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THE ECONOMICS OF DISPOSAL OF HOG MANURE IN CONFINEMENT SYSTEMS

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THE ECONOMICS OF DISPOSAL OF HOG MANURE IN CONFINEMENT SYSTEMS

W. H. M. Morris and T. W. Robinson

1. Introduction

Intensified hog production using total confinement has been made possible by overcoming health problems associated with keeping animals off the dirt. Problems of health and feeding have been satisfactorily overcome but the major problem unsolved is the handling of manure, which becomes necessary when it is not dropped in the field or on a drained dirt lot. Indeed, the remaining obstacle to automatic hog production is the disposal of manure.

The information available to farmers on which to select a system of manure handling is so vague, that the farmer doesn't even know if the manure is worth the cost of spreading on the fields or if it should be dumped into a pond.

The objective of this study was to estimate the costs of and returns from handling and disposal of manure, to provide data on which a farmer might base a logical choice.

It is assumed that hog manure must sooner or later be removed from the concrete slab. The optimum frequency of removal is unknown. However, collection of manure and waste feed on the floor produces a characteristic odor and a suitable breeding ground for the common fly (*Musca domestica*).

To break the life cycle of the fly, whenever the average temperature is above 65°F, manure should be removed from the floor or from any storage suitable for breeding of flies at intervals of seven days or less.

2. Manure Production

As a rule of thumb, a hog may be expected to excrete daily $^1/10$ of its live weight. About 52 percent of the excreta is urine and the remainder dung. The composition of dung and urine and of the complete manure has been estimated to be as follows:

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Table 1. Chemical composition of hog manure[1/].

	Water	Organic matter	N	P_2O_5	K_2O	Other solids
	Percent					
Dung	80	16	.55	.50	.40	2.55
Urine	94	2.5	.40	.10	.45	2.55
Complete manure	87	9.1	.47	.29	.42	2.60

The composition is not fixed. In hot weather, urine excretion increases up to 30 percent or more. The concentration of the urine may also be changed. The composition of the dung depends upon the diet and the digestibility of its components.

The form in which the N, P and K are present in dung differs from that in the urine. For example, nitrogen in the urine is normally present as urea and not in protein form; while much of the nitrogen in the dung is present in protein form.

Since hogs "consume" anything from about 2.6 to 5 lb per lb of weight gain, the question also arises - what happens to the extra feed consumed? Some of the difference in conversion is due to adding fat rather than muscle. However, it is clear from the law of conservation of energy that the balance of the ration above the calories required for weight gain and maintenance must be excreted. Some of the feed is spilled on the floor; this may amount to as much as 1 lb/lb gain. At this rate, the organic matter content of the manure plus waste feed would be almost double that of the manure alone.

The figures given above at least provide a basis for evaluating hog manure but cannot be considered to be absolute values.

3. Chemical Changes in the Manure

Manure is not a stable mixture. The urine obviously is not held in the dung, as with birds, and much of it runs off the floor. The phosphatic and potash compounds are relatively stable but the nitrogenous compounds not already in the form of urea are, in part, converted into urea by bacterial action. Urea is unstable and, in the presence of water, is changed into ammonium carbonate, which, in its turn, decomposes into ammonia, carbon dioxide and water.

$$CO(NH_2)_2 \xrightarrow{+\ 2H_2O} (NH_4)_2CO_3 \longrightarrow 2NH_3 + CO_2 + H_2O$$

1/ After Van Slyke, L. L., Fertilizers and Crop Production, Orange Judd Publishing Company Inc., 1932, p. 226.

The rate of breakdown of ammonium carbonate is proportional to the concentration of the solution. It can, therefore, be increased by drying or freezing of the manure.

The nitrogenous compounds decomposed in this way are those most readily available when placed in the soil. Indeed, this breakdown also occurs on the surface of the soil as well as on the concrete floor of the hog lot.

Dilution of the manure with rain water or by hosing down the floor is not expected to be detrimental to the manure but increases somewhat the cost of handling per pound of fertilizer value.

Analysis of samples of manure from storage tanks shows that the concentration of N and P_2O_5 is somewhat higher than in fresh manure - 0.64% and 0.38% respectively - while the concentration of K_2O is lower - 0.27%.

Analyses of human sewage sludge, the silt remaining after digestion, typically show 2.0% N, 1.1% P_2O_5 and 0.2% K_2O.

In order to preserve the maximum amount of the fertilizing value of manure the following must be done:

The urine must be collected.

The dung must be scraped off the floor at frequent intervals - the optimum interval is unknown but it must depend upon the temperature and insolation on the floor.

The complete manure must be delivered into the top soil and not just spread on top of the soil - especially when the soil is dry.

4. Utilization of the Manure

Provided that the soil pH is maintained by the addition of lime, it is not expected that the application of hog manure at any practical rate will have a detrimental effect on the soil. Heavy applications on clay soils without addition of lime may tend to make the soil sticky and less permeable.

