Potential for Biodrying Manure

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"This report was prepared by the Watershed Agriculture Council in the course of performing work contracted for the New York State Energy Research and Development Authority (NYSERDA). However, any opinions, findings, conclusions or recommendations expressed herein are those of the author(s) and do not necessarily reflect the views of NYSERDA."

Abstract: Studies have shown that spreading liquid manure when soils are near saturation or when they are likely to become saturated before crop uptake of nutrients can occur, can result in significant nutrient and bacterial discharges to the water through tile lines and runoff. Often nutrient management plans designed to protect water quality prescribe manure storage. Stored liquid manure can produce significant objectionable odors both during storage and when spread. Catastrophic failure of liquid systems is a risk that many farms want to avoid.

Biodrying as described in this paper is a system that has the potential to improve water quality by increasing the likelihood of nutrient export. It can provide a stabilized solid for spreading on hay ground during the growing season. Biodrying will meet the farm's need for odor control. Smaller farms' desire for a solid based treatment system would be addressed as well.

The design of a Biodrying process on an 85 cow dairy farm in the NYC Watershed will be described. This work has been funded by a grant from NYSERDA and is being constructed in the spring of 2001. This will include designing and building a composting shed, installing a forced air system that will be controlled to optimize the composting and drying of the manure. If managed carefully, the heat generated by aerobic composting can provide the energy to reduce 12% dry matter (DM) manure to a 60% DM residual. The compost would be reduced one half in volume and to one fifth the weight of the original manure due to water loss and solid conversion to gasses.

Preliminary analysis shows that the cost of operating the system minus the cost of additional benefits including off site sales is less than the cost of conventional liquid storage and land spreading that would meet the environmental goals for the farm. If successful, this system would have application on many dairy farms.

Introduction
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. Different manure treatment and handling methods will be needed to match the resources and needs of different farms.

Recent studies have shown that manure handling costs on farms can be significant. Figure 1 shows costs collected from western NewYork dairies in 1996. These costs do not include storage costs and they do not include additional costs that increased management from the implementation of a Comprehensive Nutrient Management Plan (CNMP) would require. The average farm in the western New York area had a net cost of spreading manure of $77 with a range of a net return of $37 to a net cost of $225 per acre spread. Costs were higher for farms less than 400 cows and for farms that did not store manure. There is potential cost reduction in both better fertilizer management, use of more efficient equipment, and the use of alternative handling methods on smaller farms.

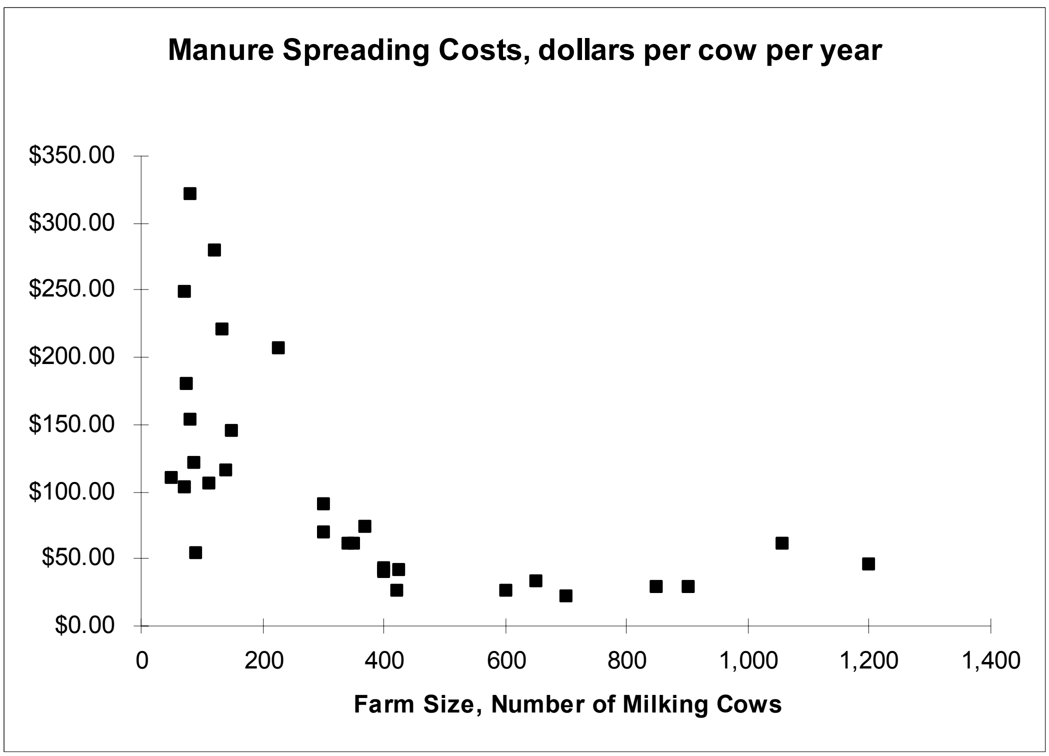

Figure 1. Calculated manure spreading costs for western NY area dairy farms. (Wright 1997)

