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SUMMARY

The disposal of waste from dairy herds is a problem of increasing importance to farmers, since the volume of manure to be handled has increased with larger herds; and generally speaking, farm labor is not as plentiful.

The four most used systems of manure disposal in Tennessee are the lagoon, liquid, conventional, and irrigation systems. The objective of this study was to estimate the initial investment requirements, annual variable or operating costs, and labor requirements for these four systems. This was done for a herd of 100 cows, considering manure as only a nuisance, and considering the costs of pulling manure into pits or loading over ramps as part of the cleaning operation and not as part of the disposal process.

The initial investment requirements per cow were $21.86 for the conventional system, $60.50 for the liquid with 15 days storage, $77.15 for the irrigation system, $86.00 for the liquid with 30 days storage, $97.59 for the lagoon, and $111.50, $137.00, $162.50, and $188.00 for the liquid systems with 45, 60, 75, and 90 days storage.

The annual costs per cow were estimated as $9.54 for the conventional, $14.11 and $16.15 for the liquid systems with 15 or 30 days storage, $17.82 for the lagoon, $18.19 for the liquid with 45 days storage, $18.42 for the irrigation system, and $20.33, $22.27, and $24.31 for the liquid systems with 60, 75, and 90 days storage.

The labor requirements for the lagoon system were lowest since no labor was required beyond scraping. The labor requirements for the other three systems were essentially the same with no really significant differences in the requirements. One factor to consider in deciding which system to use would be that of the flexibility of the labor requirement; with the conventional system, the manure has to be hauled on a regular basis, perhaps daily, regardless of weather conditions, whereas with the other systems, the manure can be stored and spread on a periodic basis when weather is favorable and the labor available.

The decision as to which system to use depends on the particular situation involved, but should consider the relative availability of resources, particularly capital and labor. For example, can the larger initial investment and higher annual cost of the lagoon system be justified in a particular situation on the basis of saving labor?

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Costs of Manure Disposal on Dairy Farms in Tennessee

INTRODUCTION

Problem

The disposal of waste from dairy herds is a problem of increasing importance to farmers. The increased emphasis on environmental pollution emphasizes the importance of manure handling systems.

The four systems for dairy manure disposal most widely used in Tennessee are the lagoon, liquid, convention, and irrigation. The problem faced by a farmer is to decide which of these is most adequate for his particular situation. Factors he should consider in making this decision include the initial investment, annual costs of operation, labor requirements, sanitation regulations, personal preference, and physical feasibility. The choice of a system on a particular farm should be made by comparing costs; however, relative scarcity of resources should also be considered.

Objective

The objective of this study was to estimate the initial investment requirements, annual operating costs, and labor requirements of the four systems of manure disposal most often used on Tennessee dairy farms.

Procedure

The costs and requirements were estimated for a herd of 100 cows. The average size of herds in D.H.I.A. in 1971-72 was 74 cows. The average size has been increasing, for all practical purposes, since 1947; therefore an average herd size of 100 cows could reasonably be expected in the not too distant future.

The estimates of initial investment requirements were obtained from dealers for equipment and from contractors for those items that have to be constructed.

Estimates of labor and hourly tractor requirements came from various secondary sources and from the experience of the senior author at the University of Tennesse at Martin farm.

Total annual costs for each system were estimated in two components, fixed and variable. Fixed costs include those items that remain the same regardless of the amount of use made of the system, while variable costs include those that vary with use.

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Specifically, the annual fixed cost on permanent structures such as pits and ramps was calculated as 8% of the initial cost.[1] This includes depreciation, interest, housing, taxes, and insurance. The annual fixed cost for equipment items such as spreaders and tanks was calculated by figuring depreciation on a straight-line basis for the appropriate number of years, and adding 5.5% of the initial cost for interest, housing, taxes, and insurance.[2]

Annual variable costs were calculated using the minimum wage of $1.60 per hour as the charge for labor. The repairs and maintenance cost on such items as spreaders and pumps was calculated as 6% of the initial cost.[3] The hourly charges were $1.33, $1.74, and $2.11 respectively for 3-plow 40 horsepower, 4-plow 50 horsepower, and 5-plow 60 horsepower tractors. These figures include charges for depreciation, repairs, interest, fuel, oil, and lubricants.[4]

In this study, the costs of moving the manure into pits or loading over ramps are considered part of the cleaning operation and are not included as part of disposal costs. Manure was considered as strictly a nuisance with no value as fertilizer. If it is desirable to consider the value as fertilizer, an estimated value of manure per cow per year is presented in the appendix.