Some agronomists[2] recommend an upper limit of 15 tons/acre, amounting to about 150 lb N, 105 lb P_2O_5 and 120 lb K_2O. This rate is at or above the most profitable level for row crops on typical Midwestern soils.

Application of hog manure to growing crops may cause damage by burning the foliage.

2/ Hawkins, G. (Iowa State Soil Testing Laboratory, Ames, Iowa) in Farm Journal, March 1961, pp. 37, 61-62, and private communication February 1961.

The basic problem in utilization of the manure from systems in use today is one of being able to use it effectively at intervals of one to three weeks throughout the year. The value of the manure is such that it will not pay to keep land out of a profitable crop, such as corn or beans, just to provide a disposal area for the manure.

For ideal efficiency of utilization, it should be possible to store the manure with a minimum of losses until the farmer is ready to apply it. Application might be made only two or three times a year. With a large hog enterprise this might necessitate handling 2 tons of liquid per hog capacity of the feeding floor. If a large area of the floor was uncovered and if the drainage from the roof of the shelter was collected with the manure, the quantity to be handled might be increased by 50 percent.

5. Dunging Habits of the Hog

While it is not expected that all hogs will behave precisely in the same way, certain observations on dunging habits have been made. The habits may be used to increase the portion of the manure deposited in the most convenient places for cleaning and to decrease the portion deposited where it is difficult to remove.

The variables affecting dunging habits include:

- The lying area per hog and the total pen area per hog
- The environment: drafts, cold, and heat
- The frequency of cleaning
- The type of fence between pens
- Size of the pig
- Breed differences

6. Obstructions to Free Movement Within the Pen

In general, especially if the hogs are somewhat crowded, the lying area is kept free of manure. However, the pigs will not lie down in a draft in winter and so the lying area may be changed. In summer they prefer to lie in the coolest part of the pen; if they feel too hot, they may wallow in dung in an attempt to increase their rate of dissipation of heat.

In Europe considerable success has been achieved in getting the pigs to dung in a narrow, well-lighted alley or in a run separated physically from the lying area by a wall, with one or two narrow exits.

An obstruction across the pen, such as an open dung channel, causes some of the pigs to dung near the channel and not to cross it. If the channel is bridged, more of the pigs will cross it and dung in a remote corner.

Placement of a feeder close to a fence or wall encourages the hogs to dung between the feeder and the wall. Generally, if the feeder is placed in the open the hogs tend not to dung near the feeder.

Hogs newly placed in a pen tend to follow the dunging habits of the hogs that preceded them if the pen is not thoroughly cleaned. By placing or leaving dung in the place that the hogs are supposed to dung, habits may be established. Some farmers accomplish this by wetting down a certain area of the pen for several days after introducing the hogs to the pen.

7. Handling the Manure

The process of handling the manure is broken down into five steps (Figure 1)*:

(i) Removal of the manure from the floor of the pen.

(ii) Transporting the manure from the pen to one or more central points for temporary storage or for loading into a spreader.

(iii) Loading the manure directly or from a temporary storage into a wheeled vehicle of suitable design, a tank or spreader.

(iv) Transport to the disposal area.

(v) Disposal of the manure on the field or in a lagoon.

These steps may be combined and, in some cases, eliminated.

(a) Cleaning the Floor

There are four main methods used for cleaning the hog finishing floor:

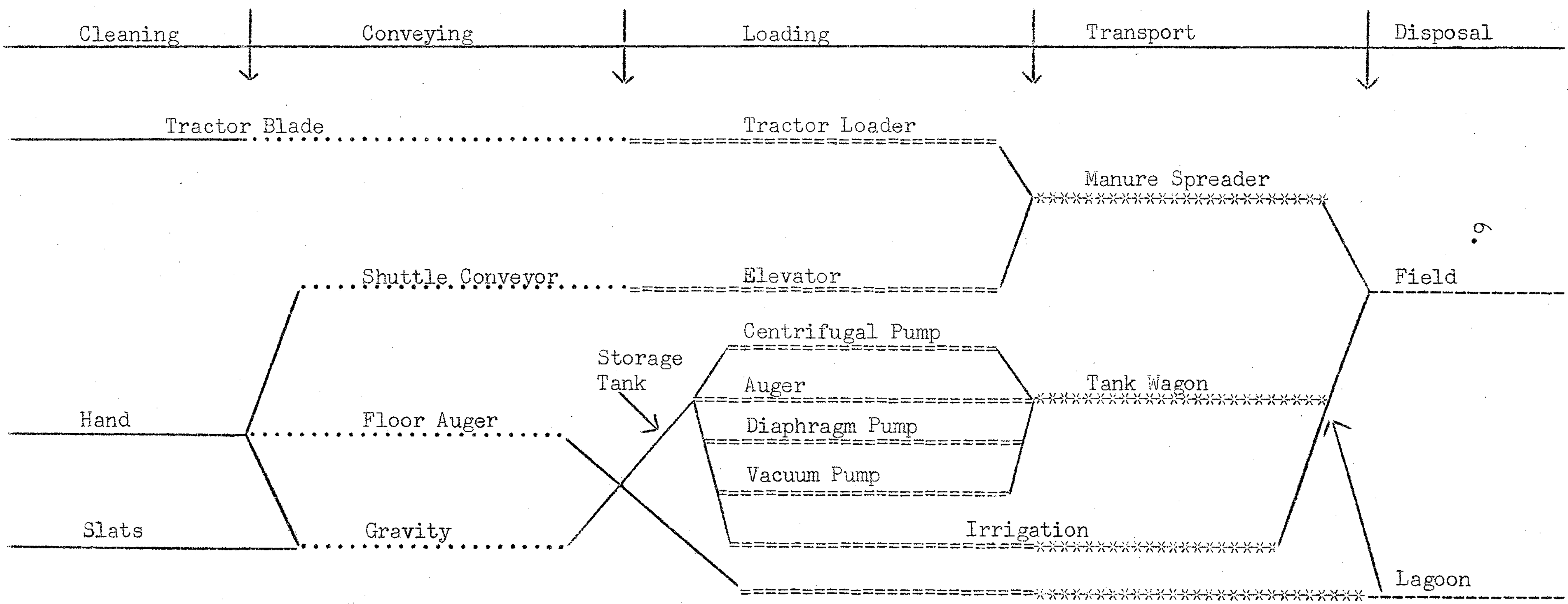
by hand with a scraper
by hand with a hose
by tractor using a scraper or bucket
by slats

The labor requirement for the first three is variable depending upon such factors as:

Effort and skill of operator
Surface of the floor
Shape of the pen and arrangement of equipment in it
Size of the pen
Area to be scraped - dunging pattern in relation to the gutter
Frequency of cleaning
Amount of feed spilled
Floor area per pig
Size of pigs

*It is assumed that bedding for the hogs is not used.

Figure 1. Systems of handling hog manure.



9.

Hand scraping takes about 0.007 to 0.03 min/sq ft (Table 2). The unit time increases with a decrease in the frequency of cleaning; daily cleaning averaged .009, every third day .011, and once a week .022 min/sq ft.

As the frequency of cleaning decreased, the fraction of the pen area that had to be scraped increased; for example, 50 percent with cleaning daily and 65 percent with cleaning every third day.

The use of water to clean the hog floor is not common. It takes about three times as long to hose the floor as to scrape it. With daily cleaning, it involves the use of a volume of water about twice as great as the volume of dung and urine from the hogs. For this reason, the farmers using water for cleaning usually dispose of the manure and wash water in a lagoon.

A number of farmers hose down the floor occasionally after scraping, in order to remove traces of manure and feed from the floor. In the one case observed this decreased the time of hosing by about 15-20 percent.

A slatted floor eliminates the need to scrape the floor. The hogs tread the dung through between the slats. If only part of the floor, perhaps the dunging alley, is slatted some of the pen floors may have to be scraped at intervals. The effect of concrete, metal and wooden slats on the feet and legs of the pig may be an important factor in the selection of material for the slats.

(b) Conveying the Manure from the Pen

Manure which has been removed from the floor is then conveyed from the pen area. This may be done

- by tractor blade or scoop when the manure has been scraped up by the tractor blade or scoop
- by gravity in a channel conveying it horizontally
- by gravity, vertically, into a tank or container beneath the hog floor
- by a horizontal auger conveyor built into the floor
- by a shuttle-type conveyor in a horizontal channel

Our results show that the gravity systems, when correctly designed, are effective. The auger is effective but unnecessary and was not observed to save time compared with a gravity system. The shuttle conveyor was often used incorrectly; it should be running all the time during cleaning of the pens and the operator should start

Table 2. Labor requirement of hand methods of cleaning hog pens.

Method	Cleaning interval days	Pen area sq ft/pig	Pen area scraped percent	Time/sq ft man-min	Time per cleaning man-min/pig	Time per year man-min/pig	
						2 batches/ year	2½ batches/ year
Hand scraping	1	10	50	.009	.045	10.8	13.5
	1	15	50	.009	.067	16.1	20.1
	3	10	65	.011	.072	5.8	7.2
	3	15	65	.011	.107	8.6	10.7
Hosing*	1	10	50	.027	.135	32.4	40.5
	1	15	50	.027	.202	48.3	60.3

*Estimated to take 2.2 gal at 80-120 psi/head.

cleaning at the end remote from the spreader. Because of the delay while the shuttle is being emptied and because farmers seem to consider that the soupy manure should not be left standing in the spreader, the time required to handle manure in this way is higher than all other methods studied. The shuttle conveyor does not appear to fit into the hog manure handling system unless the bedding used makes liquid handling impractical.

