a covered anaerobic digestion lagoon with a design retention time of 65 days. Methane gas produced during the digestion process is collected under the lagoon cover and transferred to a gas utilization building. The gas is used to fuel an IC engine turning a 120 KW generator. The power is used on farm or excess can be sent out onto the grid. Recovered heat from the engine is used to heat water for on farm use. All systems are monitored by NC State University to determine effectiveness of waste decomposition and gas yields.

- Goals:
1. Demonstrate physical and mechanical process of methane gas recovery on an actual farm.
 2. Demonstrate how collected gas can be utilized on the farm.
 3. Determine the actual economic benefits of gas collection and utilization.

Contacts: Leland M. Saele, NRCS, Raleigh, NC (919) 873-2170 or email:
leland.saele@nc.usda.gov

Project Name: Ramsey Farm – 400 Sow, farrow to nursery, operation; NRCS Conservation Field Trial

Description: All waste generated at this farm is flushed into a covered lagoon for digestion and methane gas recovery. The gas is collected from under the lagoon cover and transferred to a gas utilization control center where volume of gas is measured and (currently) flared off. All systems are monitored by NC State University to determine effectiveness of waste decomposition and gas yield.

Goals: 1. Determine how well system can be operated on a small farm on older lagoon
2. Determine cost and economics of operating on a small scale
3. Determine gas yield from an older lagoon

Contacts: Leland M. Saele, NRCS, Raleigh, NC (919) 873-2170 or email:
leland.saele@nc.usda.gov

Report of the Agricultural Animal Waste Task Force

Nicholas School of the Environment

Duke University Durham, NC 27708-0328

April 1996

<http://www.env.duke.edu/faculty/sigmon/agwaste/disposal.html>

Examples Of Alternative Waste Technologies

Innovative Uses of Waste. In response to growing concerns about manure management, Entrepreneurial farmers and scientists have designed a number of innovative uses for livestock waste. For example, when Jerry Sherrill did not have enough land to spread the waste from his 100,000 broiler operation in Huntingon, Arkansas, he started a business called Crappy Critters. Sherrill molds dried, composted chicken waste into figurines of ducks, turtles, swans, and cats, and promotes them as flowerpot ornaments that will eventually release their nutrients into the soil (Krajick 1994). At the University of Georgia, researchers are investigating means of rearing industrial quantities of insects in animal waste, then feeding the insects back to the livestock as a feed supplement. The larvae have a high protein content and are nutritionally comparable to soybeans or corn (Krajick 1994). Krajick, K. 1994. Food, flies, feed: Recycling in the chicken coop (innovative ways to use and recycle chicken manure). Audubon 96(4):16-17

Other Management

There was very little on new or alternative storage technologies. Most of what is in the literature deals with known systems or structures. There were several companies that have in-vessel composting systems that could be short-term storage. These are included in the Alternate Treatment section. Several states are looking at wetlands as a management tool for waste treatment. I did not go into depth on these since most are being used to treat the effluent released from lagoons.

Several states relate good information on the Internet covering the various storage systems and existing treatment options. Alabama has a series of publications on General Waste Management, Poultry Waste, Dairy Waste, and Swine Waste at <http://www.aces.edu/dept/extcomm/publications/anr/anrae.html>. Mississippi has an on line publication "Managing Animal Waste Nutrients" that can be found at <http://www.ext.msstate.edu/pubs/pub1937.htm>. Iowa also has a series of on line publications at <http://www.ae.iastate.edu/waste.htm>. The University of Missouri has a good site offering on line publications for Animal Waste Management at this site <http://muextension.missouri.edu/xplor/waterq/index.htm>. There are many additional sites available on the Internet.

NRCS in Connecticut is developing a GIS supported Program that utilizes a spread sheet component to determine field size and travel distance from the barn for optimum and safe manure utilization.

Contact: Kathleen.Johnson@nrcs.usda.gov

Several newspaper articles have been circulating that relates information about the Enviropig from Canada. Three scientists at the University of Guelph, Ontario, say they created a pig well, 3 pigs in fact—who were injected with a spliced bacterium and mouse gene while they were embryos. The gene allows the pigs to better digest phosphorus in their feed. One report indicated 50% less Phosphorus in the manure. It is estimated that it will be 3 to 5 years before the Enviropigs become available to growers. A couple of web sites are <http://www.loe.org/archives/990702.htm#feature8> and <http://www.agpub.on.ca/iss/99/june/cover21.htm>

Ohio State University has a series of on-line Bulletins discussing poultry manure management and utilization at <http://ohioline.ag.ohio-state.edu/b804/>.

The University of Maine Cooperative Extension (UMCE) offers a regularly scheduled Compost School. The objective of the school is to provide training to people interested and/or involved with medium and large-scale composting operations. This course is offered as a certificate program by UMCE and will train personnel to be qualified compost site operators. <http://www.composting.org/>

Odor is a growing problem that has not been documented because of a lack of odor standards. There is no doubt that hog farms produce odor; to what degree is uncertain. The only indication of the severity of the problem is from the public. Although public complaints are not substantiated with quantifiable data, the increase in public outcry with the

coincidental increase of swine is an indication that the problem is real. A couple of on line discussions are included below:

From Duke University <http://www.env.duke.edu/faculty/sigmon/agwaste/prob.html>

Heavy odors are the most common complaint from neighbors of swine farms. The intensity of odors from hog farms varies with waste management practices and farm design. In North Carolina, hog waste is typically stored in large holding ponds called lagoons. Lagoons on farms that raise more than 2,000 pigs can hold millions of gallons of waste. These waste lagoons emit ammonia, volatile fatty acids, and other gases that are carried off farm property by the wind. Due to the constant additions of new waste and subsequent anaerobic activity, odor is perpetually present. As with any odor, weather conditions of wind, temperature and humidity determine intensity and distance carried.

From Ontario Ministry of Agriculture, Food and Rural Affairs.
<http://www.gov.on.ca/OMAFRA/english/livestock/swine/facts/odour.htm>

The swine industry and especially the intensive swine operations (ISO) have had to face opposition from rural communities. This social attitude results from major developments. Large modern livestock operations concentrated the production of waste, creating a stress on the environment. In parallel, there has been a major increase in the number of dwellings in and around agricultural areas.

Effect Of Dietary Phytase And High Available Phosphorus (Hap) Corn On Broiler Chicken Performance

Research is being conducted to determine the effects on broiler chicken performance and health by reducing dietary phosphorus levels in poultry feed by treating the feed with the enzyme phytase, formulating diets using high available phosphorus (HAP) corn, or when diets were formulated with HAP corn and treated with the enzyme. Data indicates that total phosphorus can be reduced by at least 11% in diets prepared with HAP corn, or in diets supplemented with phytase without affecting the performance or health of broiler chickens. When diets are prepared with HAP corn and supplemented with phytase the dietary addition of total phosphorus can be reduced by at least 25% without affecting broiler chicken performance or health. These studies demonstrate that the poultry industry can significantly reduce phosphorus in the diets of chickens, which will reduce the environmental impact of the poultry industry.

Contact: William E Huff, USDA/ARS POULTRY PROD. RE
Email: huff@comp.uark.edu

Use Of High Available Phosphorus Corn And Phytase Enzyme Additions To Broiler Diets To Lower Phosphorus Levels In Poultry Litter

This is a companion project with the previous one. The objective of this study was to examine the effect of different broiler diets on the amount of phosphorus in broiler litter, and

the effect on phosphorus runoff when the different litter types are used as a fertilizer. The diets were as follows:

- (1) broiler feed that contained a special enzyme (phytase) to increase the amount of phosphorus retained by the bird;
- (2) a type of corn (HAP corn) which contains phosphorus that is readily available to the bird;
- (3) the special corn treated with the enzyme (HAP corn + phytase);
- (4) regular commercial broiler feed.

After two flocks of broilers were grown on each diet, the poultry litter was collected and added to tall fescue plots at 3 tons/acre. There were no significant differences in phosphorus runoff concentrations between plots receiving the different poultry litter treatments. However, the HAP corn and HAP corn plus phytase lowered phosphorus runoff by 22 and 26% respectively.

Contact: Philip A. Moore Jr., USDA/ARS POULTRY PROD. RE
Email: philipm@comp.uark.edu

Appendix I

Manure Treatment of Existing and Proposed Manure Handling Systems

Peter Wright

Animal Waste Specialist, Agricultural and Biological Engineering Department
Cornell University

Agriculture is a vital component of any society. In North America agriculture provides wholesome cheap food to consumers. Farms are also important environmentally. Open space, wildlife habitats, and aquifer recharge can be important environmental benefits of farms. However, excess nitrates in the ground water, pathogens in the drinking water and excess nutrients, BOD, and sediment in surface water can have a negative effect on the environment. Farms can effect the environment through odors, greenhouse gases, and acid rain also. Society has recognized some of these negative effects and is asking farms to improve. To maintain a competitive industry we need to be able to provide feasible alternative practices based on science and good engineering that allow productive agriculture while minimizing the effect on the environment.

There are a wide variety of farms. They vary in their resources and their environmental concerns. Some farms have access to more capital, skilled labor, management ability, land resources, water resources, and markets than other farms.

Depending on the location and the management's personal values, each farm can have different environmental concerns. Those in a watershed that supplies drinking water may be more interested in controlling pathogens and phosphorus. Those with a fresh water lake may be more concerned with sediment and phosphorus. Those with neighbors may be more concerned with odors. Those in a porous aquifer may be more concerned with nitrogen leaching and pathogens. Others may only be concerned about BOD loading that cause fish kills locally. Nutrient loading far downstream may be a concern to some farms. Manure treatment methods will be required to deal with each of these issues.

Some farms are interested in mass reduction to facilitate manure movement off their farm. Development of by-products that can be sold at a profit off the farm could help maintain profitability while improving the environment.