Manure has been traditionally applied fresh to the land as a fertilizer and soil amendment. Although this practice will continue, many farms will need to change this relatively simple manure handling to more complex storage and treatment methods to respond to the environmental concerns that are increasingly being raised.

Society has recognized that animal agriculture can lead to excess nitrates in the ground water, pathogens and excess nutrients in the drinking water, Biological Oxygen Demand (BOD), and sediment in surface water. To avoid these problems, manure will increasingly be spread on dry soils in fields where the chance of runoff and leaching are low. Environmental agencies are prescribing these changes. There are now many state, provincial, and federal regulations on the timing and amounts of manure spreading. To hold the manure until the appropriate time to spread manure storage will be a standard practice on most farms. In 1997, only 10% of the dairy farms in New York State have more than 6 months of storage (Poe).

Manure from storages is generating many complaints about odor already. When manure is stored, it starts to decompose anaerobically. The by-products of incomplete anaerobic decomposition are very smelly. Society objects to bad odors as much as, if not more than, to dirty water. Therefore, treatment for odor control will become much more common as farms are forced to convert to storing their manure.

Phosphorous has been identified as the most common limiting nutrient in freshwater. As higher phosphorous levels are building up in some agricultural soils, soluble phosphorous is being released with water flows leaving the fields. Preferential flow allows phosphorous to readily leave tile drained fields during wet weather applications (Geohring). States, Provinces, and Federal governments are responding by requiring phosphorous based nutrient management plans. Manure generally provides a higher amount of crops needs of phosphorous than nitrogen. Phosphorous based plans will require manure to be spread thinner and hauled longer distances to cover more fields. Therefore, there will be an increased need for treatment that concentrates the phosphorous, making it easier to haul long distances. Treatment that reduces the mass of manure would meet this need as well.

Development of by-products that can be sold at a profit off the farm could help maintain profitability while improving the environment. Compost or organic matter that can be used as a soil amendment may develop into a market that farms can take advantage of. Organic farms and landscapers are growing businesses that may be looking for more of this type of material. Prices for compost-like material have been reported ranging from $5 per cubic yard to $30 per cubic yard (Bonhotal).

Pathogens from manure can easily enter the environment (Geohring). Both society and regulators are increasingly trying to reduce the amount of pathogens or indicator organisms in drinking water and contact recreational water. Detection methods for disease-causing microorganism have become more sophisticated so they are able to trace the source of the pathogen. Soon treatment for pathogen reduction will be needed.

Gas releases that form smog, greenhouse gases, or contribute to acid rain may be regulated in North America in the future. Europe is regulating the amount of ammonia that farms can release. Controlling these gases will require treatment methods for manure.

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 upstream of a fresh water lake may be more concerned with sediment and phosphorus. Those with close or sensitive 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.

Composting has been proposed for years as one of the best methods to treat dairy manure. It has been used on excessively bedded dairy manure, separated dairy manure solids, and on the drier manure produced by other animal species to reduce odors. The costs of composting may be offset by sales of the compost. Most dairy manure is too wet initially (12% DM) to compost well, as shown in Figure 2. It needs to have a moisture content of less than 75% to heat up and start composting easily. Smaller farms using more bedding may have manure with a lower moisture content.

