The Economic Feasibility of Poultry Litter Composting Facilities in Eastern West Virginia

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Centralized, off-farm compost facilities were evaluated as a disposal option for poultry litter. Disposal fees to growers were required to develop an economically feasible facility for a private investor. The potential for a compost facility to compete with current litter alternatives depends upon development of compost markets comparable to urban areas along with a depressed market price for litter. Given disposal fees and uncertainty associated with market development, further expansion of land application and cattle feeding disposal alternatives is recommended.

Composting is defined as the biological stabilization of organic wastes under controlled conditions of oxygen, moisture, and temperature (Diaz, Savage, and Golueke). Organic materials are decomposed in an accelerated aerobic process through oxidation of carbon by microbial activity. This process converts nitrogen from a soluble into an organic form. The end result is a stable organic product which improves soil fertility by providing plant nutrients, reducing bulk density, increasing the cation exchange capacity, and enhancing populations of soil microorganisms (Dick and McCoy).

The ability to convert organic waste materials into an environmentally benign and potentially valuable soil amendment product is of particular interest to the poultry industry. The primary waste disposal problem in this industry is a mixture of bedding material, poultry excreta, and waste feed called litter (Malone; North and Bell). The industry's waste disposal problems are compounded by the spatial concentration of poultry production around processing plants (Malone).

The area of interest for this study is a five county region of eastern West Virginia (Figure 1). In 1990, about 98% of West Virginia broiler production (over 41 million) was concentrated in these five counties with a chicken processing plant located in Moorefield, West Virginia. The impetus for this study began in 1991 when the Moorefield chicken processing plant announced plans to double their current production capacity by 1994, requiring construction of an additional 250 broiler houses. As a result of this planned expansion, concerned government and university personnel questioned the ability of current disposal methods (land application and livestock feeding) to utilize increased amounts of poultry litter in an environmentally safe manner. This study was commissioned to investigate the alternative of centralized, off-farm compost facilities to serve the litter disposal needs of the West Virginia poultry industry. The following objectives were evaluated:

1. Project future poultry litter generation based on planned expansion by the poultry industry in the West Virginia counties of Hardy, Grant, Pendleton, Hampshire, and Mineral;
2. Determine the construction, operation, and transportation costs of centralized, off-farm compost facilities for poultry litter;
3. Compute the minimum litter disposal fee to poultry growers in order for a composting facility to be economically feasible.

Disposal Alternatives

Current poultry litter disposal alternatives available to contract growers[1] in West Virginia include:

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[1] Contract growing of chicken and turkey broilers is the practice where a grower is paid a fee to provide care and housing for the growth period, but the poultry processor retains the ownership of the birds.