There are many management issues that effect the choice of a manure treatment system Some of these issues include:

- 1) minimize environmental damage
- 2) maximize nutrient value
- 3) minimize neighbor problems
- 4) minimize damage to the land
- 5) minimize cost
- 6) minimize frustration

Although society may order these issues one through six, farmers may order them six through one. Providing manure management alternatives that will address the various concerns of these farms as well as be successfully applied with the variety of resources the farms may chose to allocate to them will require a number of different alternatives.

The following table describes some manure management alternatives that either are being used or are proposed.

Manure Management Alternative	Advantages	Disadvantages
Daily Spreading is being practiced by many farms. Manure and other wastes are spread as they are produced throughout the year.	Capital costs are low. Environmental effects are hidden. Odor problems are minor. Labor and equipment use is steady.	Total costs may be high. Nutrient and pathogen losses during times of saturated soils may provide excessive delivery to waterbodies. Field accessibility may be a problem.
Liquid Storage to reduce spreading during high loss and times when fields are inaccessible. Required in many areas, encouraged in all areas.	Nutrient management can be easier. Efficiencies in handling can be obtained to keep costs down. Manure can be spread when needed.	Odors are a big problem when spreading. Large liquid handling equipment needs to be available. Labor and equipment needs peak. Non-earthen storage can be very expensive. Catastrophic failure or heavy rainfalls right after spreading can cause peak pollutant discharges.
Odor Control of stored liquid manure is a major need. Chemical and biological treatments have been tried and proposed.	Would allow spreading of the manure during the growing season and eliminate neighbor complaints	No technology has yet shown that it can significantly reduce odors without significant costs.
Solid Separation of the manure solids mechanically can produce a "solid" portion (15-30% DM) and a "liquid portion" (4-8% DM).	Liquids are easier to handle. Solids can be recovered for bedding, soil amendment, or exported off the farm.	High capital and operating costs. Maintenance of the equipment is a problem. Marketing of the solids may not be successful on all farms.

<p>Composting of the manure by adding bedding or an amendment to produce a biologically decomposed product has had very limited success on farms.</p>	<p>Odor reduction is an important advantage of composting. Equipment for solids handling is available on most farms. Storage of solids is safer environmentally than liquid storage. Material may be marketed.</p>	<p>High moisture contents of most manure makes conventional composting difficult. Sales may depend on expensive specialized mixing equipment and good management. Composting outside on large areas can create runoff losses.</p>
--	--	---

Manure Management Alternative	Advantages	Disadvantages
Biodrying of the manure by recycling dry compost as the amendment to composting, and using the heat generated in the aerobic decomposition to dry the manure/compost mix with forced air has been proposed.	Odor reduction, volume reduction, and weight reduction would occur. Equipment for solids handling is available on most farms. Storage of solids is safer environmentally than liquid storage. Material may be marketed.	Management of drying process will be critical. Costs of operation may be high. Material handling may be excessive. Additional amendment may be required. Winter operation may require closed buildings.
High Solids Anaerobic Digestion would produce a decomposed residual and produce methane gas. Heat from the gas or from an engine generator could be used to dry the material for recycling within the system. This system has been tried experimentally on dairy manure.	Odor reduction, volume reduction, and weight reduction would occur. Equipment for solids handling is available on most farms. Storage of solids is safer environmentally than liquid storage. Material may be marketed. Energy production would meet the needs of the farm and allow excess to be sold.	Management of digestion and drying process will be critical. Capital costs will be high. Electric utility connections may be difficult. Material handling may be excessive. Additional amendment may be required.
Anaerobic Digestion takes as produced manure and digests it producing an odorless effluent that has reduced solids content while retaining the nutrients. Methane gas is recovered that can be used to run an engine generator.	Odor reduction and energy recovery will occur. Effluent is reduced in solids content and can be further reduced easily by mechanical solid separation. Demand for the anaerobically digested solids is greater than raw solids.	Management of digestion process will be critical. Capital costs will be high. Electric utility connections may be difficult.

<p>Lagoon Treatment of manure from the farms consists of diluting the manure, allowing it to settle in large shallow pools then flow to a facultative lagoon to be recycled as flush water to dilute more manure. Liquids and solids are periodically removed from the system.</p>	<p>Odors are reduced and solids are separated without mechanical treatment. Works well with a flush system to remove manure from barns. Solids may be marketed. Liquids can be easily irrigated. Management is relatively easy.</p>	<p>Solid harvesting and dewatering can be difficult. Exposure of large surface areas may result in extra water volumes. Impermeable soils on moderately flat terrain are required to keep cost down.</p>
---	---	--

Manure Management Alternative	Advantages	Disadvantages
Soil Treatment by mixing manure into a naturally aerated biologically active surface layer with an anaerobic lower layer, It is proposed that N will be removed, P concentrated and the effluent spray irrigated for disposal.	Nutrients and odor would be reduced in the liquid effluent. P would be concentrated in the soil treatment area so that a farm would not be tied to a large land requirement based on manure disposal limits.	Management of this system year round may be difficult. Build up of nutrients in the soil treatment zone will require removing and replacing the material on a regular basis. Capital cost for the impermeable layer and drainage system may be high.
Sequencing Batch Reactors to reduce the COD, N, in the liquid effluent and concentrate the P from the manure have been proposed. A large tank(s) would alternately fill, react, settle and decant a treated liquid and concentrated sludge. Mechanical separation and dilution would precede the process.	Odors, Nutrients and COD would be reduced in the liquid effluent which could be spray irrigated at hydraulic loading rates on crop fields. High P solids could be exported so that a dairy would not be tied to a large land requirement based on manure disposal limits.	Capital and operating costs may be high.
Total Resource Recovery by combining the plug flow methane production process with solid separation, and hydroponically recovering the nutrients would eliminate the waste and maximize production of useful by products.	Odors would be controlled. Energy would be recovered. Nutrients would be recycled. There would be no waste.	Capital costs will be very high. Operating costs may not offset by-product sales and savings in a cheap energy, cheap nutrient situation.

Some of these existing and potential treatment methods have not yet been implemented on a farm. The time to implement in table 2 gives relative estimates of when these systems could be available for farm use. Each system may be appropriate for some farms and not others. The size of the farm may determine the applicability of one system over another. The system and the specific pollutant(s) they will treat need to be balanced with the specific pollutant control needed on the farm, and the needs of the farm for an efficient manure handling system. The management skills of the farm as well as the closeness (and marketing skills of the operator) to a market will also have an influence on the choice of a system. Table 2 lists some of the characteristics of each system.

Manure Handling Options will have different relative values on different farms. Of course every farm is different both in their resources and their goals. This scale is an attempt to compare the systems with each other. For a specific farm it would have to be reevaluated to reflect actual conditions for that farm.

Scale 1 = poor

10 = good

Characteristic	Daily spread	Liquid Storage	Odor Control	Solid Separation	Compost	Biodrying	High Solids Methane	Methane	Treatment Lagoons	Soil treatment
Runoff and Leaching	1	4	5	5	6	7	7	6	8	9
Odors	5	1	5-10	2	9	9	9	10	8	8
small farm	5	3	?	2	5	7	6	3	6	9
large farm	2	7	?	6	2	5	6	8	8	6
N reduced	5	4	n/a	5	4	4	4	6	7	8
P export	2	1	n/a	3	5	5	5	4	6	7
Pathogen control	1	3	?	3	7	7	7	6	5	1-5
Nutrients recycled	5	8	6	7	4	4	4	9	2	2
Compaction	1	5	6	6	8	8	8	9	9	10
Capital Costs	9	3-7	?	5	7	4	2	2	4	4
Operating Costs	5	7	?	5	3-8		3-8	3-8	5-7	5-7
Material sales	2	3	4	6	9	10	10	7	6	5
Time to implement	10	9	1-9	9	9	5	3	7	7	2
Simplicity	10	8	1-9	6	7	5	2	2	5	4

The descriptions above provide background and a basis for comparing these manure management alternatives. Without a regulatory incentive to control nutrients, pathogens, or odors, it will be hard for an economically rational farm manager to increase production costs to implement some of these alternatives.

Concentrating research on those alternatives that will provide odor control, P concentration, and pathogen control at a reasonable cost should be a priority. More documentation of the costs, pathogen removal, and phosphorus concentration are important for any alternative considered.

APPENDIX A: System descriptions:

Daily Spreading

Description: Spreading manure and wastewater daily as it is produced is a low capital cost, low management option. Many farmers continue to daily spread most of their manure. Nutrient management to reduce fertilizer use can be difficult unless careful records and accurate spreading tactics are used. Spreading close to the source of the manure has caused soil storage of excess phosphorus on many farms. Unfortunately, many of the cropped soils particularly those close to the barns, have already been saturated with phosphorus, contributing to the water quality problems. While odor issues are generally not a serious problem on daily spread sites, runoff and leaching losses during saturated conditions can add to the nutrient loading of a watershed.

Environmental Impact: There are a number of important questions which need to be answered in order to document the environmental effects of daily spreading. Critical among them is the transfer rate between soluble P and bound P in the soil. Manure applications must be managed in such a way that almost all of the P is adsorbed in the soil and bound so that it cannot readily escape. Field and laboratory research will need to determine the appropriate spreading rates and frequency on different soils.

Economics: There are many misconceptions about the cost of daily spreading. Some studies have shown a wide range of costs. When no fertilizer credit is taken for the manure and inefficient methods are used to spread it the costs approach \$200 per cow per year. Efficient spreading and using the fertilizer value of the manure can produce a positive value on some farms. The average farm in one study in western NY lost \$75 per cow per year on their spreading operation.

Land Requirements: Daily spreading is a relatively land-intensive operation, especially if phosphorus limitations are placed on the spreading rate. Specialized application vehicles to move more manure further may be needed.