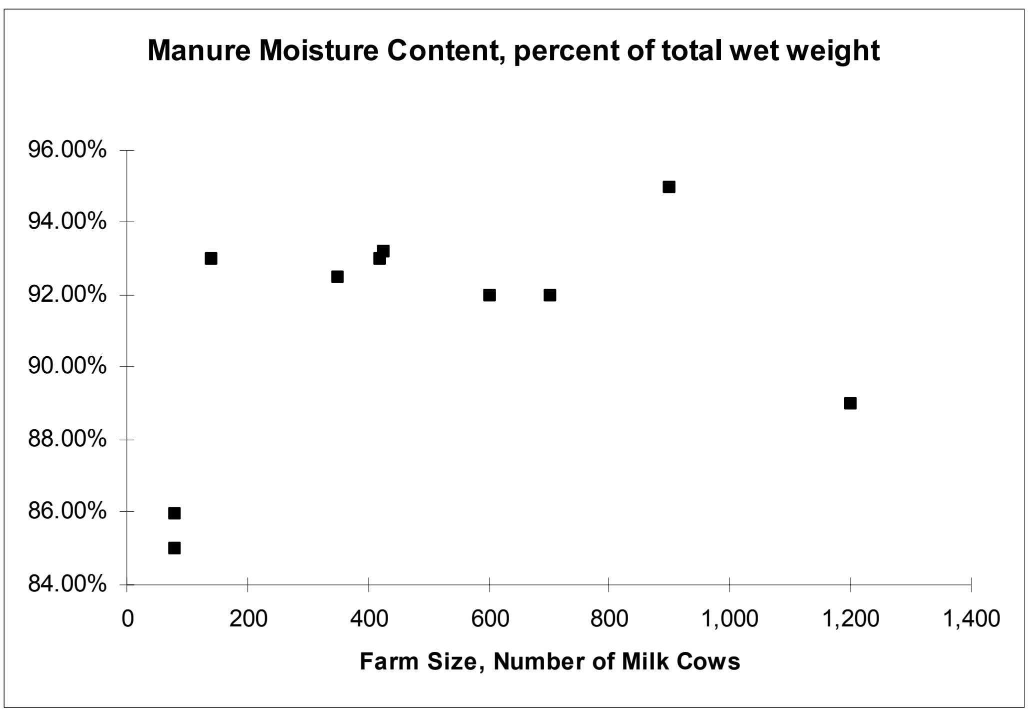

Figure 2. Reported water content of manure in a western NY 1996 survey. (Wright 1997)

There may be niche opportunities on some farms with a source of a high carbon waste stream. Farms with cheap sources of old hay, waste paper, bark, sawdust, or even recycled compost may be able to add enough solids to support a composting operation. Charging tipping fees for the material brought in or aggressively marketing the compost produced can add a profitable enterprise to the dairy operation.

Solid Separation of the manure solids mechanically can produce a "solid" portion (15-30% DM and about 20% of the original mass) and a "liquid" portion (4-8% DM and about 80% of the original mass). About 50 farms in New York have this equipment. Liquids are easier to handle than a semi-solid. Solids can be recovered for bedding, soil amendment or exported off the farm. High capital and operating costs for the mechanical equipment have caused some farms to quit separating. Maintenance of the equipment is a problem. Marketing of the solids may not be successful on all farms. The real problem with this system is the small volume of manure that is composted and the large volume of liquid waste remaining.

Biodrying of the manure by recycling dry compost as the amendment in the alleys, 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 and pathogen reduction would occur. Equipment for solids handling is available on most farms so adoption by many farms should be easy. Storage of solids is safer environmentally than liquid storage because of the lower risk of catastrophic failure. The compost material may be marketed as an income source and to move the nutrients off the farm. The management of the drying process will be critical and the costs of the operation may be high. Additional amendment may be required.

Using the heat of composting to evaporate water and dry compost has been used in municipal systems for quite some time (Haug). Biodrying had been shown to work on animal wastes in the past (Jewell 1984, and Richard 1996), but the in-vessel machinery was seen as too expensive to run on a dairy farm. Recent catastrophic failures of liquid storages, high costs of liquid handling and the odor problems associated with liquid manure storage started the search for a solid handling system for dairy manure. Systems that quickly composted and dried the solids under a roof and without turning made the composting shed seem possible. Studies showing that compost could remove significant moisture when liquid manure was added reinforced the idea.

To explore the idea of biodrying on a farm, a proposal from NYSERDA was developed with the following goals:

1) To design and build an effective Biodrying process on an 85 cow dairy farm in the NYC Watershed. This will include designing and building a composting shed, installing and monitoring the forced air system, and evaluating the product for land safe storage, land spreading and/or export. This process will be effective if it can reduce odors, treat manure to reduce pathogens, and reduce the mass of manure that needs to be moved on the farm or removed from the farm.

2) To optimize and document the process. Evaluating the on-going process in varying weather conditions will allow changing the operating procedures to obtain the best compost, the least amount of amendment, and lowest cost for the farm operation. Documenting the operating procedures will allow this process to be adopted for many dairy farms. This process will be successful if the cost of operating the system minus the cost of additional benefits including off site sales is less than the cost of conventional storage and land spreading that would meet the environmental regulations for the farm.