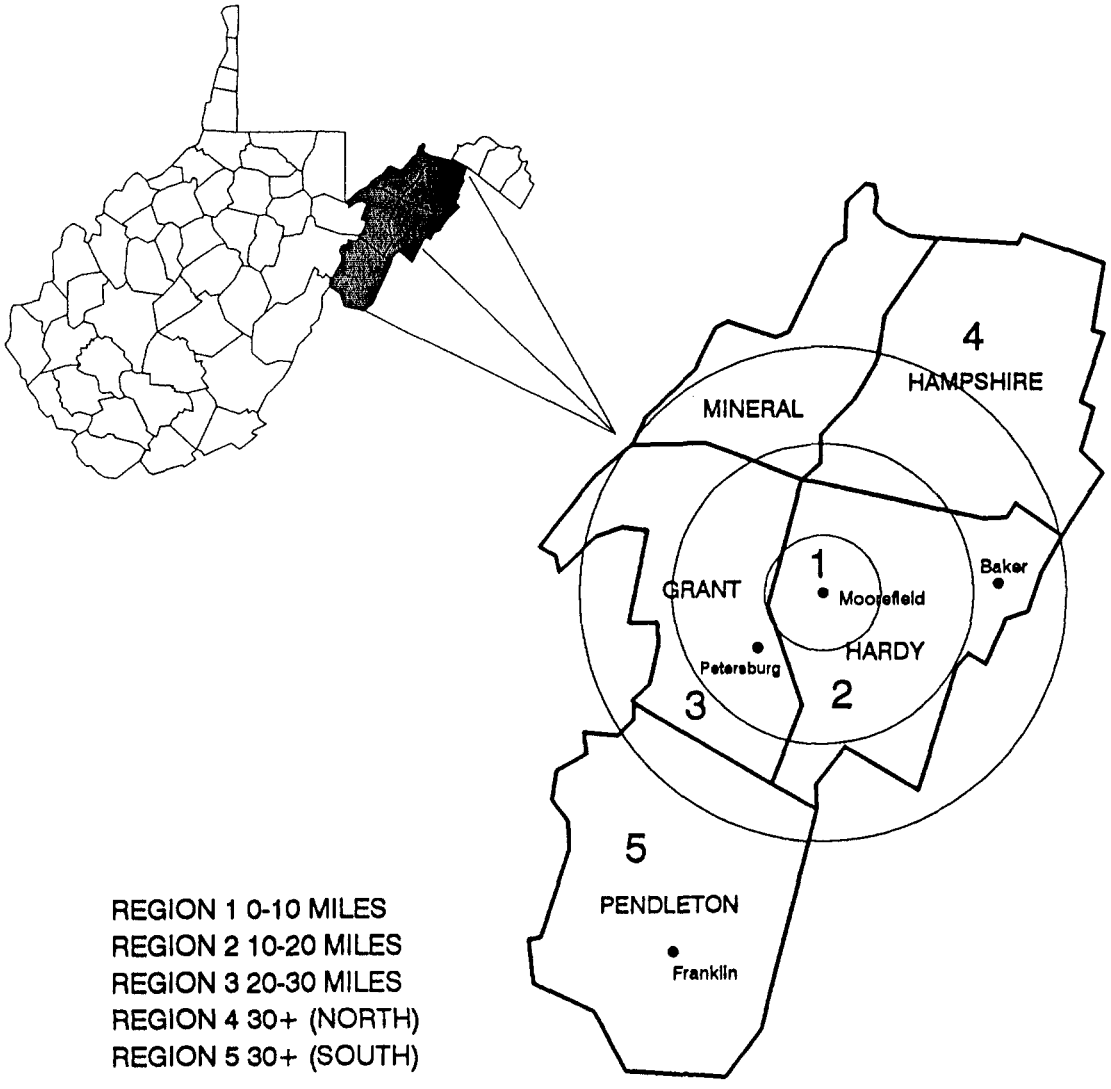


Figure 1. Five County Area of Planned Expansion by the Poultry Industry in West Virginia

(1) land application; and (2) feeding to cattle as a protein substitute. Growers utilize either their own resources or transfer litter to another party. Bosch and Napit estimated that poultry litter could be profitably shipped up to 50 miles for land application on cropland and pasture. For cattle feeding, litter has been shown to be a cost effective protein replacement when transported up to 300 miles (Weaver and Souder). Given these two alternatives, the potential amount of poultry litter which could be utilized in the five county area was calculated (Table 1).

Markets exist for litter which vary from $2 per ton for fresh turkey finishing litter for use as fertilizer, to a maximum of $10.00 a ton for covered, deep-stacked, high quality broiler litter for use as feed (Weaver and Souder). During the period of this study (1991), market prices for broiler litter were in the range of $5 to $7 per ton according to poultry industry personnel and growers. While there are costs associated with on-farm moving and storing litter, these market prices generally gave a positive net return to growers (Souder).

Despite the existence of markets, there are uncertainties associated with both litter disposal alternatives. Institutional barriers and consumer acceptance act as constraints to market growth for feeding of poultry litter to cattle. Major poultry producing states (Arkansas, Alabama, Georgia, and Mississippi) allow litter as an ingredient in

Table 1. Potential Poultry Litter Disposal Capacities for Land Application and Cattle Feeding Alternatives in the Five County Area of West Virginia

	Land Application[a]		Beef Cattle	
County	Crop and Pasture Acres[b]	Potential Litter Application[c] (tons)	Jan. 1 1992 Numbers	Potential Litter Fed[d] (tons)
Grant	32,060	43,960	17,000	10,880
Hampshire	44,317	67,062	18,100	11,584
Hardy	47,554	68,704	27,100	17,344
Mineral	25,956	39,176	8,400	5,376
Pendleton	52,606	70,776	27,000	17,280
Total	202,493	289,678	97,600	62,464

[a]Poultry litter is applied primarily on agricultural land. Some litter is used for mined land reclamation. However, the potential is minor compared to agriculture land. Only a fraction of the 4,350 acres of permitted surface coal mines in these five counties is reclaimed annually.
[b]Sources: WV Agricultural Statistics Service (cropland) and U.S. Bureau of Census (pasture).
[c]Application rates for different crops, including pasture, were based on meeting crop nutrient requirements for nitrogen with poultry litter (Bosch and Napit). Per acre rates ranged from 1 ton (pasture) to 2.1 tons (corn). If applications were limited by phosphorus requirements for crop production, rates would decline by as much as 75% (Bosch and Napit).
[d]Feeding rate of 0.9 ton per beef cow with calf and 0.6 ton per heifer or steer over a 120 day feeding season (Russell).