Purpose

The estimated figures reported here are intended to serve as guidelines to a farmer considering a new system or revision of a present system of manure disposal. It is hoped the estimates illustrate factors which should be considered as well as a general idea of the magnitudes of various requirements of labor, pit sizes, etc. However, it should be kept in mind that these requirements may differ for different circumstances and for different herd sizes.

It should also be emphasized that increases in herd sizes will not necessarily mean increases in costs proportionate to the change in herd size. In fact, for larger herd sizes the costs per cow will likely become lower due to economies of size, or the spreading of the fixed costs over a larger number of cows and in general making more efficient use of resources.

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[1]Richey, C. B., Paul Jacobsen, and Carl Wildall, **Agricultural Engineers Handbook,** McGraw Hill, New York, 1961, page 587.

[2]**Ibid.,** page 7.

[3]Conversation with J. I. Sewell, Department of Agricultural Engineering, University of Tennessee, Knoxville.

[4]Hoglund, C. R., and E. G. Orbegoso, "Investments and Operating Costs for Gasoline and Diesel Operated Tractors," **Michigan Quarterly Bulletin,** Vol. 45, No. 4, page 686, May 1963. Inflated to 1971 by prices paid for farm machinery index, Agricultural Prices, 1971 Annual Summary, Pr. 1-3(72) SRS, USDA.

DESCRIPTION OF THE MANURE DISPOSAL SYSTEMS

Conventional System

The conventional system of handling manure is still being used by many dairymen. The basic principle of this system is to scrape the manure each day and either push it onto a spreader or pile it for later hauling. Usually it is spread when the spreader is full or as soon as weather conditions permit. The handler has little choice other than regularly hauling the manure regardless of field conditions or of what other jobs he may have.

There will be times when tractors for hauling are being used for other jobs when the platform scraping is done. This means that hauling will sometimes be done as a separate operation and that manure must be stockpiled for a short time and moved again before hauling.

In this study costs were estimated for a system with a ramp for pushing manure onto spreaders, rather than loading it with a loader. Manure is often too liquid for efficient handling with a loader and this requires more time.

Liquid System

Liquid systems are rather compact and therefore take less area than other systems, especially lagoons. If it is possible to consider the system of manure disposal as the entire layout of the dairy is planned, the pit for storing the manure may be constructed underneath the walkway or holding pen. In this location no additional area is required for daily cleaning and scraping may be reduced since the pit opening will be more accessible.

Almost all liquid systems are based on the same principle though there is quite a variation in types. The manure is scraped directly into them or scraped into drops and washed into the pit. The pit must contain enough water to mix the manure into a slurry. In many cases the water from the milking system may be diverted to this use and therefore there will be little or no cost for additional water. This mixing is often done by an agitator which is used both to agitate the manure and pump it into the spreader wagon. Although enough water must be added for proper agitation, excess water should not be added and surface water should not be allowed to get into the pit since this increases the volume which must be hauled.

Most pits are constructed so that machinery may be driven over them for filling, agitating, and pumping with a tractor and blade. Commercial pits may be purchased which are simply round metal tanks.

The wagon that hauls the slurry from the pit usually has a large tank, usually between 800 and 1,500 gallons. A power-take-off driven propeller is usually attached to the outflow opening to throw the slurry in a wide swath during application.

Irrigation System

Irrigation systems may be considered a form of the liquid system since sufficient water is required to make manure fluid enough to move through the system. However, irrigation systems require more water than liquid systems. For dairy farms that have adequate water and are (or can be) built such that water is channeled to a central area, the use of an irrigation system may be feasible. This may be especially true for dairies with flush-down cleaning systems, or holding areas requiring liquid manure disposal. Irrigation systems may be used in combination with either liquid systems or lagoons.

The irrigation system of manure disposal is similar to normal irrigation systems except that the pumps must be equipped with blades to chop all materials small enough to go through the special nozzles required. The pump and accessories needed for manure disposal are heavier than those for normal irrigation systems.