3) To demonstrate the process for use on farms. Using this operation to host tours and demonstrations will help spread this technology to other farms. Two open house demonstrations are planned.

Description of Biodrying

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 have shown the feasibility of this process by using forced air to compost six foot high layers of manure in 21 days. Recycled compost or a mix of compost and sawdust, or other amendment, at 40% dry matter could be spread in the cow alleys about 3 inches thick to absorb one days production of 12% DM manure. The mixture could be scraped into a shed, piled 6 feet deep and aerated to produce 40% DM compost in 3 weeks.

Figure 3 shows a side view, plan view and cross section of the biodrying shed. The building was designed with a high overshot roof, open walls, and four foot eaves to provide good ventilation while keeping the process protected from precipitation. Manure and recycled compost can be loaded from either side, although preliminary trials have shown that a side delivery manure spreader can build a six foot pile 40 feet long.

The air flow calculated for this system compares with various air flows form the literature. Table 1 shows different air flows that were successful in composting the listed ingredients. A control system can be developed to run the fans that will optimize the composting operation (Hall).

Table 1. Comparison of air flows and ingredients for various composting operations.

Forced air Composting flow rates

Author/Reference	Ingredients	Supplied flow rates (cfm/ft^3)	
Walker	Dog food + wood chips	0.200	Continuous
Hong	Hog manure + sawdust	0.160	Intermittent
Richard / Haug	Sludge	0.169	Intermittent
Richard / Andrews and Kambhu	Sludge	0.385	Intermittent
Richard / Regan et al.	Newsprint	0.595	Intermittent
Richard / Regan et al.	Mixed garbage	1.049	Intermittent
HRHH	Hog manure + corn stalks	0.135	Continuous
Hong 2000	Hog manure + sawdust	0.135	Intermittent
Stombaugh	Cracked corn + pelleted corn cobs	0.136	Continuous
Hall	Separated dairy manure trial 1	0.265	Continuous
Hall	Separated dairy manure trial 2	0.380	Intermittent
Jewel	Dairy manure	0.217	Intermittent
Proposed 700cfm Biodrying fan	Recycled compost + fresh manure	0.364	Intermittent