Management Strategy: This alternative can be implemented on individual farms, and in many cases can be accomplished using existing manure spreading equipment. Custom

spreading may be appropriate for fields at considerable distances from livestock housing. Additional record keeping will be needed on most farms.

Acceptability: Because it is a traditional manure management practice, farmer and community acceptance of this alternative is likely to continue to be high. However, longer hauling distances, less efficient use of nitrogen with P balancing, and pathogen concerns may discourage this option.

Liquid Storage

Description: Storing manure and wastewater to spread it at an environmentally appropriate time can reduce the total loading of nutrients to a watershed. Most farmers don't limit their spreading from a storage to times when the environmental effects will be minimized. Labor and equipment availability results in considerable application during the fall, winter and early spring. Nutrient management to reduce fertilizer use is easier when spreading from a storage. Records can be kept and spreading patterns in each field observed to be sure of more uniform coverage. There can be cost savings both in reduced fertilizer use as well as efficient use of equipment when spreading from a storage. Odor issues are a serious problem when spreading stored manure.

Environmental Impact: Management is the key to reducing the environmental impact of spreading stored manure. Odor problems create a continued pressure to avoid the warmer times of the year to spread. Catastrophic failures can result when storages are breached, or when a large runoff event washes all the manure off the land after the manure storage was emptied on to many fields.

Economics: Storage can be an economic positive for the farm by allowing efficient spreading operations and the use of the manure as a fertilizer. Incorporating the manure to preserve the ammonia as a fertilizer is an option for all of the manure when spreading from a storage. Delays in planting or other operations due to the time it takes to complete the manure spreading operation can cause a large loss in net farm income. Weather variability makes spreading a years worth of manure in the spring prior to planting a difficult task.

Land Requirements: Spreading from a storage can take even more land than daily spreading if it is incorporated, as the nitrogen can be utilized more completely. This will make it a relatively land-intensive operation, especially if phosphorus limitations are placed on the spreading rate. Less nitrogen will need to be added to a phosphorus balanced rate if it is incorporated. Specialized application equipment to move more manure further may be needed.

Management Strategy: This alternative can be implemented on individual farms, and in some cases can reduce spreading costs. Custom spreading may be appropriate on some farms. Management is very important when unloading a storage to prevent spills or overloading of fields. Odor control of the stored manure is an issue that each farm with stored manure needs to consider.

Acceptability: Because of the increase in foul odors the community may not accept this practice even when it can be shown to improve water quality. Farms that can reduce their spreading costs, or improve the ease of spreading operations may be willing to put up with some odor complaints. People will be less and less willing to accept the odors as the spreading is concentrated more in the warmer months and concentrated on larger farms.

Odor Control

Description: Many processes have been proposed to treat stored manure to reduce the objectionable odors. These include some of the treatment process contained in this document as manure management alternatives. Other biological, physical, and chemical proposals include: Specific enzymes and bacteria, aeration, chemical reactants, heating, drying, raising the pH, chemical masking, magnetism, and electric currents. So far a process that is effective yet low cost has not been found. Research continues world wide to provide a solution.

Environmental Impact: Odor control is essential to allow farms to spread on land close to residences and during the summer. Potential leaching and runoff concerns during the cooler wetter times of the year is pushing those farms interested in water quality into a conflict with their neighbors as they attempt to spread manure during the summer. Spray irrigation on growing crops of an odorless manure would be the best method of manure application to provide nutrients to the crop while minimizing environmental losses.

Economics: The value of odor control is a hard quantity to define. Avoiding neighborhood conflicts, increased quality of life, and avoiding potential law suits does have a value. Regulations on odor emissions are a real possibility in the future. These regulation will make some form of odor control needed on many farms.

Management Strategy: Although there are some management techniques to reduce odors and avoid neighbor conflicts the odors from stored manure without treatment will challenge even the best managers.

Acceptability: Any system that is low cost and easy to manage will be adopted rapidly by farms.

Mechanical solids separation

Description: Separating and hauling the separated solids from the manure produced on each farm could potentially allow for the export of approximately 20% of the phosphorus. There are a number of separators commercially available. Most require the addition of extra water. The screw press separator manufactured by Fan seems to work without additional water added and provides a fairly dry product. It will produce at least one cubic foot of 30% solid manure for every minute of operation on a dairy farm. That rate will handle about one cow's daily manure production per minute. This rate may be increased, depending on the size of the solids, the moisture content of the manure slurry,

and the internal wear on the auger vanes. A truck mounted unit or units could go from farm to farm on a regular schedule separating the manure for export, or composting. A storage facility on each farm would need to handle the daily manure produced as well as the liquid remainder. This system is being used in Europe.

Environmental Impact: Since the amount of phosphorus in the separated manure solids is 20% of the total phosphorus in the manure, removal of the solid produced from the separator would only reduce the loading of phosphorus by 20%. It would have no effect on the pathogens. Nitrogen would also be removed by 20%.

Economics: The separation equipment costs about \$30,000 for each machine. If permanently installed on a farm it would take another \$25,000 for the building pipes and plumbing. One machine would be required for each 500 cows assuming an 8 hour day. The ownership costs which include depreciation, insurance, a 15 year life, and interest at 10% would be \$3.50 per hour. The Fan separator uses 4 kW to turn the auger, and 0.15 kW to run a vibrator to keep the manure entering smoothly. Assuming a 10 hp manure pump motor uses 8 kW, the electrical use per 500 cows would be 8.3 hours times 12.15 kW or 102.5 kW hours per day. Maintenance on the separator is estimated at \$2.50 per hour. The economics of truck mounted multiple units would have to be explored. Liquid manure handling equipment would need to be obtained for each farm left with the liquids.

Land Requirements: Two small three to four day storages for each farm would be needed to store the manure until it was separated and then to store the liquids until they could be spread. Vehicle access to these storages would be needed if portable separators were to be used.

Management Strategy: Most farms are not large enough to justify a dedicated separator. A private operator could set up an operation to separate the manure, haul the solids to a central site for composting or high solids anaerobic digestion, and then market the product. The profit from the sales if any could be split between the farmer and the private operator.

Acceptability: The farmers would need to convert to a liquid manure spreading system. If all the solid manure was to be moved off the farm this would not be that big a burden. The storage and spreading of the liquid is a little easier to manage than handling a solid. More uniform applications could be expected as well as slightly more N retention since the liquid portion will infiltrate into the ground sooner. There may be a slight odor reduction because the liquid manure will infiltrate into the ground quicker.

Composting

Description: Composting is an aerobic decomposition process which is an established on-farm manure management method. The energy liberated during the decomposition process raises the compost temperature to accelerate decomposition and evaporate water, resulting in a dried, stabilized product in 3 to 6 months. A primary constraint on composting is the requirement for a dry bulking amendment to create adequate porosity

in high moisture manures. This requirement can be reduced or eliminated via the use of solid separation technology (see above) and/or recycling dried product in the mixture (see Biodrying).

Composting could happen on individual farms with mobile equipment, or at a centralized facility depending on the tradeoff between equipment and manure transportation costs. Product marketing would likely be a centralized function performed by a private contractor, who would also provide equipment maintenance and management services.

Environmental Impact: Export of the compost product would result in removal of phosphorous and nitrogen from the farm. To the extent compost was used on the farm, phosphorus would remain while nitrogen would be reduced through ammonia volatilization by 30 to 70%. In either case the high temperatures achieved during composting would greatly reduce or eliminate pathogens. The amount of manure composted could include only the excess intended for export, or it could include the entire manure stream as a way to treat manure before returning it to cropland. Application rates could be limited to the phosphorus required by the crop, so that nitrogen fertilizer would need to be imported. Odors will be controlled with proper management.

Economics: The economics of on-farm composting have been documented through a number of studies, including cases studies from throughout New York State. Combined amortized capital and operation costs typically range from \$5 to \$20/ton. The value of the compost product will offset that cost to a limited degree, although marketing expenses will also need to be considered. Tradeoffs between material transport (bulking amendment and manure) and equipment transport will be analyzed for specific clusters of farms to determine the optimal scale of a facility.

Land Requirements: The composting site(s) envisioned would most likely be outdoor windrow systems, and would have to be designed with adequate water quality protection measures. Retention ponds and pasture irrigation systems have been used successfully for runoff management at other farm composting facilities. Typical windrow composting operations require one acre for every 3000 yards of material. Including some space for runoff management, approximately 1.5 to 2 acres would be required for a 50 cow dairy.

Management Strategy: Several management options are possible for this technology. In the scenarios proposed, a subsidized private contractor could manage the manure for several farms, either moving equipment to individual on-farm sites or hauling manure to a centralized facility. In a decentralized processing scenario, equipment would need to visit each site regularly, with increased frequency during the summer and early fall to provide relatively dry finished compost for storage and sale the following spring.

Acceptability: Composting is an established manure management approach, and multi-farm implementations already exist in the Northeast. Several sites operate centralized facilities collecting manure from many farms, while one operation contracts compost turning and management services for several farms. Although these existing models

demonstrate widespread acceptance of composting by farmers and private businesses, they also provide indications of the critical issues for community acceptability. Centralized facilities, because of their larger impact on the immediate neighborhood, are more likely to raise concerns about odor and traffic. If economic and transportation analysis suggests a centralized solution, these concerns must be carefully addressed.

Biodrying

Description: If managed carefully the heat generated by aerobic composting can provide the energy to reduce 12% DM manure to a 60% DM residual. Forced air composting, under a roof, with the air flow controlled carefully would optimize this process. Composting works best with an initial moisture content below 70%. Recent applications of composting operations that have used forced air to compost six foot high layers of manure in 21 days have shown the feasibility of this process. Recycled compost at 40% dry matter could be spread in the alleys about 3 inches thick to absorb one days production of 12% DM manure. The mixture could be scraped into a shed, piled 6-8 feet deep and aerated to produce 40% DM compost in 3 weeks. This recycle loop could be continued indefinitely. One third of the compost produced each day would not be needed to be recycled and would be stock piled for sale or land application on the farm. This process could potentially compost all of the manure produced with little additional amendment needed. The compost would be reduced one half in volume and one sixth in weight from the original manure due to water loss and solid conversion to gasses.