feed rations based on regulations recommended by the Association of American Feed Control Officials. In West Virginia, however, state regulations prohibit the commercial sale of poultry litter feed products (G. Carpenter). Thus, all elements of litter transactions, including pathogen control[2] and feed preparation, must occur only between poultry growers and cattle feeders and can not be facilitated by feed mills. Despite precautionary measures recommended by the National Research Council, the potential always exists for the cattle feeding market to disappear rapidly if consumer groups react adversely to information about poultry waste being used as feed in beef production. The use of alar in apple production is one example of the adverse consumer reaction to potentially harmful substances utilized in food production (Bidinotto; Consumer Reports).

For land application, the primary limitation to market growth is environmental concerns. Improper handling and land application of litter can contribute to nitrogen and phosphorus contamination of surface and ground water. Surface water quality from runoff on pastures with poultry litter applications is dependent upon the interval between application and the storm event (McLeod and Hegg; Westerman and Overcash). However, poultry litter application does not influence runoff quantity (Edwards and Daniel). Increased nitrates in ground water have been linked to poultry house location (Robertson; Ritter and Chirnside; Bachman) and land application of poultry litter (Leibhart et al.). While protection of surface and ground water contamination from poultry litter application currently is dependent upon voluntary programs in West Virginia, mandatory programs may be put in place if voluntary programs prove to be ineffective[3]. Mandatory programs will most likely limit the extent of cropland application and/or the quantity of litter that can be applied.

With the current focus on environmental impacts of agriculture, the alternative of composting poultry litter has been critically examined based on production (Sweeten), marketing (Holden 1990), and economic cost evaluations (Safley and Safley). Proper site design and management of compost facilities are required to prevent potential environmental problems from the composting process, i.e. surface runoff, soil erosion, leachate, and odor (Diener et al.; Rynk). In West Virginia, both local and state government approval are required to minimize environmental problems in the construction and operation of a centralized, off-farm composting facility for poultry litter. A composting facility would have to meet the siting requirements of the county solid waste authority and be issued a permit by the Division of Environmental Protection.

[2] Poultry litter pathogens can be safely removed through the methods of dehydrating, ensiling, or deepstacking (National Research Council).

[3] For ground water, regulations are voluntary guidelines to implement best management practices for animal manure application on farmland (WV Department of Agriculture). If these do not protect ground water, the Commissioner of Agriculture may develop mandatory best management practices.

Methods

Poultry Litter Generation

Flow and location of waste are critical determinants of centralized composting facilities. Broiler operations generate the bulk of litter, with pullet and breeder houses also required to provide a constant flow of chicks to broiler operations. Although litter generation estimates vary widely among broiler production areas due to type of bedding material, bedding depth, and frequency of litter removal (Malone), averages were estimated for the amount of litter generated by various sizes and types of poultry operations in West Virginia (Table 2). Each broiler house generated approximately 175 tons per year over seven production cycles. Since turkey houses were not a standard size, litter generation was measured by square footage of floor space.

For location of litter generation, the numbers of broiler, pullet, and breeder houses, and square footage of turkey houses, were gathered for each zip code area within the five counties. Zip codes were then grouped into five regions according to distance from Moorefield (Figure 1). Ten mile regions were used to estimate the pattern of poultry house expansion by 1994. Because exact house locations were not available, the following estimates of expansion were made for each region based on contacts with potential poultry growers as of September 1991: 20% in region 1; 20% in region 2; 30% in region 3; and a combined 30% between regions 4 and 5 (Ellington). For turkeys, there were no major plans to expand processing and new houses are added periodically to accommodate grower interest (D. Carpenter). Based on past growth, a 20% expansion in square footage of turkey houses was projected by 1994. This expansion translates into eleven new houses which were added into zip code areas with existing turkey houses.

Table 2. Poultry Litter Generation Estimates

Type of Bird	Amount Generated (wet-tons/house)	Production Time Period
Chicken		
Broiler	25	7 weeks
Pullet	25	21 weeks
Breeder	75	annual
Turkey	(pounds/sq ft of floor space)	
Hens	18	annual
Toms	30	annual

Sources: Ellington and Carlton.