(c) Loading

The method of loading used depends in part on the consistency of the manure to be handled. If the manure is left to dry on the floor and the free liquids drained off, the tractor scoop can be used. It may be used by lifting and dumping into the spreader, in which case the load is often pushed against a wall or block to force it back into the scoop. A more liquid product may be loaded by pushing the manure off a ramp directly into the spreader. No separate time standard was obtained for this operation due to the integration of the whole process of manure handling with the tractor - scraping, conveying and loading.

Loading the manure from the shuttle stroke cleaner is done by an integral elevator. The free liquid is drained away, either by the channel sloping away from the elevator or by a drain at the foot of the elevator. Nevertheless, the product loaded from the shuttle stroke is what is often termed soupy. A dam board is generally needed to retain it in the spreader for transportation; the dam is removed for spreading.

Loading liquid manure out of a storage tank is done with an auger or a pump (vacuum, diaphragm, or centrifugal). In Europe, it is generally done with a centrifugal pump. It may be pumped, as in the U.S., into a tank wagon; in Europe, it is sometimes pumped directly through an irrigation system.

The centrifugal pump is installed in the storage and cannot easily be removed. The pump observed had four times the rated capacity of the vacuum and diaphragm pumps.

The time taken to load the wagon depended upon the amount of sludge at the bottom of the storage tank, unless the contents were agitated. As the manure became thicker, the auger became more efficient, while the suction pumps became less efficient. The time taken to load the tank wagon changed accordingly.

There was no difference observed between the performance of vacuum and diaphragm pumps in handling the manure. Farmers experienced considerable trouble in using augers for this purpose; the task of moving the auger is not a very pleasant one.

(d) Disposal

The time for spreading the drier manure from a mechanical spreader loaded by the tractor was about 25 percent lower than for the soupy manure from the shuttle stroke. In part this is due to the necessity to spread the soupy manure more thinly on crop land to avoid burning the foliage.

Tank wagons used for manure hauling and spreading were commonly of 500 gallon capacity. In some cases a reversible pump was mounted on the wagon to suck the manure in and to expel it by pressure. In other cases, the tank wagon is emptied by gravity. The pressurized tanks were emptied in about half the time taken to empty the non-pressurized tanks.

Nutrient losses under certain soil conditions are quite high. When the soil is dry these could be reduced by applying the liquid through tines into the soil. The present design includes a revolving splash plate which distributes the manure; as the rate of flow decreases, towards the end of the load, the swath decreases in width. This makes the distribution uneven.

(i) Lagoons

The lagoons observed were mostly of the anaerobic type; that is, the digestion of the organic matter was done by bacteria living in the absence of oxygen. The liquid in the lagoons is turbid and dark in color, and there are no oxygen producing algae present.

One aerobic lagoon was observed, with relatively clear water. Algae and fish were present. The area involved in an aerobic lagoon, or oxidation pond as it may be called, is about 2 acres per 50 hogs produced, making no allowance for wasted feed getting into the system. This clearly will only be used by farmers who happen to have a large pond available.

The capacity of the anaerobic lagoon, based upon human sewage disposal practice, is 3.65 lb of dry organic matter per cu ft per year under Midwestern conditions. There is almost no activity when the lagoon temperature is below 50°F. In some areas, lagoons have been heated to permit an increase in the rate of loading. The anaerobic digestion process itself provides a negligible amount of heat.

On this basis a design capacity of about 35 cu ft per hog produced per year would be adequate. The depth is not critical. However, with a depth of 3 ft the surface area per hog would be about 12 ft.

No anaerobic lagoons were observed with this capacity. The average was 15 cu ft per hog. Further observation is needed to see whether these systems are working satisfactorily. To date no disorders have been observed or reported. It is not clear how the digestion of hog manure will differ from the digestion of human municipal waste; it would seem that the fibrous matter content might well be lower for the hog manure. This may account for satisfactory operation above the rated design capacity.

It is theoretically and practically feasible to place a lagoon under a slatted floor. Allowing 8 sq ft per hog and two lots of hogs a year, the depth of the lagoon should be 6 ft deep or greater.

The manure sludge is expected to be richer in N and P_2O_5 and poorer in K_2O than the liquid manure. However, the availability of the N is expected to be low.

8. Handling Costs

The costs for the five most common methods used - daily, every third day, and, where appropriate, weekly - show that the least cost method is with the tractor front loader (Table 3, Figure 2). Labor is charged at $2/hour.

Costs of the complete liquid systems are not very different. It seems that loading the vacuum tank is done at a lower cost with an auger in small hog enterprises, because of the lower investment cost. In larger enterprises, it is done at least cost with a centrifugal pump, because of the high speed.