Lagoon System

Lagoons are ponds dug to certain specifications. In practice, the manure is pushed or flushed by water directly into the lagoon and left to decompose. The ramp over which manure is pushed is a hard-surfaced strip, usually concrete, that goes to and down the side of the lagoon. On some dairy farms, the manure is flushed into the lagoon through galvanized culvert pipes. Although not all land is suitable for lagoons, suitable sites exist in each section of the state.

The two major types of lagoons are aerobic and anaerobic. The aerobic lagoons must be shallow, 5 feet or less,[5] and therefore require a much larger surface area per animal or per volume of refuse than do the anaerobic lagoons which are deeper, a minimum of 9 feet and a recommended depth of 14 feet.[6] Anaerobic organisms live only where free oxygen is not available, and they depend on combined oxygen taken from organic matter.

In general only anaerobic lagoons are used for cattle manures. These are septic and will give off some odor, though minimal, if the lagoon is properly built and maintained. Little research has been done on the extent of buildup in anaerobic lagoons over time. Since none of the anaerobic organisms can completely decompose all components of manure, some buildup occurs. Removing this sludge could become necessary if the lagoon volume is significantly reduced by the sludge.

Before constructing a lagoon, a farmer should consult the Tennessee Department of Public Health to make sure their requirements and restrictions can be fulfilled. Among these are location of the lagoon at least 700 feet away from residences other than that of the owner, at least 200 feet from the nearest well, and certain restrictions as to size, depth, and earth embankment. Soil testing should also be done to insure that the lagoon will not contaminate ground water.[7]

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[5]U. S. Department of Agriculture, Soil Conservation Service, Advisory ENG-5, Washington, D. C., January 28, 1970.

[6]Tennessee Engineering Standard, USDA, SCS, Nashville, Tennessee, March 1972.

[7]Ibid.

Proper lagoon management is a necessity. Foreign material, manure, and waste silage may float on top and decompose slowly. This leaves an objectional appearance and may prevent manure from sinking beneath the liquid surface where it will decompose. To prevent contamination of streams, surface water must be diverted from lagoons so they will be less likely to overflow. Lagoon systems must be operated so that effluent will not run off the property of the owner,[8] so a holding pond must be built if there will be any overflow from the lagoon. To prevent overflow from the secondary holding, an irrigation system, or some other method of removing water to a field must be available.

Due to climatic conditions in Tennessee, a holding pond is essentially a necessity even though not specifically required by Department of Public Health regulation. Proper slope of inside walls is essential to prevent caving and to minimize insect breeding. The area adjacent to the lagoon must be graded so weed growth can be controlled mechanically since herbicides may be injurious to the essential bacteria in the lagoon.

COSTS OF MANURE DISPOSAL SYSTEMS

Conventional System

A conventional system for 100 cows requires a standard type manure spreader and a loading ramp. The most efficient method will have the spreader available when the platform is cleaned so the manure can be scraped directly into the spreader.

The average refuse from the larger breeds of dairy cattle is 110 to 115 total pounds per cow per day.[9] After normal losses of 15% of the feces[10] and 50% of the urine,[11] about 85 pounds of manure per cow per day is left for hauling. Standards for determining capacity of spreaders are based on 38 pounds per bushel,[12] so 2.25 bushels per cow or a total of 225 bushels per day must be hauled for a herd of 100 cows.

The original investment required for the conventional system is shown in Table 1.[13]

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[8]**Ibid.**

[9]Bear, Firman E., Carl B. Bender, and Willis A. King, **The Dairy Cow As a Consumer of Soil Fertility**, New Jersey Agric. Expt. Sta. Bul. No. 730, September 1950.

[10]Parsons and Wells, **Manure Handling for Free Stall Dairy Housing--An Economic Analysis**, N. C. State Agric. Ext. Ser. Circular 480, June 1961.

[11]Estimate of senior author.

[12]New Holland Spreader, Sales Pamphlet, 1969.

[13]The price of the 225-bushel capacity spreader was obtained from equipment dealers and the cost of the ramp was based on the senior author's consultations with farmers who have had such ramps constructed.

Table 1. Initial investment required for a conventional system of manure disposal for a 100-cow herd of dairy cattle.

Item	Initial Investment
Spreader (225-bushel capacity)	$1,640
Ramp	546
Total Investment	$2,186

The annual costs for the conventional system are presented in Table 2. The annual fixed cost of the ramp is 8% of the initial cost. The spreader is depreciated on a 12-year straight-line basis, so annual depreciation is 8 1/3%. Fixed costs for the spreader also include 5.5% to cover interest, taxes, housing, and insurance.