Composting Facility Costs and Location

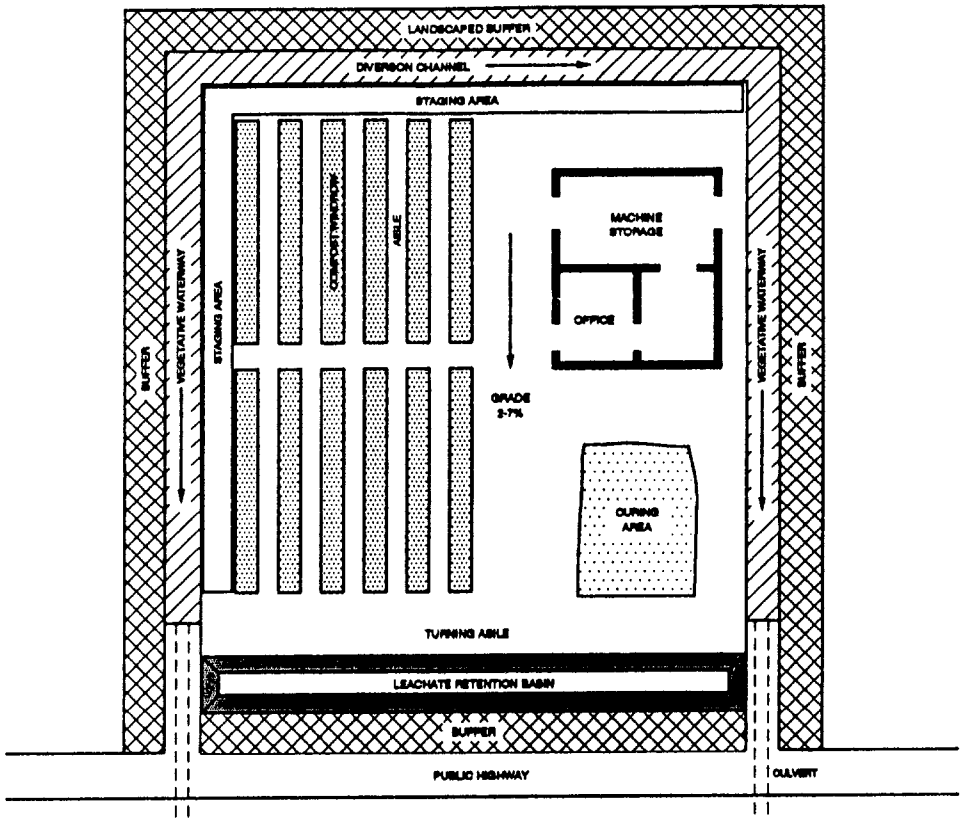
Four types of compost facilities were examined at two capacities: 40,000 and 80,000 tons of litter annually. The type of facility was varied to examine the impact on cost from different process technologies for aeration and turning of poultry litter. Capacities were based on previous research (Safley and Safley). Two facilities used windrow technology to compost litter: standard windrow operation and aerated pile. In a standard windrow operation, litter would be formed into piles four feet high and 11 feet wide at the base. In this low technology operation, windrows would be turned periodically for aeration and mixing. A sample design for a standard windrow facility is shown in Figure 2a. The aerated pile technology would utilize covered buildings with floor vents to force air through six foot high piles of litter. Less frequent turning would be required, mainly to mix the litter during composting.

The other two facilities were in-vessel: Farmer Automatic system and LH Resources system. In-vessel technology would consist of concrete trough bays under covered buildings to contain the poultry litter during the composting process. Motorized agitators would be used to mix the litter and provide aeration (Figure 2b). The Farmer Automatic system has a agitator which is electrically driven, runs on rails, and requires a transfer unit to move it between composting bays. One agitator can service up to four bays for a daily mixing of poultry litter. The LH Resources system is based on a self propelled gasoline driven agitator which rides in the grooves between four foot high composting bays. The bay design also includes aeration to speed up the composting process. Both LH Resources and Farmer automatic are designed for a batch[4] system of composting.

A summary of resource requirements for each composting technology is presented in Table 3. Labor requirements were similar, but longer composting periods required greater land area. Cost estimates for capital and operating resources are presented in Appendix A. These resource requirements and costs were used to compute a capital cost per facility and the average cost of operation at full capacity per ton of poultry litter accepted. The capital costs and operating cost per ton were used in a net present value (NPV) analysis conducted to compute economic feasibility. Poultry

[4] In a batch operation the litter is loaded into the bay all at once. The compost agitator turns and pushes the material forward in the bay one day and back the next day.