Environmental Impact: Pathogen control and odor control would be substantial. Heat produced during the compost process has been shown to reduce pathogen viability substantially. The aerobic nature of the composting process produces few odors if managed correctly. Storing and spreading a high solids product should reduce the runoff potential and eliminate the potential of a catastrophic failure from the storage system.

Economics: The capital cost for this system would consist of a three sided composting shed with an aeration system installed in the floor. Most farms have the needed material handling equipment on the farm. The additional material handling, amendment if needed, and power for the aeration equipment would be the operating costs. These costs may be offset by sales of the product or use of the compost as bedding.

Land Requirements: The composting shed would need to be large enough for 21 days storage of the compost manure mix piled 6-8 feet high. Additional storage for the excess compost could be provided on a pad with controls for rainwater runoff.

Management Strategy: Although the air control/temperature feedback system may need to be automated to optimize moisture removal, the rest of the system is well within the management capabilities of most dairy farm operators. Solid handling of odorless compost should make manure spreading much easier.

Acceptability: If successful this system would likely be adopted by many small and medium sized farms that have yet to adopt to liquid storage systems. Farmers and the community will enjoy the odor and pathogen reduction.

High Solids Anaerobic Digestion

Description: This system would take the manure produced on the farm, mix it with the dried by-product and send it through a high solids anaerobic digester. The system would produce a stabilized pathogen free by-product much like compost available to export off the farm. All the phosphorous from the manure would be in this by-product.

Manure at 12% solids would be mixed with 50% solid by-product to make a 28% solid material that would be placed in a closed tank and heated to thermophilic temperatures. This will produce methane which when generated for electric use on the farm will also produce the heat needed to both heat the digester and to help dry the effluent from the digester. The effluent would need to be dried in a roofed structure with aeration and waste heat from the generator. Most of the dried by-product would be reused in the process but ultimately a steady flow of 5 cubic yards per day per 100 cows of 50% solids would be produced to be marketed off the site.

This process has not been used on a farm but has worked in large scale operations in previous research activity by Professor William Jewell at Cornell.

Environmental Impact: This process would package all the phosphorus produced on the farm in a stabilized, deodorized humus much like compost for export off the farm. The pathogens and weed seeds would probably be killed. The volatile nitrogen (NH_3) would be lost during the drying phase. The farmer would have a portion of the by-product available to use on the farm for fertilizer or organic matter amendments. Application rates would be limited to the P required by the crop, so that nitrogen fertilizer would need to be imported.

Economics: This system may be put on a single farm or at a central site. The advantages of placing it on each individual farm include: the ability to use the electricity generated on the farm to replace electricity being purchased; the equipment needed to handle the high solid materials are generally already on the farm; and transportation costs would be limited to those used to export the final by-product off the farm.

A central system would find some economies of scale in building the digester tanks and in the engine generator to use the methane. The expertise needed to run the system and market the by-product could be concentrated at one site.

The capital costs would be high for this system. They would include a closed vessel for the digestion, an engine generator, and a drying shed. These costs could be as much as \$200,000 for a 100 cow farm.

The operating costs may provide a break even or better situation on a single farm resulting in savings from electricity generated and bedding produced. A centralized site may have difficulties selling the electricity and have added transportation costs to move the dried material back to farms for bedding.

Land Requirements: The area this system would take up would include a 20 foot high by 15 foot diameter vessel and a 70 x 100 drying shed for a 100 cow dairy. This should not be a significant constraint on most farms.

Management Strategy: This technology would be about the same complexity as existing anaerobic digestion systems. We can expect those farmers with an above average management ability being able to operate the system with ease, while those farms that are not managing well will find running the system to be a burden. Handling the manure as a solid would mean that most of the equipment to move the material would already be on the farm and the operator would be familiar with the operation of it. An outside service person could be used to check the systems on a regularly scheduled basis if enough farms were using the system. At a central site a manager with the capabilities of a sewage plant operator would be required to run the operation efficiently.

Acceptability: There would be some disadvantages to this system on the farm. This system would potentially reduce the amount of recycled nitrogen and phosphorus to the land. The nitrogen deficit would have to be imported. It would add another enterprise that would have to be managed on the farm. The advantages include electricity and bedding cost savings and odor control. Good managers who were provided the capital cost should benefit from this system.

The community should expect this low odor processing. There would be an increase in truck traffic especially at a multi-farm site. This system would provide pathogen control, phosphorus export.

Anaerobic Digestion

Description: These biological treatment systems take manure as produced at 12% DM and heat it, with waste heat from the engine generator, then anaerobically digest it in an enclosed insulated trough for about 20 days. The manure is continually being fed in and an odor reduced effluent at about 8 % DM is continuously released. Methane is produced that is used to power an engine which drives a generator. Electricity produced exceeds the average dairy farm consumption of electricity providing the possibility of power sales. The effluent with all of the nutrients still in it could be stored to apply to the land.

Environmental Impact: The anaerobic process does reduce most pathogens. The extent of this reduction depends on the temperature regime in which the digester is operated. Most are run mesothermally but thermophilic digesters are possible. Odor reduction is another benefit of this process. The slight liquification and the enhanced ability to separate the solids mechanically after digestion can make the effluent easier to

pump and irrigate. With the odor reduced spray irrigation on growing crops is a real possibility. This has the potential to reduce runoff and leaching losses.

Economics: There are economies of scale with this system. Farms with over 800 cows would be more viable and may make a profit with these systems. Smaller farms may not make a profit. Design modifications to reduce the capital costs will continue. Centralized systems must overcome transportation costs to be profitable. In cheap energy times the sales of power may not produce enough of a cash flow to warrant use of this system.

Land Requirements: The size of the digester needs to be large enough for 20 - 30 days of hydraulic retention time. The engine generator and solid separation system, if used, would require a building to house them. The total volume of manure is not significantly reduced with methane generation.

Management Strategy: Management of these systems is difficult for most dairy farms. While the ordinary monitoring could be done with existing personnel on the farm, when problems develop like engine failure or reduced gas production in the digester, farm labor may not have the expertise or be available to fix them. A private design and maintenance organization should be able to provide this service for a group of dairy farms.

Acceptability: Although these systems have been installed and demonstrated for over twenty years few farms have continued operating them. Cheap energy and the high capital costs are economic disincentives. Maintenance demands also caused existing systems to be abandoned. The need for odor control at a low cost may make them more popular in the future.

Treatment Lagoons

Description: This patented process (Bion) uses managed shallow pools to separate the manure solids into aquatically stabilized solids. These solids are then harvested, dried, screened and then sold as a soil amendment. The system recycles the biologically active liquid to move the manure through the ponds. This is typically done by flushing the alleys of a barn.

Environmental Impact: Although the amount varies, the phosphorus can be concentrated in the solids so that up to 75% of it can be removed. Although there is no specific knowledge of pathogen reduction, this may be significant since the retention time in the system is long. There is no temperature increase above ambient in this system. Odors are much reduced when this system is operating correctly. Ammonium nitrogen is lost into the air from this system.

Economics: The pond system and recycling pump would be a relatively low capital cost on a favorable site. A flat site with low permeability soil would keep the costs of installation down. Steep sites that require an artificial liner would be much more expensive. The operating costs may be offset by the sale of the product. If the barns

were set up for flushing, additional labor savings could be obtained as the recycled water would clean the barns. Retrofitting a flushing system into a flat barn would be very expensive. An existing 2% slope on the alley's would be ideal. A method to further treat or spread the extra waste water would need to be provided.

Land Requirements: The land requirements for the Bion system would be high. A 100 cow operation would need about one acre of ponded area and storage for 1 million gallons of effluent.

Management Strategy: The operation could be managed by:

Bion Technologies, Inc.
606 N. French Road, Suite 6
West Amherst, NY 14228
716-691-3385

The capital costs for the installation and a management fee would be paid to this company and the profits from the sale of the Bion soil would be split between the company and the farmer.

Acceptability: This process should be acceptable to the farmer once the initial capital cost is taken care of. The effluent to be spread or treated in a wetland will need to be managed. The system includes over winter storage and does reduce odors. This system would be most efficient operated on the farm in conjunction with a flushed freestall housing. By potentially removing a larger portion of the phosphorus and reducing odors, this system may become more popular with dairy farms.

Soil Treatment

Description: Applying high amounts of manure on a small area that is managed for nitrogen removal and phosphorus concentration would convert the manure into a soil amendment that could be exported. Manure would be spread, aerated and mixed with the soil to promote aerobic activity in the surface zone. Leaching into an anaerobic layer beneath the surface would denitrify the nitrates produced in the aerated zone. The nitrogen would be released as nitrogen gas. Phosphorus would be taken up by the biological activity and adsorbed to the soil matrix. When the amount of phosphorus leaching out became excessive the whole matrix could be dug up and sold out of the watershed as a soil amendment. The site would need a positive barrier to prevent water from leaving and would probably require a roof for year round operation.

Environmental Impact: If successful this method would contain most of the phosphorus for export out of the water shed. Pathogen removal would be limited in this area since the retention time would be fairly rapid. No temperature increase above ambient would occur, so pathogen reduction would be dependent on processing time.

Economics: If no roof was required this system would be relatively low cost on the right site. A flat area with a very low soil permeability would be the least cost situation. A synthetic liner, a drainage system, specific sand and loam fill would be needed. The

mixing and aeration operation should be able to be accomplished with existing on farm equipment. The amount of time required is unknown. Professor Bill Jewell at Cornell is currently evaluating the feasibility of this system.