The most costly method of those observed was that with the shuttle stroke conveyor.

A pressure-treated white oak slatted floor costs about $1.50/sq ft and the concrete paved floor which it replaces is estimated to cost 40¢/sq ft installed. The cost of metal gratings installed is believed to be about the same as for a slatted wooden floor. If the whole floor area, say 8 sq ft/hog, is slatted or grated, there will be no need to scrape at all; but if only a dunging alley is slatted or grated, it may be considered necessary to scrape a few of the pens at intervals, because of lack of control of dunging habits.

Estimates of the use cost of slatted floors indicate that it is not economical to spend about $12.00 per pig (capacity) to slat the floor saving 1/2-3/4 man-hours of labor at $2/hour (Table 4). However, for the farmer who considers it necessary to clean the floor daily (taking $1^1/4$-$1^1/2$ man-hours), a slatted dunging area might pay over hand scraping. Note that for these calculations it is assumed that the space requirements per hog in an enclosed system are 10 sq ft and for fully slatted enclosed system 8 sq ft.

Daily cleaning was, of course, more costly than cleaning every third day.

Table 3. Costs and returns: handling hog manure on finishing floor by selected methods. (Capacity of floor 300/hogs, production 840 hogs/year)

Task	System						
Clean Convey Load Transport Disposal	Hand Gravity Centrifugal 2/ Tank Field	Hand Gravity Auger 2/ Tank Field	Hand Gravity Diaphragm 1/, 2/ Tank Field	Hand Auger Centrifugal 2/ Tank Field	Hand Shuttle Elevator Spreader Field	Hand Gravity – Gravity Lagoon	Tractor Tractor Tractor Spreader Field
Annual fixed cost $	159	147	147	225	286	38 3/	201
Total annual cost							
cleaning daily	588	606	643	818	1173	284 3/	
every 3rd day	475	493	530	703	707	172 3/	
weekly							379
Estimated value of manure							
cleaning daily	966	966	966	966	731	0	
every 3rd day					588	0	
weekly							437
Man hours							
cleaning daily	165	193	198	165	355	106	
every 3rd day	108	136	141	108	135	49	
weekly							61
Return per man-hour $							
cleaning daily	4.30	3.87	3.61	2.90	0.75	0	
every 3rd day	6.53	5.47	5.05	4.43	1.12	0	
weekly							2.94

1/ Diaphragm and vacuum pumps have similar costs and returns.
2/ Assumes emptying storage tank 25 times a year.
3/ For lagoon 100 feet from floor: use of adjacent lagoon costs about $40 more per year. No tile is required for conveying the manure to the lagoon.

Table 4. Estimated annual use cost of confined hog finishing buildings with and without slatted floors.

System	Cost per hog		Estimated annual building use cost	Building area		Paved area inside and outside		Slatted area		Total cost
	2 batches/ year	2½ batches/ year		sq ft/ hog	Cost at $1.25/ sq ft	sq ft	Cost at .40¢/ sq ft	sq ft	Cost at $1.50	
Partly covered	.68	.54	1.35 (10%)	6	7.50	15	6.00			13.50
Fully enclosed	.82	.66	1.65 (10%)	10	12.50	10	4.00			16.50
Fully enclosed fully slatted	1.40	1.12	2.80 (10% + 15%)	8	10.00	0	0	8	12.00	22.00
Fully enclosed 20% slatted	1.01	.81	2.02 (10% + 15%)	10	12.50	8	3.20	2	3.00	18.70