(a) Design of a Windrow Compost Facility



(b) Sample Design for an In-Vessel Composter

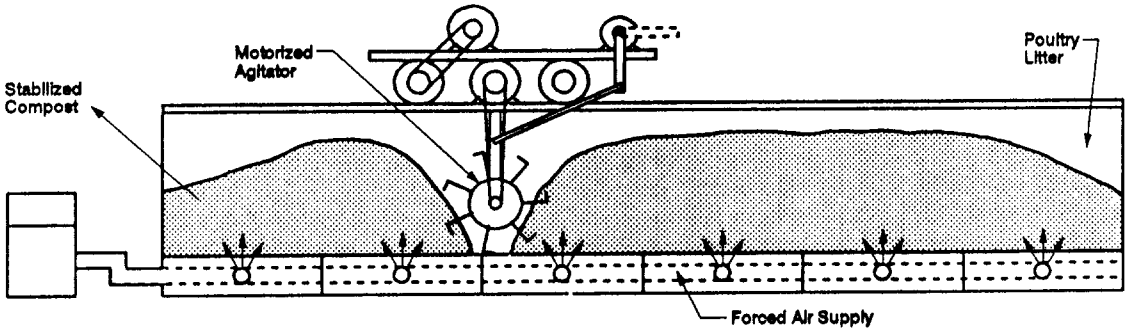


Figure 2. Illustration of Windrow and In-Vessel Compost Facilities

litter was assigned a zero cost in the cost analysis because calculation of a litter disposal fee was the objective of the economic feasibility analysis.

Transport of litter to and operating costs of the composting facility(s) were minimized by linear programming (LP) models (Appendix B). Potential composting facility locations were the communities of Moorefield, Petersburg, Franklin, and

Table 3. Composting Technology Requirements

Composting Technology	Time Required	40,000 T Capacity Land (Acres)	40,000 T Capacity Annual Labor (Hours)	80,000 T Capacity Land (Acres)	80,000 T Capacity Annual Labor (Hours)
Standard Windrow	16 weeks	30.0	2744	39.0	5489
Aerated Pile Windrow	10 weeks	24.2	2464	30.1	4837
Farmer Automatic	3 weeks	5.0	2964	8.3	5887
LH Resources	1.5 weeks	3.6	2544	5.7	5087

Baker (Figure 1). Four scenarios were used to project the amount of poultry litter which might be disposed at the compost facility(s):

A. 70% of Chicken Expansion;

B. 50% of Current Chicken + All Chicken Expansion;

C. All Current Chicken and Turkey + All Chicken and Turkey Expansion; and

D. One Facility at Full Capacity taking closest litter.

For each scenario, the minimum cost number, size (40,000 or 80,000 tons), and site location(s) were determined with LP models.

Scenario A was chosen to examine facility(s) handling the litter solely from the expansion of chicken production based on the assumption that 30% of the litter generated by expansion will go to land application or livestock feeding. This estimate of 30% was based on experience of poultry industry growth in Rockingham County, Virginia (Souder). For scenario B, projections were for environmental regulations of litter management plans similar to Rockingham County. It was assumed that 50% of current poultry growers and all growers involved in expansion would not have adequate on-farm resources to have acceptable plans and would use the compost facility(s). Scenario C was the worst case scenario where the facility(s) would be required to handle all chicken and turkey litter due to strict environmental regulations eliminating litter disposal alternatives. Scenario D examines one facility operating at full capacity and receiving litter from the closest sources. This would be the most cost-efficient scenario since composting facilities in A through C may have excess capacity.

Economic Feasibility

A compost marketing report conducted for this study concluded that there was limited interest in compost locally primarily due to a projected lack of demand by farmers (Albrecht). The Baltimore-Washington D.C. area could provide a market for poultry litter compost at a delivered price of $4 to $7 per cubic yard ($8 to $14 per ton) for bulk compost (unbagged). However, high transportation costs ($16.60 per ton for compost transported to Washington, D.C.) eliminated this market from consideration.