Table 2. Annual costs for a conventional system of manure disposal for a 100-cow dairy herd.

Item	Annual Cost
Fixed	
Spreader:	
depreciation	$137
interest, housing, taxes, insurance	90
Ramp	44
Annual fixed cost	$271
Variable	
Labor:	
hauling, 149 hours at $1.60 per hour	$238
loading, 30 hours at $1.60 per hour	48
Tractor:	
50 horsepower, hauling, 149 hours at $1.74 per hour	259
40 horsepower, loading, 30 hours at $1.33 per hour	40
Spreader: repair and maintenance	98
Annual variable cost	$683
Total annual cost	$954

Variable costs of the conventional system are for spreader repair and maintenance and for tractor and labor expenses in hauling the manure. It was estimated that routine unloading, with a 50-horsepower tractor, will take about 24.5 minutes per day. A smaller tractor, 40-horsepower, is needed for 5 minutes per day. Repair and maintenance on the spreader is 6% of its initial cost.

Liquid System

The size of the holding pit for the liquid system of manure disposal is determined by the size of herd and by the number of days of desired holding capacity. Six different holding capacities were analyzed in this study. Required pit capacity for liquid systems is about 2 cubic feet per cow per day.[14] Therefore pit sizes of 3,000, 6,000, 9,000, 12,000, 15,000, and 18,000 cubic feet are required for holding periods of 15, 30, 45, 60, 75, and 90 days, respectively, for a 100-cow herd.

Pit construction costs are figured at $.85 per cubic foot.[15] The required initial investment for each of those pits is shown in Table 3.

Table 3. Initial investment required for a liquid system of manure disposal with various holding capacities for a 100-cow herd of dairy cattle.

Item	Initial investment					
	Holding capacity (days)					
	15	30	45	60	75	90
Pit	2,550	5,100	7,650	10,200	12,750	15,300
Hauling tank	1,750	1,750	1,750	1,750	1,750	1,750
Pump	1,750	1,750	1,750	1,750	1,750	1,750
Total invest.	6,050	8,600	11,150	13,700	16,250	18,800

A 1,500 gallon hauling tank and an agitator pump are required to move the manure from the pit to the field. The initial cost of each of these pieces of equipment was estimated as $1,750[16] (Table 3).

Annual fixed costs of the pits are 8% of the initial cost. The tank and pump are depreciated on a straight line basis of 12 years, 8 1/3% of the initial cost per year, and 8 years, 12 ½% of the initial cost year, respectively. The annual fixed charge for interest, housing, taxes, and insurance on tanks and pumps was calculated at 5.5% of original price. Total annual fixed costs for pits and equipment are given in Table 4.

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[14] Midwest Plan Service, **Structures and Environment Handbook**, MWPS-1, September 1971.

[15] Based on figures prepared by Ozzie Vaigneur, West Tennessee, Experiment Station, Jackson, Tennessee.

[16] The estimate for the tank came from the Badger Equipment Company and for the pump from the Clay Equipment Company.

Average daily labor of 14.5 minutes for hauling and 8 minutes for agitation is required in order to handle manure from 100 cows.[17] The use of a 60-horsepower tractor for 14.5 minutes per day for hauling and a 40-horsepower tractor for 17.25 minutes per day for agitation is needed.

The variable costs in Table 4 are based on a wage rate of $1.60 per hour, and hourly charges of $2.11 for the 60-horsepower tractor and $1.33 for the 40-horsepower one. Also included is a repair and maintenance charge of 6% of the initial cost for the pump.

Table 4. Annual costs for a liquid system of manure disposal with various holding capacities for a 100-cow dairy herd.

	Annual cost					
	Holding capacity (days)					
	15	30	45	60	75	90
Fixed						
Pit	204	408	612	816	1,020	1,224
Tank:						
depreciation	146	146	146	146	146	146
interest, housing, taxes, insurance	96	96	96	96	96	96
Pump:						
depreciation	219	219	219	219	219	219
interest, housing, taxes, insurance	96	96	96	96	96	96
Total fixed cost	761	965	1,169	1,373	1,577	1,781
Variable						
Labor:						
hauling, 88 hours	141	141	141	141	141	141
agitating, 49 hours	78	78	78	78	78	78
Tractor:						
60 horsepower, 88 hours	186	186	186	186	186	186
40 horsepower, 105 hours	140	140	140	140	140	140
Repair and maintenance on pump	105	105	105	105	105	105
Total variable cost	650	650	650	650	650	650
Total annual cost	1,411	1,615	1,819	2,023	2,227	2,431

[17] Based on records at the University of Tennessee at Martin farm. These closely agree with a study done at another station by—High, Joe W. Jr., John R. Owen, and John I. Sewell, **Tennessee Farm and Home Science,** "Field Tests of Liquid Manure Systems at Two Dairies," University of Tennessee, Knoxville, December 1970.