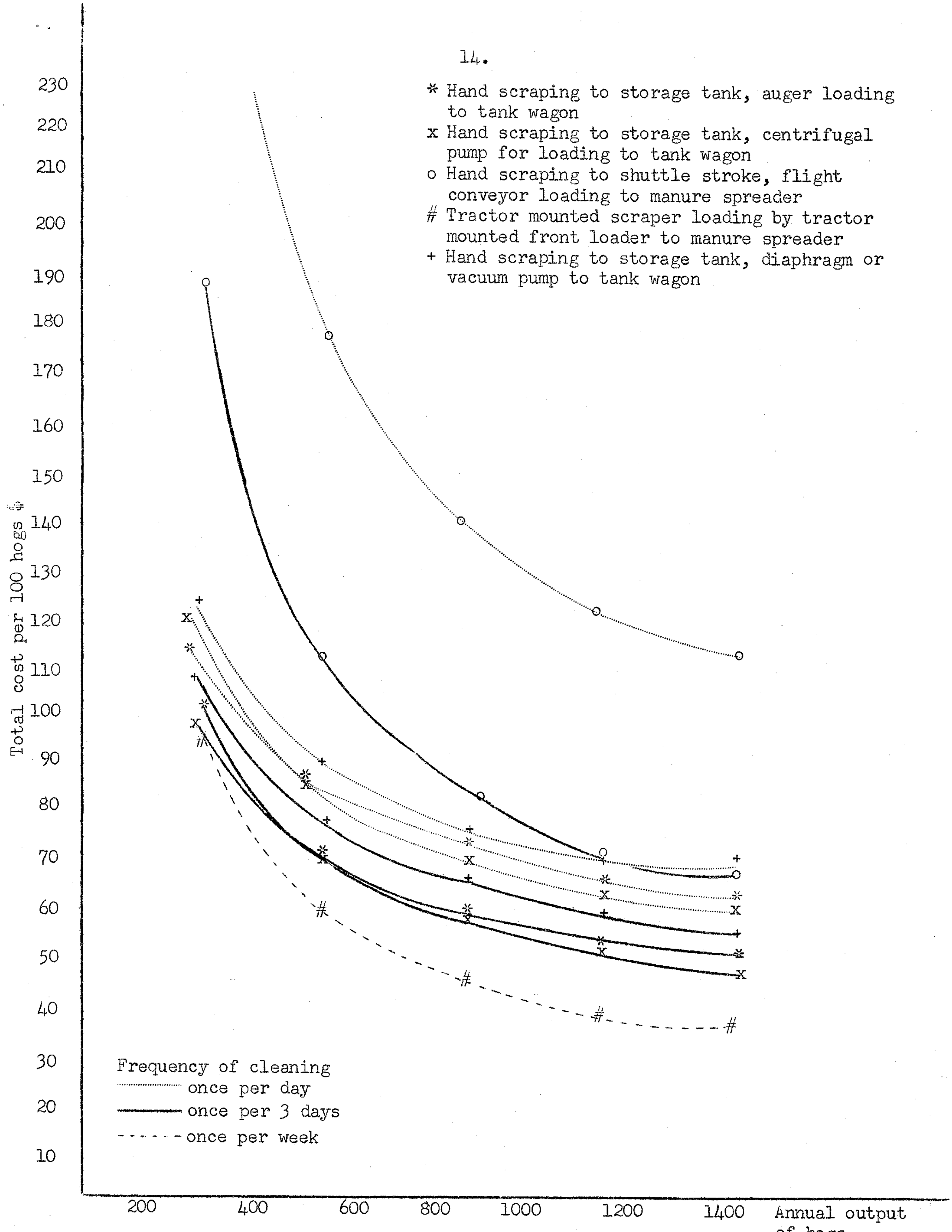


Figure 2. Total cost of manure handling and disposal per 100 hogs using different systems and frequency of cleaning with different size of enterprise.

9. Returns

Value of the manure

The complete manure from the hog for 120 days on the finishing floor is estimated to be 1200 lb with an analysis of .47% N, .29% P_2O_5, .42% K_2O. This provides 5.64 lb N at 14¢ (79.0¢), 3.48 lb P_2O_5 at 10.8¢ (37.6¢), and 5.04 lb K_2O at 6.3¢ (31.7¢) - a total of $1.48. Analyses of the contents of storage tanks holding liquid manure showed 0.64% N, 0.38% P_2O_5 and 0.27% K_2O. This manure has a value of NPK, on the same basis as above, of $1.81 for 1200 lb.

The value of the manure in the field cannot be so easily estimated. There are potential losses in each phase: losses on the floor, losses in storage, losses in distribution, and losses from the soil. Furthermore, the availability of the nutrient elements differs from that in typical commercial fertilizers, particularly with respect to nitrogen. It seems that the nitrogen in the faeces is the least digestible and is only slowly made available in the soil. The nitrogen in the urine, much of it in the form of urea, is readily available.

An attempt has been made to allow for losses and non-availability of nitrogen. Since the nitrogen availability is only 40 percent in the first year, the $1.81 value per hog is discounted to $1.15. No allowance has been made for the residual value for lack of information. A value for the manure per hog is then estimated (Table 5). Allowance has been made for the loss of much of the urine with the shuttle conveyor and the tractor front-loader systems. A greater loss of nitrogen - through ammonium carbonate breaking down into ammonia and carbon dioxide - has been estimated in the tractor front-loader system.

Using these assumptions, values have been estimated for the return to labor spent in handling hog manure by different systems (Table 3 and Figure 3). All systems, saving the complete liquid, return more than the average return per man-hour to Indiana hog producers - $1.30 to $1.50. The other systems, because of the lower value of the product, only produce positive returns in large hog enterprises.

Table 5. Estimated quantity and value of utilizable manure per hog in different handling systems.

Frequency of cleaning floor	System	Estimated amount of manure utilized (gals/hog/day)	Value of manure $
Once a day	Hand scraped; storage tank; spread as a liquid	1.25	1.15
Once a day	Hand scraped; shuttle conveyor; conventional spreader	.94*	.87
Once in 3 days	Hand scraped; shuttle conveyor; conventional spreader	.75*	.70
Once a week	Mechanical scraping; tractor front loader; conventional spreader	-	.52

*Estimated from observations of volume of manure handled per hog on feed floor.