Three levels of market development for bulk compost were assumed based on this report: (1) low; (2) medium; and (3) high. Under low market development, compost would be given away without charge to individuals, including growers, or organizations. This level was used to simulate an oversupply of compost and litter from the expansion resulting in the highest possible disposal fee for the composting facility. At a medium level, local markets were assumed to be established such that an average price of $8.00 per ton of compost was received by the facility (i.e. the low range of delivered prices in the Baltimore-Washington D.C. markets). Markets would include a combination of sale to farmers, local landscapers, mine land reclamation, and homeowners. To simulate a medium level of market establishment process, the sale of compost was expanded to 100% of production at 25% intervals during the first four years of operation.

At a high level of market development, local markets would need to be established which use compost in production of a higher valued product that is economical to transport to larger markets. Some market development ideas include bagged retail, plant nurseries, christmas tree production, and sod farms. Under high development, revenue of $14 per ton was projected for compost, the upper end of price in the Baltimore-Washington, D.C. market.

Economic feasibility for centralized, off-farm poultry litter composting facility(s) was evaluated by using the cost information on production and litter transport for the minimum cost facilities from the LP models. A NPV approach was used to compute litter disposal fees under which composting facility(s) would be financially attractive to a private investor under each market development assumption. NPV was set equal to zero over 20 years of facility operation in order to calculate the maximum amount the facility operator could afford to

Table 4. Composting Facility Costs at Full Capacity for 40,000 and 80,000 Tons of Poultry Litter Annually

	Composting Facilities: 40,000 Ton Annual Capacity			
	WINDROW	AERATED PILE	FARMER AUTO	LH RESOURCES
		(Dollars)		
Capital Cost	758,125	848,100	677,830	533,820
Annual Costs		(Dollars)		
Operating	43,366	41,076	41,520	80,976
Capital	147,131	167,626	148,242	128,072
Total	190,497	208,702	189,762	209,048
Average Cost		(Dollars/Ton of Poultry Litter)		
Operating	1.08	1.03	1.04	2.02
Capital	3.68	4.19	3.71	3.20
Total	4.76	5.22	4.75	5.22
	Composting Facilities: 80,000 Ton Annual Capacity			
	WINDROW	AERATED PILE	FARMER AUTO	LH RESOURCES
		(Dollars)		
Capital Cost	1,258,200	1,216,700	1,175,950	889,190
Annual Costs		(Dollars)		
Operating	86,732	79,784	83,040	161,952
Capital	217,086	223,975	231,735	191,558
Total	303,818	303,759	314,775	353,510
Average Cost		(Dollars/Ton of Poultry Litter)		
Operating	1.09	1.00	1.04	2.02
Capital	2.71	2.80	2.90	2.39
Total	3.80	3.80	3.94	4.41

pay poultry growers for litter and still meet expenses of operation and capital[5]. If this maximum amount was positive, a litter disposal fee would have to be paid by poultry growers to financially support a compose facility. A negative maximum amount represented a payment from the facility to growers for litter. Maximum disposal fees were computed for each of the litter shipment scenarios with the three market development assumptions.

Results

Poultry Litter Generation

Current poultry litter generation was estimated at 82,000 tons annually in the five counties. The bulk of generation was in Pendleton (33,000 tons), Hardy (29,000 tons), and Grant (15,000 tons) Counties. After the projected expansion in 1994, about 131,000 tons of poultry litter will be generated annually. The largest amounts were in Hardy county (45,000 tons) adjacent to the Moorefield processing plant and Pendleton county (43,000 tons) where chicken and turkey operations overlap. Compared to land application and cattle feeding alternatives in Table 1, about one-third of the disposal capacity would be required to absorb litter generation upon expansion.

Composting Facility Costs and Location

For both 40,000 and 80,000 ton sizes, in-vessel technology had lower capital costs than windrow technology (Table 4). On an annual cost basis, the least cost technology for the 40,000 and 80,000 ton size facilities were Farmer Automatic and aerated pile, respectively (Table 4). Economies of size were apparent for all compost facility types. Annual costs per ton of poultry litter composted were lower by $0.81 per ton for both in-vessel systems and $1.42 lower for the aerated pile facility when size was increased from 40,000 to 80,000 tons (Table 4).

Minimum cost site locations for all four scenarios included a facility in Moorefield, WV (Table 5). For scenario A, only a 40,000 ton facility was required while the other three scenarios utilized the 80,000 ton size. In scenario C, an additional

[5] Capital expenses were based on a 4:1 debt-equity ratio and an assumed 18% before tax return to net worth based on returns to agricultural services corporations with assets between $500,000 and $1,000,000 (Troy).