The variable costs of hauling the manure should be fairly constant for the various holding periods since the amount of manure to be hauled is the same in all cases.

Irrigation System

Irrigation systems require a holding pit, an agitator pump, irrigation pipe, and a sprinkler head. The required pit size is 60 gallons or 8 cubic feet total slurry per cow per day assuming rainfall runoff is diverted from the pit.[18] The daily slurry per cow is four times that for the liquid system. The holding period, however, need not be as long as for the liquid system since soil conditions will not hamper the actual spreading as much as with the liquid system. Three and one-half days holding capacity was used for calculating costs to assure ample capacity in case of breakdown or abnormal weather conditions even though daily spreading would be the usual practice. A herd of 100 cows would require a pit of 2,800 cubic feet capacity under the conditions considered.

Construction costs per cubic foot for irrigation systems are less than for liquid systems because there is less need to travel across the pit with heavy equipment, so a figure of $.60 per cubic foot[19] was used (Table 5).

Table 5. Initial investment required for an irrigation system of manure disposal for a 100-cow herd of dairy cattle.

Item	Initial Investment
Pit	$1,680
Pipe	840
Pump and sprinkler	5,195
Total Investment	$7,715

It was estimated that a minimum of 800 feet of pipe at $1.05 per foot[20] would be required for moving manure away from buildings. Pump sizes and prices were determined through correspondence with an irrigation equipment dealer[21] (Table 5).

The annual fixed cost for a pit was figured as 8% of construction cost. Annual fixed costs for pumps, pipe, and sprinkler are based on 10% of the original cost for depreciation with an additional 5.5% for interest, taxes, housing and insurance (Table 6).

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[18]Correspondence with Joe Gribble, Agpro, Inc., Chattanooga, Tennessee.

[19]Based on cost of pit constructed at the University of Tennessee at Martin farm.

[20]Delta Irrigation Company, Memphis, Tennessee, sales catalog a) Racebilt pipe, b) Ireco pipe.

[21]**Op. cit.**, Agpro, Inc., Chattanooga, Tennessee, October 1971.

Table 6. **Annual costs for an irrigation system of manure disposal for a 100-cow dairy herd.**

Item	Annual Cost
Fixed	
Pit	$ 134
Pipe:	
depreciation	84
interest, housing, taxes, insurance	46
Pump:	
depreciation	520
interest, housing, taxes, insurance	286
Total fixed cost	$1,070
Variable	
Labor:	
checking, 91 hours	$ 146
moving pipe, 51 hours	82
Tractor:	
40 horsepower, 26 hours at $1.33 per hour	35
Repair and maintenance:	
pump and sprinkler	312
pipe	34
Utilities	163
Total variable cost	$ 772
Total Annual Cost	$1,842

The annual variable costs for the irrigation system are also shown in Table 6. Included are charges for labor, for a tractor, for pump and sprinkler, for repair and maintenance, and for utilities.

The labor requirements include 15 minutes per day for checking the system plus time required for moving irrigation pipe. To avoid runoff when the manure is spread on the field, the pipes must be moved about every 2.4 days,[22] or 152 times a year. It is estimated that each move will take about 20 minutes. A total of 91 hours are needed per year for checking the system and 51 hours for moving pipes. It is estimated that a 40-horsepower tractor will be needed one-half the time that pipes are being moved--a total of 26 hours per year.

Repair and maintenance on the pump is 6% of its initial cost, and 4% of the cost of the pipe since there are no moving parts involved. Utility costs were based on TVA schedule.[23]

[22] Personal letter from Professor Tom McCaskey, Department of Animal Science, Auburn University.

[23] Tennessee Valley Authority, **Weakley County Municipal Electric System,** Schedule C-5, revised, Knoxville, Tennessee, September 1970.