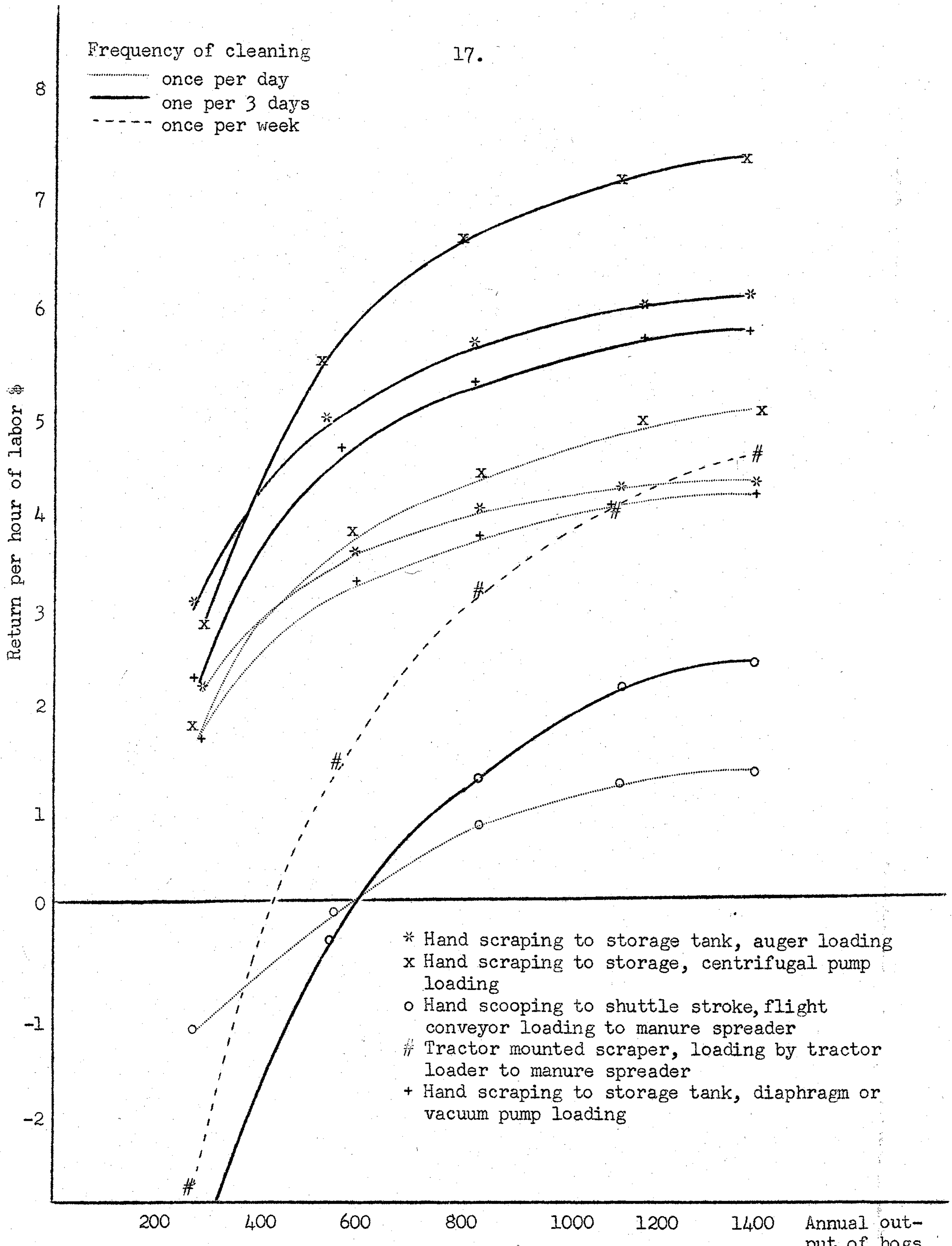


Figure 3. Returns per man hours of labor using different systems and frequency of cleaning.

Summary and Conclusions

Composition. The average manure production per hog is 1/10 of its body weight per day. Of this, slightly over half is urine. This totals 1200 lb for one pig from weaning to market.

The analysis of this is approximately 108 lb organic matter, 5.6 lb N, 3.6 lb P_2O_5 and 5.1 lb K_2O. This has a value "as is" of NPK of $1.50. About 40 percent of this (60¢) is in the urine.

Manure is not a stable mixture:

(a) the urine may be lost by drainage,

(b) on standing on the floor, the nitrogen compounds are broken down by bacteria into urea. Urea is converted into ammonium carbonate, which is unstable except in dilute solutions. As the manure dries out on the floor much of the nitrogen is lost as ammonia.