Table 5. Least Cost Compost Facilities and Maximum Litter Disposal Fee for Economic Viability Under Four Market Development Assumptions

Scenario A: 70% of Chicken Expansion	
Least Cost Facility: Farmer Automatic with capacity 40,000 tons per year located in Moorefield and produces 21,438 tons of compost from 30,625 tons of litter[a]	
Market Development Assumption	Maximum Disposal Fee ($/Ton)
Low	7.64
Medium	2.99
High	−2.16
Scenario B: 50% of Current Chicken + All Chicken Expansion	
Least Cost Facility: Aerated Pile with capacity 80,000 tons per year located in Moorefield and produces 48,514 tons of compost from 69,305 tons of litter	
Market Development Assumption	Maximum Disposal Fee ($/Ton)
Low	6.59
Medium	1.94
High	−3.21
Scenario C: All Chicken & Turkey + All Chicken and Turkey Expansion	
Least Cost Facility: Two Aerated Pile facilities each with capacity 80,000 tons per year located in Moorefield and Franklin and produces 88,756 tons of compost from 126,794 tons of litter[b]	
Market Development Assumption	Maximum Disposal Fee ($/Ton)
Low	6.21
Medium	1.56
High	−3.59
Scenario D: One Facility at Full Capacity Taking Closest Litter	
Least Cost Facility: Aerated Pile with capacity 80,000 tons per year located in Moorefield and produces 56,000 tons of compost from 80,000 tons of litter	
Market Development Assumption	Maximum Disposal Fee ($/Ton)
Low	5.58
Medium	0.94
High	−2.55

[a]A 30% weight reduction from the litter received was assumed to occur during the compost process (Holden 1991).
[b]The Moorefield facility is at full capacity while the Franklin facility is operating at slightly over half capacity.

80,000 ton facility at Franklin, WV was included to minimize litter transportation costs.

Economic Feasibility

Under low and medium market development, an off-farm facility will require a disposal fee to be charged to poultry growers in order to be economically feasible for private investors (Table 5). Under an assumption of giving away compost, poultry growers would be charged a disposal fee of between $5.58 and $7.64 per ton depending on the amount of litter received by the facility. If markets could be established such that $8 per ton of revenue was received for compost, disposal fees would drop to between $1 and $3 per ton. Thus, even with revenue from compost sales, litter disposal fees would be required for the facility to cover litter transportation, compost production, and investment costs. Only at a high level of market development was an owner of the compost facility able to pay an average of about $3 per ton to poultry growers for litter (negative disposal fee in Table 5).

These fees reflect the economic feasibility for construction and operation of a composting facility which functions as a disposal option for poultry litter, i.e. taking in all or a substantial portion of litter generation in the five county area. There are facilities in other areas which compost (e.g. for mushroom production) or process (e.g. pelletizing for organic fertilizer) poultry litter and are able to

pay growers the current market prices for litter (Long; Miller). These facilities are not disposal options in the sense that they operate in relatively small markets compared to poultry litter generation quantities, and they exist to meet market demand for an end product rather than to facilitate disposal of a substantial portion of litter generation.

To examine the effect of lower interest rates on disposal costs, a sensitivity analysis was performed. Even if a compost facility could be constructed with low interest rate loans, disposal fees for poultry litter would still be required to make the facility economically feasible for private investor under low and medium market development. Lowering the rate of interest for over 12% to 6% resulted in the disposal fees dropping about $1 in most cases.

Conclusions

When a composting facility is constructed as a disposal option for poultry litter, disposal fees to growers would be required for the facility to be economically feasible for a private investor. These fees were projected for centralized, off-farm poultry litter composting facilities in the eastern panhandle of West Virginia under realistic compost market development projections of low (give away compost) and medium (receive $8 per ton). Even if high compost market development was projected, comparable to urban markets, poultry growers would receive only about $3 per ton of litter which is lower than the return of currently available from land application or cattle feeding alternatives.

The potential for an economically feasible composting facility to compete with current litter disposal alternatives depends upon creation of a medium to high level of market development for compost along with depressed litter prices. For compost market development to be successful, a variety of other local markets must be developed throughout the life of the facility[6]. Given the large quantities of compost produced by a centralized, off-farm facility, cropland application would have to be one market. Compost does have an economic value to farmers when used in conjunction with commercial fertilizers (Collins; Holden Farms). However, farmers have been reluctant to pay for compost application (Biocycle staff). Improved economic information and aggressive marketing may overcome this reluctance. Other markets include nurseries, sod farms, or bagged retail.