Land Requirements: A 100 cow dairy may need a 2.5 acre area for their total waste management for this system.

Management Strategy: Once the process is demonstrated it should be possible for the typical dairy farmer to manage the system. A consultant may need to be available for trouble shooting, and to assist in the marketing of the soil matrix when it is saturated with phosphorus. There would be no advantages to a centralized system.

Acceptability: These systems may not be acceptable to the farmer. As much time and effort may be required to operate the system as daily spreading, while the fertilizer value of the manure would be lost to the farmer. The sale of the soil matrix may pay for some of the fertilizer imports needed. Good phosphorus reduction but the pathogen treatment is unknown.

Sequencing Batch Reactor

Description: Certain microorganisms store phosphorus under alternating aerobic - anaerobic conditions. Biological phosphorus removal creates fluctuations in the oxygen content of a wastewater to encourage this excess P uptake by microbial biomass. During the anaerobic stage some of this phosphorus enriched biomass is withdrawn as a sludge. This is an established treatment technology for municipal wastewater, but has not been applied often to agricultural wastes. In order to achieve adequate settling of the solids, manure collected as a semi-solid would need to be diluted prior to treatment. Much of the effluent from the system would be recycled as dilution water.

Environmental Impact: In this application the phosphorus enriched sludge would be dried into a marketable product. Export of the product would result in removal of phosphorous and nitrogen from the watershed. Because of the relatively high tech nature of this treatment approach, a centralized system would likely be built to serve a large number of individual farms. Effluent from the system (beyond that required for dilution) may be suitable for direct discharge, or might require spray irrigation fields.

Economics: This is an expensive option, with costs similar to those of a conventional wastewater treatment plant on a BOD basis. Professor Carlo Montemagno at Cornell is currently developing this system in the lab, to establish feasibility and costs for agricultural manure applications

Land Requirements: Siting requirements would be similar to those of a wastewater treatment plant. If spray irrigation of the effluent were necessary, land requirements could increase significantly.

Management Strategy: As envisioned, manure in excess of crop phosphorus needs would be hauled to a central plant for phosphorus removal. The plant would be run by a public authority or under contract to a private operator. The complexity and capital economies of scale implicit in this approach would likely preclude operation on individual farms.

Acceptability: On farms that need both odor control and phosphorus balancing, this system may be required to stay in business. Farms just meeting odor control may see the high cost as a disadvantage. If energy and nutrient prices increase this system will not be the preferred treatment system.

Total Resource Recovery

Description: This system in essence creates a high value recycling system for the manure nutrients. The liquid stream from a solids separator would be diluted and used to grow plant proteins hydroponically that could then be fed to the cattle. On-farm production of a high nutrient feed would reduce the need to import extra feed onto a farm and into the watershed. The diluted manure could come from several different treatment systems. An anaerobic digestion system operated at thermophilic temperatures preceding the hydroponics system would provide pathogen and odor control. The hydroponics system would be contained in a greenhouse environment and potentially be used to grow bacteria, simple and complex plants.

Environmental Impact: By reducing the import of nutrients this intensive recycling program could improve the nutrient use efficiency on the farm significantly. This would eliminate the extra phosphorus loading onto the fields. Pathogens and odors would be completely controlled if the system was preceded by a thermophilic anaerobic digester. Caution should be exercised before using untreated diluted manure, which could potentially recycle pathogens to animals through the feed.

Economics: Depending on the operating costs this system could be very feasible. A high protein feed, bedding or soil amendment from the fibers, and energy are produced. There would be no waste discharge. The capital cost would be high. A 100 cow dairy could expect the initial costs to be on the order of \$250,000. Professor Bill Jewell at Cornell is currently evaluating the feasibility of this system at pilot scale, and those results should provide the necessary information for a field scale pilot system.

Land Requirements: The 100 cow dairy would need about 2 acres of greenhouse production. The anaerobic digester and the engine generator would also need a building space.

Management Strategy: This system would be very intensely managed. The greenhouse would have to be managed by an expert. One scenario would be for the farmer to enter into a partnership with an individual or a corporation with this expertise. If successful, this strategy would provide a range of opportunities for local economic

development, including services related to greenhouse production, digesters, and composting of separated solids.

A centralized site would provide the opportunity for economies of scale on the digester, and better management and production of the protein supplement. Transportation cost of the manure and the difficulty of selling the electricity produced would be the disadvantages.

Acceptability: This system could not be adopted by the farmer on his own. The hydroponics production would be a complex and new skill to learn. With the right partner this system should be accepted by the farmers. The potential economic advantages are attractive.

This system should be seriously consider for the future. The capital costs will be high but it would achieve the goal of pathogen, odor, and phosphorus control. It should increase the economic viability of the area with the creation of jobs and cheap energy.

APPENDIX B: Two Existing Odor Control Systems:

By comparing two feasible alternatives to manure handling that achieve odor control, agricultural engineers and producers will be better able to chose an effective and economically viable system for farms today. These systems improve neighbor relations, reduce the impact on the environment, and will help provide for sustainable development of the dairy industry.

A comparison of two existing odor control treatments on dairy farms in New York State shows the costs and benefits of each system. On Farm A an anaerobic digester is used to stabilize the manure and collect methane for the production of electricity. The effluent is then run through a screw press to separate the solids for composting. The liquid effluent is then stored for land application. This system is compared to Farm B that uses the Bion treatment lagoon system. This farm uses flushing to carry the manure to shallow ponds for solid settling. The solids are recovered for off site sale. The liquid effluent is treated in a facultative lagoon. The effluent from the lagoon is recycled for use as the liquid for flushing the barn. Excess liquid is applied to crop land as a nutrient supplement.

Both of these systems achieve significant odor control. The farm with the anaerobic digester has a positive present value of the manure handling system of \$698 per cow. This includes nutrients remaining, solids sold off farm and electricity produced. The farm with the treatment lagoon system has a negative present value of the manure handling system of (\$390) per cow. This includes nutrients remaining and solids sold off the farm.

Farm A:

This dairy farm is a 500 cow operation with a business plan goal of milking 1,000 cows. Samples of manure were taken at the end of each process in this system. The manure

before and after anaerobic digestion was sampled, as well as both flows from the separator. The manure storage pond was sampled prior at the surface after winter storage. There could be significant variation in these samples especially the one from the waste storage pond. Dilution by precipitation milking center wash water as well as settling may have distorted the nutrient contents. Table 1 shows the percentages from each sample.

Table 1 Manure characteristics and estimated amounts per cow from Farm A Anaerobic Digestion System.

	%M	%N	%P	%K	Lb.
As produced per day	90	0.44	0.09	0.29	152
After digestion per day	93	0.45	0.07	0.26	146
Separated liquid per day	95	0.43	0.06	0.28	126
Separated solids per day	77	0.51	0.11	0.26	21
From storage per day	98	0.27	0.02	0.16	165
Nutrients available					
Lb. per year		163	12	97	

Costs on Farm A

The \$365,000 first year expense for this system is high but there is more opportunity for potential returns. After converting to a present value over a 20 year life with 8% interest, the net per cow benefit is \$698.22. Sales of electricity are assumed to \$24,000 per year. The sales of solids are assumed to be \$32,445 per year, and assuming the value of the nutrients at \$0.25 per pound the nutrients remaining are worth \$34,060 per year. There are of course many factors not taken into account in this analysis. The nutrients were assumed to be needed when it may be that only nitrogen is needed on the farm. The electric value will depend on a number of pricing and production interactions. The sales of the solids hopefully will continue without competition from another farm that might be closer to the market providing the organic material at a lower cost.

Yearly expenses include \$15,000 per year for the maintenance of the digester, engine, and generator. This will include occasionally replacing the cover and removing the grit in the bottom of the digester. The engines and generator repairs and scheduled overhauls are also included in this yearly cost as is the one half hour of daily maintenance to check the system. The spreading costs of the manure were ignored as well as the offsite storage. The cost of the alley scrapers is also not included in the system. The pumps were estimated to have a 10 year useful life. Their replacement was included in the present value calculation. These costs are shown in table 2

Table 2. Costs for anaerobic digestion manure handling system for Farm A.

Present Value	Yearly Amount
---------------	---------------

First Year Expense	(\$365,000)	
Ten Year Expense	(\$22,696)	
Operation and Maintenance	(\$151,786)	(\$15,460)
Nutrient Value Remaining	\$334,406	\$34,060
Solids Sold	\$318,550	\$32,445
Electricity Sold	\$235,636	\$24,000
Net Income	\$349,109	
Net Income per Cow (with 500 cows)	\$698	\$35

Without including the nutrient value the system has a present value of \$1 per cow over the 20 year life of the system. When the dairy expands to 1,000 cows, the net income present value will be \$1,100 per cow or \$55 per year. Some farms may not be able to obtain a benefit from the manure. Farms with fields that have high to excessive levels of phosphorus and potassium may even see these nutrients as a detriment. Appropriate nutrient management will be needed to utilize the nutrients to maximize crop uptake. The ability to irrigate the effluent on growing crops without excessive odors will increase the likelihood that the nutrients can be used.

Farm B

This dairy farm is presently a 170 cow operation that can hold up to 300 cows. Samples of the solid leaving the farm and the liquid effluent being applied to the fields were taken in this system. There is a significant variation in these samples from ones taken in 1997. There are differences due to the weather and the uncontrolled nature of the biological processes that will make the nutrient concentrations and the volume of waste water vary considerably. Dilution by precipitation, milking center wash water, and silage leachate as well as settling may have distorted the nutrient contents. Table 3 shows the percentages from each sample from the spring of 1998.

Table 3 Manure characteristics and estimated amounts per cow from Farm B lagoon treatment system.