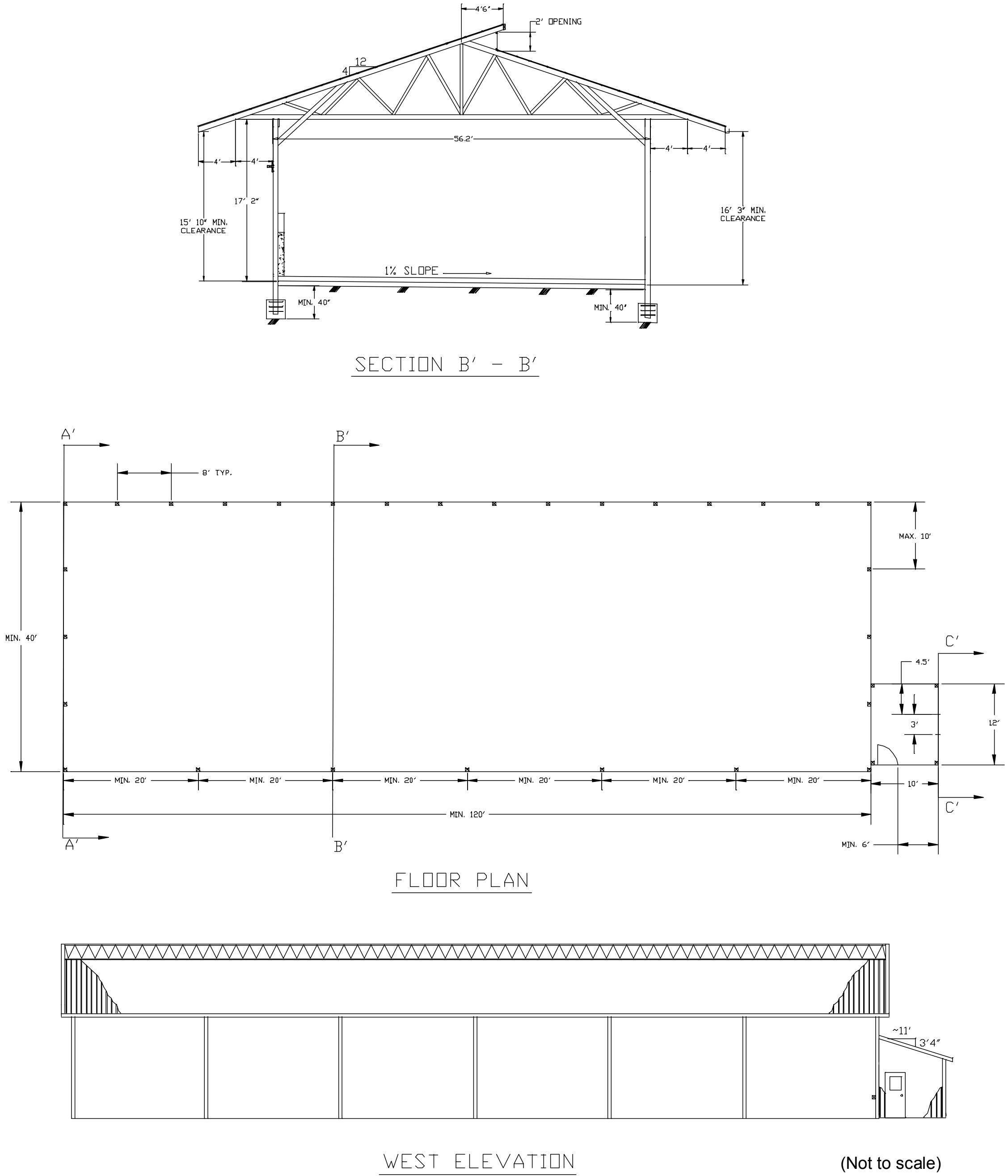

Figure 3 Proposed Biodrying Building.

The resulting material would then be used as the dryer material, mixed with an amendment if needed and placed in the alley each day. 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.