The costs of the irrigation system were based on the assumption that adequate water would be available from other sources, such as a farm flush system. If additional water was pumped or stored for the irrigation system, costs would increase considerably.

Lagoon System

Lagoon construction is normally done with dozers or other heavy equipment at a cost that will average about $.35 per cubic yard of operation[24] plus $.05 per cubic yard for leveling, smoothing, sowing, and fencing around the lagoon.[25]

The recommended anaerobic lagoon volume is 1 cubic foot of water for each pound of cow,[26] or 85 square feet of surface with a depth of 14 feet[27] for an average mature cow of the larger breeds. This amounts to 1,190 cubic feet of lagoon per cow or about 4,407 cubic yards of lagoon volume for a herd of 100 cows.

The size and cost of the holding pond were assumed to be the same as those of the lagoon.

With a properly-built holding pond of the proper size, water will have to be removed from the holding pond through an irrigation system on a relatively infrequent basis, perhaps only once or twice a year. The costs of the supplemental irrigation system are based directly on the costs estimated in the previous section on irrigation systems. It was assumed that the volume of water going through the irrigation equipment would be small enough such that the pipe would not have to be moved, thus eliminating—relative to the irrigation system discussed previously—the costs for labor and the tractor needed for moving pipe.

Ramp construction consists primarily of laying a concrete slab reinforced by wire that slopes into the lagoon. The cost was estimated by the senior author on the basis of consultation with farmers who had built them. The total cost of constructing a lagoon including a holding pond and irrigation equipment for a herd of 100 cows would be about $9,759 (Table 7).

The annual costs for the lagoon system are shown in Table 8. The annual fixed costs for the lagoon, holding pond, ramp, and fencing are 8% of the initial investment for each.

Variable costs of lagoons are those related to periodic cleaning. This study assumed that lagoons would be cleaned every 5 years. Cleaning costs were estimated based on a requirement of about 2½ days to clean sludge from a 4,400 cubic yard lagoon. This would require a dragline and two trucks at $30.00 per hour[28] for a total of $600.00 or $120.00 per year.

[24]Personal correspondence with Wray Construction Company, Gleason, Tennessee.

[25]Estimate of senior author.

[26]Midwest Plan Service, **Agricultural Engineers' Digest,** "Anerobic Manure Lagoons," Ames, Iowa, 1969.

[27]Tennessee Engineering Standards, **op. cit.**

[28]Personal correspondence with Wray Construction Company, Gleason, Tennessee.

Table 7. Initial investment required for lagoon system of manure disposal for a 100-cow dairy herd.

Item	Initial Investment
Lagoon	$1,542
Leveling, seeding, fence	220
Holding pond	1,542
Leveling, seeding, fence	220
Ramp	200
Irrigation pipe	840
Pump and sprinkler	5,195
Total initial investment	$9,759

Table 8. Annual costs for a lagoon system of manure disposal for a 100-cow dairy herd.

Item	Annual Cost
Fixed	
Lagoon	$ 123
Holding pond	123
Fence	36
Ramp	16
Irrigation pipe:	
depreciation	84
interest, taxes, insurance	46
Irrigation pump:	
depreciation	520
interest, housing, insurance	286
Total fixed cost	$1,234
Variable	
Cleaning lagoon	$ 120
Repair and maintenance:	
pump and sprinkler	312
pipe	34
Utilities	82
Total variable cost	$ 548
Total annual cost	$1,782

The costs for the irrigation equipment are taken from the section discussing the irrigation system, except only half the utilities are included since the amount of water to be removed should be considerably less with the lagoon system. In particular situations where the volume of water to be removed from the holding pond is quite low, costs can be reduced considerably if water could be removed on a custom basis.

COMPARISONS AND IMPLICATIONS

The initial investment, annual labor requirements, and annual costs per cow of the four disposal systems analyzed are summarized in Tables 9, 10, and 11. The fertilizer value of the manure has not been considered in any of the systems.

The conventional system has the lowest initial investment requirement (Table 9) followed in order by the liquid with 15 days storage, the irrigation system, liquid with 30 days storage, the lagoon, and the remainder of the liquid systems.