	%M	%N	%P	%K	Lb.
As produced	90	0.40	0.09	0.30	152
Separated liquid	99	0.08	0.01	0.07	135
Separated solids	83	0.37	0.10	0.07	17.5
Nutrients available Lb. per year		39	5	35	

Treatment Lagoon Costs

The \$94,919 first year expense for this system is a moderate investment for a manure handling system. There is some opportunity for potential returns, but the revenues from the sale of the solids have to be split with the managing partner. After converting to a present value over a 20 year life with 8% interest, the net per cow cost of this system is (\$390.27). The sales of solids are assumed to be \$6,000 per year, and assuming the value of the nutrients at \$0.25 per pound the nutrients remaining are worth \$3,354 per year. There are of course many factors not taken into account in this analysis. The nutrients were assumed to be needed when it may be that only nitrogen is needed on the farm. The sales of the solids hopefully will continue without competition.

Yearly expenses include \$2,995 per year for the electricity and \$3,360 to remove the solids from the shallow solid settling ponds. The pump was assigned a ten year life. The spreading cost of the manure was ignored as well as the offsite storage cost. The additional benefit of cleaning the barn is included in this system. The farmer, the veterinarian, and the hoof trimmer are pleased with the results of the flush system. These costs are shown in table 4

Table 4. Costs for lagoon treatment manure handling system for Farm B.

	Present Value	Yearly Amount
First Year Expense	(\$94,920)	
Ten Year Expense	(\$1,880)	
Operation and Maintenance	(\$62,396)	(\$6,355)
Nutrient Value Remaining	\$32,930	\$3,354
Solids Sold	\$58,910	\$6,000
Net Income	(\$66,346)	
Net Income per Cow	(\$390)	(\$20)

Without including the nutrient value the system has a negative present value of (\$584) per cow over the 20 year life of the system. When this system spreads it's costs over 300 cows the negative present value will drop to (\$125) per cow over 20 years. This is (\$6) per cow per year. Again, some farms may not be able to obtain a benefit from the manure. Farms with fields that have high to excessive levels of phosphorus and potassium may even see these nutrients as a detriment. The lower amounts of these nutrients in the effluent of this system will make this less likely. Still appropriate nutrient management will be needed to utilize the nutrients properly. The variation of the nutrient concentrations because of the effects of weather on the process may make this system a little more difficult to develop a nutrient management plan. The ability to irrigate the effluent on growing crops without excessive odors will increase the likelihood that the nutrients can be used.

Conclusions

Both the lagoon treatment system and the anaerobic digester are feasible systems for dairy farms that will provide excellent odor control. The management required is well within the abilities of most dairy farms.

There are advantages and disadvantages to each system that may be more or less important to each farm. The lagoon treatment system works very well with a flushing system to clean the barns. Gently sloping topography and relatively impermeable soils will keep the initial costs low. Farms that don't need all the nutrients in the raw manure may benefit from the nutrient losses of this system. The anaerobic digester system would be best for a farm that had high electric costs and could use the nutrients for crop production.

Nutrient utilization and by-product sales are important in reducing the cost of a manure handling system. Marketing the separated solids and fully utilizing the nutrients in the manure can help pay for odor treatment systems.

References:

Jewell, William J., P. E. Wright, N. P. Fleszar, G. Green, A. Safinski, A. Zucker, "Evaluation of Anaerobic Digestion Options for Groups of Dairy Farms In Upstate New York" Final Report 6/97 Department of Agricultural and Biological Engineering, College of Life Sciences, Cornell University, Ithaca, New York 14853

Wright, Peter and S. P. Perschke, "Anaerobic Digestion and Wetland Treatment Case Study: Comparing Two Manure Odor Control Systems for Dairy Farms" Presented at the 1998 ASAE Annual International Meeting Paper No. 984105 ASAE 2950 Niles Road St. Joseph, MI 49085-9659

Wright, Peter, Manure Spreading Costs and the Potential for Alternatives. Proceedings from Managing Manure In Harmony with the Environment and Society, 2/10-12/98 Ames, Iowa, West North Central Region of the Soil and Water Conservation Society.

Appendix II

Memo on Current and Future Dairy Waste Management Technologies and Practices

Prepared for the Alternative Dairy Manure Management Technology Working Group

Prepared by Ben Huebner, 8/3/99

Introduction: This memo is a result of the many conversations I have had with agricultural scientists, agricultural economists, and businessmen regarding how to deal with the problem of dairy waste runoff. Although it was originally supposed to summarize documents about existing technological practices, the lack of both documentation and practices themselves has led to a different format. The **Mechanical Separators** and **On the Market** sections give basic information about commercial products including information on costs, services provided by the company, capabilities, and contact information. When applicable, the evaluation and contact information for a scientist who has evaluated the technology is also included. The overview is not exhaustive, but instead a cross section of the different technologies currently on the market. All other sections are culled from conversations with various experts in their respective fields. An extremely brief synopsis of their work, opinions, and contact information is included. A few other brief notes should be mentioned. Almost all figures in this memo were either estimations or highly contingent upon external factors, and are therefore meant solely to provide an idea on cost or results. Secondly, I have spoken with everyone mentioned in this report. All of them are available for any questions you may have. Also, the Supersoil project has been omitted, as the group already has extensive information. And lastly, Jim Hannawald of the USDA is currently working on a similar project to this one. His report will be much more comprehensive, but will only include a one or two sentence description of every technology he finds. Mr. Hannawald will complete his project by October 1st, and will make his findings available over the Internet. He can be reached at 301-504-3950 or jhannawald@md.usda.gov. Mr. Hannawald has received a copy of this memo.

Synopsis of Findings: There was one statement I heard from almost every animal waste expert in the field. If I knew a real solution for the phosphorus problem, I wouldn't be sitting here talking to you. I would be a millionaire. Their point was that there are no silver bullet solutions that will eliminate the P problem. There are, however, various practices and technologies that tend to reduce P runoff. A combination of these practices could provide the solution Vermont needs.

There are three major ways to reduce P runoff: nutrient management, land management, and technologies that convert the waste into a marketable product that can be moved off the farm. Nutrient management should probably be the first action undertaken, as many dairy farmers are wasting money by feeding more P to their herd than the cows require. Much of this P is excreted, contributing to the waste problem. Good land management practices are also essential, for 90% of phosphorus runoff comes from only 10% of the land. By reducing or eliminating the amount of manure spread on high runoff areas, the P problem, as well as other animal waste runoff problems, can greatly be reduced.

Technological solutions tend to be far more expensive, but have the added advantage of reducing or eliminating the need to spread excess waste on the fields. These waste management practices first require solid separation at the farm. The solids can then be composted in a variety of ways, or be treated by a bioreactor to create a soil supplement. Neither system reduces the amount of P in the end product, but they do convert the waste into a product that can be sold off the farm, given that a market has been developed.

Below are further explanations of the practices and products described above, as well as prices and contacts. Also included are the thoughts of waste management experts who could provide further information about particular systems and waste management in general.

Nutrient Management: Reducing P intake by the animal can reduce both P levels in excretion as well as reduce farmer feed costs. Larry Satter with the US Dairy Forage Research Center of USDA-ARS researches dairy nutrition and nutrient concentrations in manure. His own research, research in the University of Bonn, and research in Holland have found that dairy farmers are feeding their cows 20 - 30% too much phosphorus. They confirmed studies done years ago by the National Research Council (NRC) that even the highest yield dairy cows need only .38 - .40% phosphorus as percent of dry matter, but are currently being fed an average of .48 - .50%. Many dairy farmers over supply phosphorus because of a myth that the NRC statistics are too old to be accurate and that low phosphorus levels lead to reproductive problems (this last one is only true in the extreme, not within the ranges of phosphorus intake for dairy cows). Nutritionists are only beginning to realize that phosphorus intake should be reduced. Mr. Satter also said that a reduction of phosphorus intake from .50% to .40% will both lower phosphorus excretion by 20 - 30% and save farmers \$10 - \$15 per cow per year. Mr. Satter can be reached at 608-264-5353. See also Dr. H. H. (Jack) Vanhorn's contact information below.

Land Management: Dr. Andrew N. Sharpley, Adjunct Professor of Soil Science at Penn State, USDA-ARS, researches what controls phosphorus lossage@ from watersheds. Dr. Sharpley points out that 90% of phosphorus loss comes from only 10% of the land. The land most susceptible to phosphorus loss, not surprisingly, are areas with a great deal of runoff. Good land management practices, such as conservation tillage and crop residue management, buffer strips, riparian zones, terracing, and contour tillage can therefore reduce the levels of phosphorus that ends up in Lake Champlain. The results will not be immediate, but they will be significant, especially if combined with other waste management systems. Mr. Sharpley can be reached at 814-863-0948.

Mechanical Separators: All kinds of dairy waste treatment begin with solid separation. Without separation, the value per tonnage is far too low to have any economic benefit to either the farmer or the waste management provider. In addition, many treatment processes will only work if the moisture level in the manure is reduced. Solid separation by itself will yield some phosphorus results, as between 20 - 40% of the phosphorus (depending on environmental conditions and who you talk to) will be separated out with the solids. The solids can then be composted, as is currently being done by a few farmers in Vermont, or can be treated in a variety of ways (see technologies listed below). Multiple separators are currently on the market. I chose the three listed below mostly because they are the separators used by some of the other companies below who have developed more advanced waste technologies or they have done specific research on dealing with dairy waste. Their prices are consistent with the rest of the market.

Fan Separator - This company sells a solid/liquid separator called the Press Screw Separator (PSS). The technology is similar to a centrifuge. It is currently being used in over 2,000 dairies including a few in Vermont. Typically the machines are purchased for dairies with 100 cows or

more, but they are portable enough to be shared by several small farms. Phosphorus reduction, according to the company, is approximately 60% in the liquid phase and 60% in the solid matter. (Note: This is inconsistent with some of the other reports I have heard.) Costs vary, but usually are around \$30,000. Contact: Kyle Weidmayer, 1-800-451-8001.