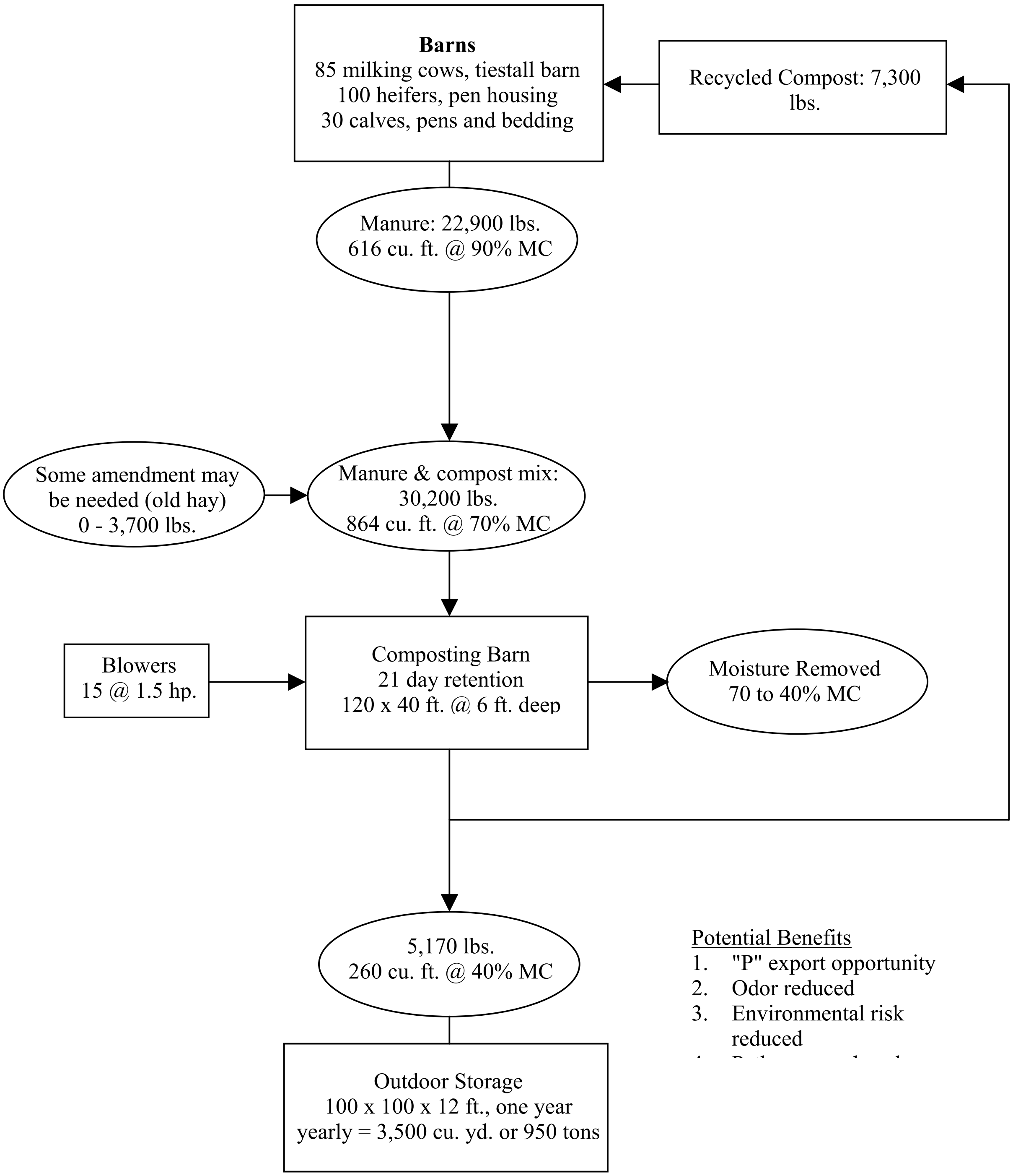

Figure 4. Schematic of biodrying system on a farm showing daily amounts.

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.

For 85 cows, 100 heifers, and 30 calves, it is estimated that the shed to compost the material will need to be 40 feet by 120 feet if the material is piled 6 foot deep. 365 cubic feet of compost will need to be mixed with the 616 cubic feet of manure and bedding produced each day. 865 cubic feet of compost plus manure will be placed in the compost building each day. This will produce 624 cubic feet of compost at approximately 40% moisture in 21 days. Taking away what is needed for recycling, there will be a daily production of 260 cubic feet or 5,170 pounds of compost per day. This is shown in a schematic in Figure 4. Yearly production would be 950 tons or 3,500 cubic yards.

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. With odor controlled, spreading the compost during the growing season can occur without offending neighbors. Storing and spreading a high solids product should reduce the runoff and leaching potential of land spreading, and eliminate the potential of a catastrophic failure from the storage system. If the compost is sold off the farm, all the phosphorous can be exported. This can be a huge advantage for those farms in a phosphorous excess situation.

Economic Impact: The reduced volume from a composting system that minimizes the amount of amendment needed will keep both spreading costs down as well as costs for the amendment. Selling the compost produced potentially can add a cash enterprise to the farm. Selling to a wholesaler may produce less profits, but will keep the marketing effort low.

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 reduction. Environmental agencies will enjoy the pathogen reduction and the ability to export phosphorous.

The capital cost for this system would consist of a three-sided composting shed with an aeration system installed in the floor. The estimated cost of this is $192,000. Fifteen, 1.5 Hp, fans will be needed in this installation. Piping every 32 inches will deliver the air. A control unit on the fans that has a feed back system to the temperature of the compost will be needed for each fan. Additional ventilation/condensing or reversing the air flow may be needed in the winter to optimize the process. Additional testing and feedback systems will be installed.

It is anticipated that the dairy farm selected will 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, use of the compost as bedding or reduced storage and spreading costs.

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

The air control/temperature feedback system will need additional controls and testing to optimize moisture removal. The rest of the system is well within the management capabilities of most dairy farm operators.

The costs of the present manure handling system are shown in Table 2. It should be noted that the present system is unacceptable environmentally as the phosphorous is being concentrated on the fields close to the barn and spreading is done on a daily basis with the risk of loss to the environment. The milkhouse waste cost is included in this table. It would need to be fixed as it is presently discharging inappropriately, and to better compare the manure handling systems that will deal with the milkhouse waste. The cost of this system is comparable to the costs shown in Figure 1 for farms without considering milkhouse waste.

Table 2. Costs of manure handling on an existing farm.

Capital Cost Items	**Initial investment**
V spreader	$15,000
Loader	$20,000
Milkhouse waste system	$12,000
Total annual fixed costs (including depreciation and interest)	$6,268
Operating costs	
Repairs and maintenance	$3,100
Labor @ $15/hr	$6,395
Fuel	$170
Insurance	$400
Tractor rent	$12,780
Fertilizer	$1,500
Total annual operating costs	$24,345
Total Annual Costs	$30,613
Annual cost per cow	$360

Installing a traditional liquid manure handling system would have the costs shown in Table 3. The soils at the site are not suitable for an earthen storage. The milkhouse waste could be handled with the liquid manure after pumping to the storage. This system would save on fertilizer costs but add a huge labor demand during the spring when corn planting and first cutting of hay already demand high labor. This plan would spread out the phosphorous but would still be providing excess to the land over time. The liquid manure would add odor as a concern to the farm and the community. Catastrophic failure and pathogen pollution are also risks with this method.