Table 9. Initial investment required per cow for various manure disposal systems

System	Investment per cow
Lagoon	$ 97.59
Liquid (days storage)	
15	60.50
30	86.00
45	111.50
60	137.00
75	162.50
90	188.00
Conventional	21.86
Irrigation	77.15

The conventional system also has the lowest annual cost per cow (Table 10) followed in order by the liquid with 15 days storage, the liquid 30 days storage, the lagoon, liquid with 45 days storage, the irrigation system, and the remaining liquid systems.

The labor requirements (Table 11) are of course lowest for the lagoon system since it requires no labor beyond that required for scraping. The liquid systems required 1.37 hours beyond scraping, the irrigation system 1.42, and the conventional system requires 1.79. These differences are quite small; the conventional system requires only 42 hours per year more than the liquid systems.

In deciding on which system to use, such things as the relative availability of resources in a particular situation and the flexibility of labor requirements should be considered. For example, in the case of the conventional system the initial investment requirements and the annual costs are the lowest of any of the systems. However, the labor requirements are the greatest and the most inflexible; the manure has to be hauled on a regular basis regardless of the weather or of the alternative uses to which labor might be put. The question that has to be answered in individual situations is: Is the lower cost of the conventional system worth the inflexible labor requirements that one would have?

Table 10. Annual costs per cow for various manure disposal systems

System	Costs per cow
Lagoon	$17.82
Liquid (days storage)	
15	14.11
30	16.15
45	18.19
60	20.23
75	22.27
90	24.31
Conventional	9.54
Irrigation	18.42

Table 11. Annual labor required per cow for various manure disposal systems.

System	Labor (hours)
Lagoon	0
Liquid (days storage)	
15	1.37
30	1.37
45	1.37
60	1.37
75	1.37
90	1.37
Conventional	1.79
Irrigation	1.42

In the case of the lagoon system, the question to be answered for an individual operator is: Can the relatively high initial investment and annual costs be justified on the basis of reduced labor requirements? For a 100-cow herd, a lagoon system would save 180 hours per year when compared to a conventional system. A consideration would have to be the relative availabilities of capital and labor in a particular situation. Where labor is very scarce, the advantages of the lagoon system would be enhanced. As was pointed out previously, the cost of the lagoon system could be removed from the secondary holding pond on a custom basis. This would be feasible for those situations where the water had to be removed infrequently. When considering a lagoon system, the regulations of the Tennessee Department of Public Health should be carefully checked to make sure they can be fulfilled. This would especially involve having soil conditions checked.

The investment requirements and annual costs for the liquid and irrigation systems are relatively high when compared to the conventional system. The question here is whether or not these higher costs can be justified on the basis of more flexible labor requirements. Another consideration is that the costs estimated here are for herds of 100 cows and it is quite possible that for larger herds the attributes of the irrigation and liquid systems would become more favorable relative to the conventional system.

APPENDIX

Throughout this analysis, manure was considered as only a nuisance with no value as a fertilizer. If it is desired that the manure be treated as having some fertilizer value, the cost figures can be reduced by $14.25 per cow per year for the conventional, irrigation, and liquid systems. However, it should be pointed out that the costs for these systems will also be increased because of the necessity of spreading manure over a wider area.

The value of $14.25 per cow per year was arrived at in the following manner: The annual production of manure from a 1,500 pound dairy cow contains about 197 pounds of nitrogen (N), 54 pounds of phosphoric acid (P_2O_5), and 101 pounds of potash (K_2O).[29] An estimated 15% of the manure is voided in areas where it cannot be recovered,[30] so this leaves 167, 46, and 86 pounds of N, P_2O_5, and K_2O respectively. Morris[31] and others have found that the effectiveness of manure when compared to commercial fertilizer is 50%, 67%, and 75% for N, P_2O_5, and K_2O; therefore, the effective poundage of the three minerals is approximately 84, 31, and 65. With a per pound value of $.09, $.09, and $.06,[32] the total annual value is $14.25 per cow.

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[29]Miner, J. Ronald, editor, "Farm Animal-Waste Management," North Central Regional Publication 206, Iowa Agricultural Experiment Station, Ames, May 1971.

[30]Parson and Wells, **op. cit.**

[31]Morris, W.H.M., **Economics of Liquid Manure Disposal from Confined Livestock,** American Society of Agricultural Engineers, Publication No. SP-0366, pp. 126-131.

[32]These prices are consistent with those that existed in Tennessee during the Spring of 1971 according to **Agricultural Prices,** 1971 Annual Summary, Pr 1-3(72), SRS, USDA, June 1972.

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