The other condition for a composting facility to successfully compete with other disposal alternatives is depressed litter prices which could occur due to an oversupply from expanded production. Riley has shown that increased litter generation from expanded poultry production can depress litter prices without an expanded demand for litter. Litter prices also could be depressed by elimination of current disposal alternatives. Land application and livestock feeding would be essentially no longer available for litter disposal if: (1) the groundwater protection regulations in West Virginia become mandatory and significantly reduced the amount of land application available for poultry litter; and (2) an adverse consumer response occurred to litter being fed to cattle.

Given the drawbacks of a disposal fee for poultry growers and uncertainties of local market establishment, expansion of land application and cattle feeding alternatives should be seen as viable methods to meet increased litter disposal needs of West Virginia's poultry industry. These alternatives can be expanded through an educational campaign on the benefits of land application and cattle feeding and by establishment of a market broker for litter. Rockingham County, Virginia serves as a model for expansion with an educational campaign by the Virginia Cooperative Extension Service and operation of a market broker to expand litter demand to meet the disposal needs of increased poultry production (Souder). To date, the West Virginia Soil Conservation Agency has taken the lead in coordinating federal and state efforts to provide nutrient testing programs for land application, to conduct demonstration field days on litter use (both within and outside the five county area), and to develop lists of growers interested in buying and selling litter (Warnick).

[6] Based on the experiences of a poultry litter composting operation in Goodhue County, Minnesota, the 64,000 ton capacity of this operation satisfied local cropland application demands within 10 years and has since gone national with its marketing efforts (Holden 1991).

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Appendix A. Capital and Operating Cost Assumptions, 1991 Data

CAPITAL COSTS Land and Improvements	Units	Purchase Price	Annual Costs of Ownership[a]
Land-Agricultural (Unimproved)	Acre	$2,000	$240
Improvements	Acre	5,000	895
Land-Industrial (Improved)	Acre	6,300	819
Asphalt Pavement	Acre	72,750	9,022
Office Building	50′ × 100′	50,000	6,700
Composting Building	80′ × 300′	150,000	20,100
Screening & Storage Building	50′ × 200′	60,000	8,040
Machinery and Equipment			Operating Cost Per Hour
Towing Tractor	120 HP	20,000	11.00
Scat Turner	56 HP	80,000	5.13
Sitler Turner		22,000	—
Truck	2 Ton	10,000	11.00
Front End Loader	160 HP	50,000	14.67
Floor Aeration	80′ × 300′	10,000	0.75
Composting Machine	FA 610	61,390	0.45
Trolley Transfer	FA 610	9,695	—
Crane Rail	Per Ft	7.75	—
Pit Walls	3′ × .5′ xL	4.35	—
Composting Machine	LH Resources	125,000	14.33
Pit Aeration	15′ × 200′	10,000	0.75
Pit Walls	Per Ft	11.60	—
Separator Screens		9,000	0.33
Well and Pump		4,000	0.20
Water Pump	2 HP	1,300	0.12
Thermometer	6 Ft	60	—
OPERATING COSTS			
Labor	per hour	—	7.00
Transportation	per ton mile	—	1.00/0.10b[b]
Interest Rate	%	—	12.4
Electricity	KWH	—	0.03/0.06[c]

[a]Ownership costs include depreciation, interest, insurance, and taxes.
[b]One dollar for the first ton-mile and $0.10 per ton-mile thereafter.
[c]Three cents per KWH for industrial service (in-vessel facilities) and six cents for non-industrial (window and aerated pile).

Appendix B: Linear Programming Models

The objective was to minimize the variable costs of transportation and production cost of composting. This objective was constrained by the capacity of each facility and the quantity of litter generated by zip code. The objective function and constraints were:

Minimize TVC =

$$\sum_{j=1}^{J} \sum_{i=1}^{I} [C_j + T_{ij}]W_{ij}$$

$$\text{st.} \sum_{j=1}^{J} W_{ij} = W_i \quad \text{for } i = 1,2, \ldots I$$

$$\sum_{i=1}^{N} W_{ij} \leq W_j \quad \text{for } j = 1,2, \ldots J$$

$$W_{ij} \geq 0$$

Variables

- I: Number of zip code areas
- J: Number of composting facilities
- W_i: Amount of waste generated annually at zip code area i not disposed of through some other alternative.
- W_{ij}: Quantity of waste transported from zip code area i to facility j
- T_{ij}: Cost of transporting 1 ton of waste from zip code area i to facility j
- C_j: Cost of composting 1 ton of waste at facility j
- W_j: Capacity of waste which can be processed at facility j