Table 3. Costs of manure handling with a liquid storage on the farm.

Capital Cost Items	Initial investment
Metal Storage	$168,000
Pipes valves and pumps	$72,000
Truck mounted liquid spreader	$70,000
Milkhouse waste system	$4,800
Access road	$12,000
Box spreader	$5,000
Total annual fixed costs (including depreciation and interest)	$33,070
Operating costs	
Repairs and maintenance	$5,300
Utilities	$550
Labor @ $15/hr	$4,680
Fuel	$4,022
Insurance	$400
Tractor rent	$1,980
Fertilizer	$0
Total annual operating costs	$16,932
Total Annual Costs	$50,002
Annual cost per cow	$588

Meeting a CNMP by biodrying and spreading the compost on the farm result in the costs shown in Table 4. This method of manure handling reduces the odor potential and reduces the pathogen concerns. It is the most expensive alternative.

The cost of operating a biodrying system can be offset if the compost material is sold off the farm. This exports the phosphorous, so it adds to the environmental benefits as well. Fertilizer would need to be purchased for the farm, but the fertilizer could be obtained at the correct proportions reducing the problem of phosphorous build up. The costs for this are shown in Table 5 using $5 per cubic yard for the profits from the sale of the compost.

Table 4. Costs of manure handling with a Biodrying system and spreading the compost on the farm.

Capital Cost Items	**Initial investment**
Compost building	$192,200
Storage pad	$6,680
Truck mounted dry spreader	$70,000
Milkhouse waste system	$12,000
Skid loader	$20,000
Total annual fixed costs (including depretiation and interest)	$23,088
Operating costs	
Repairs and maintenance	$5,500
Utilities	$5,300
Labor @ $10/hr	$10,700
Fuel	$18,875
Insurance	$400
Bedding	$5,360
Fertilizer	-$1,500
Total annual operating costs	$44,635
Total Annual Costs	$67,723
Annual cost per cow	$797

Selling the compost at a higher price can have a large positive effect on the system's cash flow. Selling the compost for $20 per cubic yard can actually show a $136 profit per cow per year for manure handling.

Table 5. Costs of manure handling with a biodrying system and selling the compost off the farm.

Capital Cost Items	**Initial investment**
Compost building	$192,200
Storage pad	$6,680
Tractor	$45,000
Spreader (V or box)	$16.000
Milkhouse waste system	$12,000
Skid loader	$20,000
Total annual fixed costs (including depreciation and interest)	$22,675
Operating costs	
Repairs and maintenance	$6,100
Utilities	$5,300
Labor @ $10/hr	$9,090
Fuel	$6,414
Insurance	$400
Bedding	$5,360
Fertilizer	$3,000
Sell compost @ $5 per yd^3	-$17,500
Total annual operating costs	$18,208
Total Annual Costs	$40,884
Annual per cow cost	$480

Conclusions:

- Manure handling on farms presently ranges from a cost under $50 per cow per year to over $350 per cow per year. The example farm has a cost of $360 per cow per year to handle their manure.
- Meeting environmental concerns with traditional liquid storage will increase costs and create odor problems. The costs for alternative manure handling that meet environmental objectives potentially can increase the cost of manure handling. The costs for a traditional liquid storage and handling system on the example farm are estimated to be $588 per cow per year.
- Biodrying may be a way to meet both environmental, odor, and economic considerations for dairy farms. Costs of the system have been estimated to vary from $797 per cow per year if the compost is utilized on the farm, to a cost of $480 per cow per year if the compost is sold for $5 per cubic yard.
- By-product sales are important in reducing the cost of a manure handling system. Marketing the by-products from the manure can help pay for treatment systems. Costs of the system have been estimated to decrease to a profit of $136 per cow per year if the compost is sold for $20 per cubic yard.
- Alternative manure handling methods need to be tested on farms to verify the actual costs of the systems.

Disclaimer:

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References:

Bonhotal, Jean. "Compost Marketing and Labeling Project." Presented 7/6/2000 by New York State Association to Reduction, Reuse and Recycling, Organic Recycling Composting Council.

Fleming, Ron, Malcolm MacAlpine. 1999. Testing of a Field-scale Liquid Manure Composting System. ASAE Annual International Meeting, Paper Number 994037. ASAE, St. Joseph, MI.