Key Dollar Cab Incorporated - This is a side hill separator. Waste is pumped up to a feed box, where it slides down a screen, separating the liquids from the solids. The solids then fall into a roll press, which removes the remaining liquid. This separator is used mostly by those who use the solids for composting or vermicomposting (see Tom Christenberry's operation below). While not as effective at separation as the fan separator, it is cheap. A model for a 300 head dairy costs about \$7,500. For more information, contact Hank Svehaug at 1-800-241-2427

Or-Tec Incorporated - Or-Tec actually doesn't produce solid separators, but builds a belt-press dewatering technology that can accomplish similar results. The Or-Tec Mark II Belt Press System contains a belt press and flocculation system to separate and dewater solids. Liquids would then be spread on the fields, while the solids are ideal for composting. The Mark II costs approximately \$60,000. Or-Tec has also worked with soil management groups to address nitrogen, potassium, and phosphorus issues. Specifically, they have worked with the issue of the expense of adding polymers to dairy waste (see comments below) and how this expense can be reduced. For more information, contact Ciaran O'Melia at 440-232-4224.

Composting: After solid separation, the cheapest and most common way of dealing with the solid material is to compost it. Straw or sawdust bedding are also good sources of carbon which can be used to dry the materials. Adding carbon will help reduce nitrogen loss during composting to the atmosphere. The composted material can then be used on the farm or be sold, either in bags or in bulk. A good paper on the advantages/disadvantages of large-scale, out-door composting of dairy solids can be found at: <http://ianrwww.unl.edu/pubs/wastemgt/g1315.htm>

On the market: The following technologies are currently on the market. Many of them are quite expensive, and almost all of them would require some sort of cooperative effort between a number of dairy farmers and possibly even some investors.

Bion Technologies - The Bion Nutrient Management System uses a variety of different technologies to treat dairy waste. A Solid Ecoreactor captures and dewater waste solids, which then undergo a biological conversion into an organic soil-like material. This material is marketed by the Bion Technologies company or can be used on the farm. A Bioreactor assimilates nutrients using microbes. The technology is scalable, dairy applicable, and designed specifically for each site. There currently is a full scale test plant in Denmark, and a few other commercial plants in various stages of construction in Europe. A feasibility study can be obtained from the Danish Consul Bent Kiilerich (312-787-7725). Unlike other companies, Bion is looking to build the facility and charge a tipping fee, meaning that the farmers will not have to put up capital or worry about the operation, but will incur operational costs and will not receive a value added product. Tipping fees would be highly site specific. Alan Grant is working on the American side of this operation, and can be reached at 215-753-7725. He will give Susanne a call when he can obtain better tipping fee numbers. Dr. John Classen of the NCSU Animal and

Poultry Waste Management Department is currently conducting a study, but is not ready to make preliminary conclusions. Dr. Classen can be reached at 919-515-6800 or john_classen@ncsu.edu.

BW Organics - This company has developed an in-vessel composting technology for dairies which is currently being used in Texas and Wisconsin. After using a solid separator out of a flow system, the in-vessel composter makes the solid waste into a commercially viable peat moss in three days (not including curing time before bagging or bulk sale). The composter kills all pathogens and weed seeders. Operational costs are minimal. Initial costs depend on the scale of the dairy. A composter for a 100 cow herd would be about \$45,000, including conveyer belts, and would fit in a 6' by 16' space. A 500 cow herd machine would run \$145,000 and would measure 10' by 50'. A front end loader and a building cover with a level cement slab would also be needed. The cement slab must be level, as the angles within the machine are important for the composting process. Stationary models and portable models (that could be used by a group of farmers) are on the market. Dr. Don Cawthon of Texas A&M University-Commerce has worked with BW Organics on utilization of this technology, and a good summation of his work can be found at: <http://www.tamu-commerce.edu/coas/agscience/res-dlc/dairy/dlc-dair.html>. He noted that this is a technology that was adapted from the BioConversion Companies similar design for municipal wastes. Some of the benefits he saw are that it is a continuous flow system and that a market could be developed for the peat moss like-substance. The product would have to be spiked with nutrients, although the AspiKing® would not be necessary for the actual composting of the material. For more info contact John Willis, owner of BW Organics at 1-800-933-1507. Dr. Cawthon can be reached at 903-886-5350 or Don_Cawthon@tamu-commerce.edu.

Environmental Products & Technologies Corporation (EPTC) - EPTC has a commercialized, scalable technology called the Closed-loop Waste Management Process that incorporates four different technologies: a solid separator, an aerobic bioreactor, an anaerobic digester, and a dual-fuel engine that drives a cogeneration powersystem. After the slurry from the flow system goes through the separator, solids go to the bioreactor and are converted into a marketable aerobic soil amendment. Liquids go to the anaerobic digester where an enzyme promotes methane production. The methane is used by the cogeneration powersystem, creating electricity for the farm and the power grid. The remaining liquids are filtered and spread. Waste is treated in about 1 - 3 days. The system costs between \$150,000 for a 9 ton/day system to \$330,000 for a 40 ton/day system. Integration of all of the components of the system is still ongoing. EPTC will also remove all solids from the farm at no cost. Contact CEO Marvin Mears at 818-865-2205.

Gaston County Dyeing Machine Co. - This company, with the help of (or in conjunction with, this was unclear) QED Environmental Systems out of Australia, produces the Mobil Tangential Flow Separator (TFS). This is a chemical solid separator, a technology that is especially effective for phosphorus removal. The TFS system uses lime, ferric chloride, and polymers to precipitate and settle phosphorus. Testing by the North Carolina State University Animal and Poultry Waste Management Research Department found that 90% of the phosphorus was removed. The technology is fully dairy applicable, and in fact was originally developed in

Australia for phosphorus problems resulting from dairy waste. The end product is a compost that can be sold for use in landscaping. Wandalup Farms in Australia and Murphy Family Farms in Rose Hill, N.C. are currently using the technology. At the Australia location, income from the compost products is covering operating expenses and infrastructure costs associated with the construction of the treatment plant. (John Williams, NCSU Animal Waste Department). The machine is 10 ft. by 15 ft. and must be protected from the elements. The technology is scalable, depending on manure flow rate, with costs starting at about \$100,000. Contact Chris Aurich of Gaston County Dyeing Machine Co. (704-263-6000). For an economic and technical evaluation of this technology, contact Dr. Phil Westerman chief investigator of this technology for the NCSU Waste Management Department (919-515-6742 or phil_westerman@ncsu.edu) or visit the evaluation web site: <http://www2.ncsu.edu/unity/lockers/users/k/kzering/resproject.htm>

Harmony Waste Management Technology - Harmony Products Inc. - Based out of Chesapeake, VA, this company produces commercial fertilizers (for agriculture, golf courses, etc.) from a variety of different waste sources. While the company is in the process of building its first plant, it has already licensed out its technology to other users, including a farm in New York. The waste is mixed with dry granular nutrients and then put into a reactor to create water insoluble nitrogen. Ten to twelve ton can be processed per hour. The technology is dairy applicable, but has not been used in this way due to the low analysis (nutrient level) of dairy waste. In order to ship in chemicals and ship out fertilizer, transportation (preferably rail) would be needed, as well as natural gas. The technology could also be combined with an anaerobic digester, although the company does not offer them. Dairy waste could be combined with human sewage. This would produce methane gas for energy usage, as well as provide the extra nutrients to make fertilizer. Initial capital investment for the machinery, not including a building to house it in, would be \$1.5 million. Operational costs range from \$18 - \$40 per ton depending on the moisture level of the manure. Further information can be obtained from Ray Grover, Executive VP, Technology at 757-523-2849.

Thermo Tech Technologies Inc. - This company licenses a waste technology which pasteurizes any wet waste (will work with dairy, but can also process any other wet waste, including human sewage), and turns it into pelletized animal feed. This is large-scale technology, requiring an approximately \$12 million plant to be built. The plant would be able to process 1200 tons of waste per day. Contact: Don Dyer, 1-800-377-5085 for basic information, Ed Kroeker 905-561-3816 for technical information.

Vermicomposting Process - This is not so much of a specific technology as an existing process that is being researched by the NCSU Animal and Poultry Waste-Management Center. After solids and liquids are separated, the solids are added to worm beds which are covered by greenhouses. The worms are harvested and sold, while the substance left by the worms (called castings) is a peat-like soil amendment which can also be sold. The NCSU investigator, Dr. Robert Mikkelsen, found the results to be encouraging, but urged that a local market must be found for the worms and the castings first. Dr. Mikkelsen worked with Tom Christenberry, who owns a hog waste management business in North Carolina. Mr. Christenberry suggested using a third party or co-op approach, with a location in close proximity to a few dairy farmers. He has found that vermicomposting produces a much higher quality product than traditional composting,

because much less nitrogen is lost to the atmosphere. Costs are highly variable, as one needs to set up the business on their own. A heated shed or greenhouse would need to be built, as well as beds for the compost, and a lot of worms would need to be purchased. Mr. Christenberry suggested that this process should be done in addition to traditional composting, not in its place. This procedure does not solve the phosphorus problem found in the liquid. Dr. Mikkelsen can be reached at 919-515-2388 or robert_mikkelsen@ncsu.edu. Tom Christenberry can be reached at 252-243-3928.