Rain falling on the manure is likely to leach out soluble nitrogen compound and potash.

Losses may also be incurred during and after spreading on the fields by breakdown of the nitrogen compounds and by leaching and, if on frozen ground, by run off.

Removal from the Floor. In confined systems the manure must, sooner or later, be removed from the floor of the hog pen whatever system of manure disposal is used. For this reason, the cost of removing the manure from the floor is attributable to keeping the hogs and not to disposal of the manure.

The interval between cleanings is related to the method, and the longer the interval the greater the loss in nitrogen. Therefore, the return from handling the manure is dependent upon the interval between cleaning.

Cleaning the floor every third day brings a higher return than daily or weekly cleaning when the liquid was collected in a storage tank.

The lowest cost method of removal is with a tractor and blade. However, this necessitates large pens to maneuver the tractor and long intervals between cleaning to reduce the time required. This method results in the lowest return from the manure.

Hand scraping is the most practical method in common use for cleaning small pens.

Slatted floors with a suitable subfloor or pit underneath may be the least cost system in the future, but none were observed in the survey. Fully slatted floors, although reducing the space required per hog, may not be profitable.

Water is not commonly used for cleaning the concrete floor because of the time required, and the high pressure and large volume used. If the manure is to be spread on the fields, the added cost of handling the cleaning water is excessive. Some farmers wet the floor in the summer.

Transport from the Pen. After hand scraping, the manure is removed from the pen at least cost by gravity. Augers set into the floor did not reduce the labor requirement but increased the costs on the farms studied.

Barn cleaners set in the floor slowed the whole floor cleaning process on the farms studied, because of the slow rate of movement of manure in these systems. On these farms most of the urine passed into field tile and was not spread on the land. This system was among the least profitable.

With the tractor mounted blade, manure was removed from the floor and loaded with the tractor.

Disposal. The least cost method of disposal - the lagoon - produced, in general, no return.

The highest returns were observed from systems in which the complete manure was handled in a tank wagon. Loading the manure was done fastest using a centrifugal pump set in the manure storage. Next in speed was the auger, when suitable powered. Vacuum pumps and diaphragm pumps were slow, especially when the manure was somewhat thick in consistency.

Based upon the chemical analysis of manure in the concrete storage tank, the returns for labor spent in handling the manure from floor to the fields ranged from $1.50 an hour to $7 an hour as the enterprise increased from 250 up to 1400 hogs finished a year.

It is concluded that with most confined hog systems, time can be profitably spent in handling and spreading manure on the fields but nutrient losses should be kept to the minimum.

Capital investment in the most effective and profitable manure handling systems is little beyond that necessary for construction of the feeding floor.

Appendix

Table 1. Capital investment required for different systems of manure handling and size of hog enterprises.

Combination of items	Capital investment $				
	Capacity of feeding floor				
	100	200	300	400	500
Lagoon[1/]: Remote[2/]	190	280	370	460	550
Adjacent	189	378	567	756	945
Storage tank; auger (loading); tank wagon	1160	1160	1160	1160	1160
Storage tank; diaphragm pump; tank wagon	1330	1330	1330	1330	1330
Storage tank; vacuum pump; tank wagon	1200	1200	1200	1200	1200
Storage tank; centrifugal pump; tank wagon	1420	1420	1420	1420	1420
Auger (floor); storage tank; auger (loading); tank wagon	1790	2070	2350	2630	2910
Auger (floor); storage tank; diaphragm pump; tank wagon	1960	2240	2520	2800	3080
Auger (floor); storage tank; vacuum pump; tank wagon	1830	2110	2390	2670	2950
Auger (floor); storage tank; centrifugal pump; tank wagon	2050	2330	2610	2890	3170
Shuttle type conveyor; elevator loader; manure spreader	1830	1910	1990	2070	2150
Tractor scraper and fore-loader; manure spreader	1450	1450	1450	1450	1450

1/ Excavation cost estimated at 32¢ per hog; 40 cu ft excavated per hog. This was the average cost reported by the four farmers who had the work done by a contractor.

2/ Remote lagoons have been assumed to be 100 ft from the feeding floor.

Table 2. Summary of methods of hog manure handling observed in sample of 28 Indiana farms.

Tasks									
Cleaning		Conveying		Loading		Transporting		Disposal	
Method	No. of cases	Method	No. of cases	Method	No. of cases	Method	No. of cases	Method	No. of cases
Hand	23	Gravity	13	Centrifugal	1	Tank	11	Field	22
Hose	1	Auger	3	Auger	2	Spreader	11	Lagoon	6
Tractor	4	Shuttle	8	Vacuum	6	None	6		
		Tractor	4	Diaphragm	1				
				Elevator	7				
				Tractor	4				
				None	6				