Geohring, Larry D., Peter E. Wright, and Tammo S. Steenhuis, Preferential Flow of Liquid Manure to Subsurface Drains, Drainage in the 21st Century: Food Production and the Environment, Proceedings of the 7th Annual Drainage Symposium 3/8-10/98 ASAE 2950 Niles Road St. Joseph, MI 49085-9659.

Hall, Steven G., Daniel J. Aneshansley, Stanley Weeks. 1997. Agway-Cornell Compost Control Field Studies. Cornell University, Ithaca, NY. pp. 42.

Haug, R.T. *Part I – IV: Composting Process Design Criteria.* 1994.

Hilborn, Donald Manure Handling Systems: Economic and Environmental Comparison. Proceedings from the Animal Agriculture and the Environment North American Conference Rochester NY Dec. 11-13. 1996 NRAES 152 Riley-Robb Hall, Ithaca NY 14853.

Hong, J.H., H.M. Keener, D.L. Elwell. 2000. Biofiltration Using Partially Stabilized Hog Manure Compost. ASAE Annual International Meeting, Paper Number 004095. ASAE, St. Joseph, MI.

Hong, J.H., H.M. Keener, and D.L. Elwell. "The Effect of Continuous and Intermittent Aeration on Composting Hog Manure Amended with Sawdust – Progress Report." *ASAE Meeting Presentation.* (1998) Paper No. 984098.

Jewell, W. J., *et al*. 1976. Bioconversion of Agricultural Wastes for Pollution Control and Energy Conservation. US Energy Research and Development Administration. Report Number TID-27164. September.

Jewell, W.J., N.C. Dondero, P.J. van Soest, R.J. Cummings, W.W. Vergara, and R. Linkenheil. *High Temperature Stabilization and Moisture Removal from Animal Wastes* *for By-Product Recovery.* Department of Agricultural and Biological Engineering, Cornell University. 1984.

Jewell, W.J., P.E. Wright, N.P. Fleszar, G. Green, A. Safinski, and A. Zucker. *Evaluation of Anaerobic Digestion Options for Groups of Dairy Farms in Upstate New York.* Department of Agricultural and Biological Engineering, Cornell University. 1997.

Keener, H.M., D.L. Elwell, Tom Menke, R. Stowell. 1999. Design and Management of a High-Rise Hog Facility Manure Drying Bed. ASAE Annual International Meeting, Paper Number 994108. ASAE, St. Joseph, MI.

Patni, N.K. and Kinsman, R.G. "Composting of Dilute Manure Slurries to Reduce Bulk by Water Evaporation." *ASAE Meeting Presentation.* (1997) Paper No. 974115.

Poe, Gregory , Nelson Bills, Barbara Bellows, Patricia Crosscombe, Rick Koelsch, Michael Kreher, and Peter Wright, "Documenting the Status of Dairy Manure Management in New York: Current Practices and Willingness to Participate in Voluntary Programs" Staff Paper SP 99-03 September 1999, Department of Agricultural, Resource, and Managerial Economics, Cornell University, Ithaca, New York 14853-7801 USA.

Richard, T.L. "Composting Strategies for High Moisture Manures." *Manure Management In Harmony With the Environment and Society.* Ames, Iowa: Soil and Water Conservation Society. (1998): Pages 135-138.

Richard, T.L., and Choi, H.L. "Optimizing the Composting Process for Moisture Removal: Theoretical Analysis and Experimental Results." *ASAE Meeting Presentation.* (1996) Paper No. 964014.

Rynk, R., ed. *On-Farm Composting Handbook.* NRAES-54. Northeast Regional Agricultural Engineering Service. 1992.

Stombaugh, D.P. and Nokes, S.E. "Development of a Biologically Based Aerobic Composting Simulation Model." *Transactions of the ASAE.* (1996) Vol.39(1), Pages 239-250.

Walker, L.P., T.D. Nock, J.M. Gossett, J.S. VanderGheynst. 1999. The role of periodic agitation and water addition in managing moisture limitations during high-solids aerobic decomposition. Process Biochemistry 17:601-612.

Walker, L.P. *et al.* The Design and Analysis of an Energy Integrated Dairy System. In Trans. ASAE 1984 pp.229-240. American Society of Agricultural Engineers.

Wright, Peter "Survey of Manure Spreading Costs Around York, New York." Presented at the 1997 ASAE Annual International Meeting Paper No. 972040.