Still under development:

Addition of Aluminum Sulfate or Aluminum Chloride to Reduce Phosphorus Solubility - Most phosphorous runoff is not in the form of chunks of P₂, but instead soluble P. Converting the P in dairy manure to an insoluble material could greatly reduce the levels of P runoff. Dr. Phil Moore of the University of Arkansas has worked with aluminum sulfide and aluminum chloride as additives that could create the insoluble aluminum phosphate. Aluminum sulfide has the unfortunate byproduct of hydrogen sulfide, the chemical used in stink bombs to produce that rotten egg smell. Aluminum chloride, however, has been a successful substitute for aluminum sulfide. Phosphorus runoff was reduced by 90% with chicken litter and between 40% - 80% with hog waste. Mr. Moore is currently testing the success of the aluminum chloride additive to dairy waste, and will have full results in about two months. Preliminary results show one problem. Dairy manure does not have the buffer qualities of hog and poultry waste, and therefore the waste becomes acidic. This can be rectified with the addition of lime. Secondly, the reduced nitrogen ammoniazation benefits which make this process very cost effective for poultry and swine do not apply to outdoor dairy herds. Therefore, the addition of aluminum chloride is all cost, offering no value-added product to the farmer. Costs have yet to be determined. More information can be obtained from Phil Moore at 501-575-5724 or phillipm@comp.uark.edu .

Addition of Polymers to Precipitate Solids from Liquid Wastewater Streams - Dr. Pat Hunt is working on this project for the Agricultural Research Service of the USDA. This could be a solution to the soluble P problem, and technically it works. Unfortunately, for reasons yet to be determined, it takes 4 to 6 times more polymers for cow waste as for hog waste. This makes the costs prohibitively expensive, although Dr. Hunt believed that the \$7 per cow per day figure cited by others was a bit of an overstatement. Research is ongoing. Dr. Hunt can be reached at 843-669-5203 x 101 or hunt@florence.ars.usda.gov .

Alkaline Stabilization - ARS is working on alkaline stabilization over in Beltsville. Stabilization is achieved by mixing the manure with certain industrial wastes, such as ash. The result is an odorless, pathogen free lime that can be sold on the commercial market. Alkaline stabilization is not harmful to the environment. In fact, the exact same process has been used for biosolids for years. ARS is currently finishing up a study on using the process for dairy manure. One added benefit is that while a solid separator is useful, it is not necessary to achieve good results. Straw or sawdust can be used. Another benefit is the process is relatively quite cheap, although good cost numbers have not been nailed down. Pat Millner works on this project and can be reached at 301-504-8163 x 344 or pmillner@asrr.arsusda.gov

Using Algae to Remove Nutrients from Wastewater - Walter Mulbry of ARS is working to modify an existing technology used by the Smithsonian to clean fish tanks with algae into a technology that could remove nutrients from wastewater. Initial investigations show that algae can be grown on the liquid portion of manure, removing close to 100% of the nitrogen and phosphorus from the liquid. After being treated by an anaerobic digester, the liquid is pumped to the top of a 1 m by 50 m Raceway@ with a 1% or 2% grade. The depth of the liquid is 1 inch. The raceway is covered by a screen upon which the algae grows. Harvesting is easily accomplished by scraping the screen once a week. Testing so far has been exclusively on a small scale in the laboratory, but an outdoor testing site should be built by the end of September. Once enough algae is grown on the outdoor raceway, testing will begin to find uses for the algae. The hope is that the protein-rich algae can be fed back to the cows, perhaps eliminating the need for dairy farmers to buy soy beans. The algae could also be dried and made into a fish food for aquacultural use. Further testing is also being done to determine whether the residual liquid is safe for discharge, or whether the process will work without the use of an anaerobic digester or solid separator. The process would only work in temperatures of 50 degrees Fahrenheit or higher, meaning that the liquid manure would have to be stored during the winter. Costs are still being determined, but the components seem to be very cheap. The real question is whether uses for the algae crop can be developed. For more information, Walter Mulbry can be reached at 301-504-6417 or wmulbry@asrr.asrusda.gov

General Resource List:

H.L. Goodwin, Poultry Economist for the University of Arkansas - Dr. Goodwin is currently working on a feasibility study for setting up a manure bank in the Ozark Plateau region. A manure bank is a third party organization which allocates manure (electronically or physically) from the farmers and transfers it to businesses utilizing some of the technology above or to farms which require fertilizer and do not have P runoff problems. These organizations are often needed to create an economy of scale for waste treatment technologies to be financially viable. He has a number of contacts in Europe, where manure banks are currently in use with varying degrees of success. Dr. Goodwin's speciality is essentially the logistics of what it takes to get enough manure to the right place at the right time from a number of farmers. His belief is that the economics of the waste transport would require that the manure bank be a quasi-government organization. Dr. Goodwin can be reached at 501-575-7118 or haroldg@comp.uark.edu .

Keith Hummel, Agricultural Research Service - Mr. Hummel has worked for the last 5 years with an anaerobic digester in Beltsville, MD. The machine was installed for odor control, and for that purpose it has had great success. They have not bought a methane cogenerator, however, because they found that not enough electricity can be generated to make the system economically viable. He also stressed that their tests have shown that anaerobic digestion has no effect on phosphorus levels. A digester, such as the one ARS uses, would cost somewhere under \$200,000 (he was not sure, as their digester had special attachments for research purposes), and would service up to 450 dairy cows. Mr. Hummel can be reached at 301-504-9243.

Barry Kintzer, National Resource Conservation Service - Mr. Kintzer has worked with Mr. Yamada (see below) and Andy Fish of the Senate Minority Agriculture Committee on soil waste management issues. He believes that currently there are no true solutions to the P problem. He also adds that systems which only treat the solid portion of the manure after liquid/solid separation are problematic because approximately 30 % of the phosphorus remains in the liquid stream. Coagulants used to remove more phosphorus from the stream will be prohibitively expensive, up to \$7.00 per cow per day. For small dairies with solid removal systems, he suggests setting up a community composting facility. The fertilizer produced by this facility may require Aspiking® with nutrients to be commercially viable, but this may be an economically viable solution. Mr. Kintzer may be reached at 202-720-4485.

Dr. H. H. (Jack) Vanhorn, Researcher on dairy waste issues from the University of Florida - Dr. Vanhorn has worked with the P issue, as well as general waste management. It is his belief that most of the technologies on the market will have limited economic success, as they are just too expensive for most dairy farms. He suggests that the first action that needs to be taken is nutrient management to reduce the amount of dietary phosphorus being fed to the cows in the first place. (vanhorn@dps.ufl.edu or 1-352-392-5594)

Dr. Mike Williams, Director of the North Carolina State University Animal and Poultry Waste-Management Center - Dr. Williams is in charge of conducting multiple research projects on waste management systems. He is a good source for what is out there and what will be out there in the coming years. (mike_williams@ncsu.edu or 1-919-515-5386)

Jim Wimberly, President of the non-profit organization Foundation for Organic Resources Management (FORM) - FORM is an organization which deals with agricultural waste and environmental issues. Mr. Wimberly is an expert in this field. It is his belief that the technology is certainly out there to treat the animal waste problem. The problem is not in the technology, but instead in the economic strategy. Without the development of economies to scale, farmers do not have the incentive to adopt these new technologies because they will result in a net loss. He is currently conducting a study on what kind of an organization could make technologies such as composting truly cost effective (public/private, non-profit, co-op, or other third party). Even with these organizations taking care of the waste, transportation will only be economical if the dairy farms are highly concentrated (say 10 within a 10 mile area), or if the individual farms first use a solid separator to get rid of some of the added water weight.

As for specific technologies, Mr. Wimberly believes that composting or anaerobic digestion may be viable alternatives if done in a cooperative fashion. He also sees a lot of promise in two emerging technologies. The USDA and EPA are working in a technology that will gasify manure. The ash produced (within which will contain all of the phosphorus), will be a dry, homogenous, and highly marketable nutrient supplement. A feasibility study that is currently in the works has found that the ash could be sold for \$50 - \$70 per ton. The gases would be combined to form ethanol, a clean fuel. As Congress has already approved ethanol subsidies, some of this money could legitimately be funneled into this project. The technology is being developed specifically for dairy manure. He also sees promise in a manure-to-ethanol technology being developed by Professor of Poultry Science Dan Long, of Crowder College. I spoke with Dr. Crowder. It seems that his technology is still in the developmental stages, and

would require major governmental funding to be achievable. He is however working with a 500 cow dairy, so this technology might be useful for a larger Vermont dairy in the future. Dr. Long can be contacted at 417-451-4700 or dlong@crowdercollege.net

In the few months, Mr. Wimberly will also be calculating the amount of manure being generated and phosphorus levels from that manure county-by-county. This information could be useful for getting more funding at a later date. In addition, Mr. Wimberly offered his services as a consultant to the group, and would be willing to travel to VT to meet with the group. Mr. Wimberly can be contacted at 501-442-3918 or jim@organix.org. More information on waste management can be found at his web site www.organix.org.

Randy Yamada, US Agency for International Development (USAID) Managing Director for Activity Development Mr. Yamada is working with agricultural waste companies in Taiwan to develop new waste management systems. He emphasizes that there is no silver bullet technology out there that will solve all agricultural and municipal waste problems, partially due to the existing technology and partially due to economics. Mr. Yamada is a good resource for animal/human waste projects, and for a look at the future of waste management. Most of his projects, however, are fairly large scale and capital intensive. (202-712-1699)

Bob Wright, Soil Management Division of the Agriculture Research Service - Mr. Wright is a good general resource for finding contacts about various research programs. It is his belief that technological solutions are only one part of the phosphorus puzzle. For technologies, he sees anaerobic digesters and treatment technologies to only be viable for large operations. For smaller farms, land management and nutrient management might be a better solution. He pointed out that 90% of the phosphorus runoff is coming from 10% of the land. Reducing or eliminating the spread of manure on these areas can greatly reduce the amount of phosphorus that ends up in Lake Champlain. Changing the diet of the animals can also reduce phosphorus levels in the manure up to 25 - 30%. This can also be done by adding an enzyme to the feed that changes the phosphorus into a more digestible form. Mr. Wright is involved in many projects on soil management being conducted by ARS, and therefore is a great source for further contacts. Mr. Wright can be contacted at 301-504-4638.