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A Review of Recent Studies of Liquid Manure Handling and the Use of Slatted Floors

Dairy Systems in Northwestern Europe, 1960-1965

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Associate Professor Gunnar Öygard, from the Department of Agricultural Economics, Royal Agricultural College, Vollebekk, Norway, has been a visiting professor at Cornell University during the academic year 1965-66. During that period he has studied and brought together recent research and scholarly publications from the countries of Northwestern Europe on the subject of dairy housing and management of dairy systems. This report provides a brief summary of a number of studies not generally available in English to professional workers in the United States. Further details can be obtained from the original publications which are listed in the bibliography.

A REVIEW OF RECENT STUDIES OF LIQUID MANURE HANDLING AND THE USE OF SLATTED FLOORS

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Considerable interest has been generated in the United States with respect to new technology which will allow dairy farmers to avoid spreading manure every day. Waste disposal is now one of the major problems of interest to research workers and managers of large farms wherever livestock is the principal enterprise. Because Europeans have been working with various systems to make use of liquid manure for many years, it is natural that farmers and research workers should report in one way or another their observations about the use of various systems in Europe. This report summarizes some of the recent publications and research efforts in England, the Netherlands, Germany, and Sweden. In all of these countries respected agricultural research institutions have been studying methods of feeding, milking and handling manure in dairy systems over much of the post-war period.

Liquid Manure Systems, Stanchion Barns

Before World War II there were liquid manure systems in use that were associated with stanchion barns in Northwestern Europe. The first systems were quite expensive and designed to save fertilizer or reduce losses of manure. Straw was still used for bedding. A mixture of straw and manure had to be pushed by hand into a canal and storage tank. The straw solidified with other materials in storage and this mass had to be cut up and mixed with the heavier liquid material. As a result it was necessary to have heavy pumps as well as relatively expensive cutting and agitating equipment.

During the last 10 years these original systems have been modified. The new systems are based on little or no bedding. Rubber mats are used in the stalls or saw dust is used on an insulated floor. The gutter or canal behind the cows is covered by a grate so that the manure will fall directly into the gutter or canal. To move manure from the canal behind the cows to a pit or collection point different methods are used. Commonly water is mixed with the manure to make it flow to a central point. This may be either accomplished by gravity without the use of a pump, or by occasional circulation of the manure with a pump. In all of these systems a central storage facility or pit is required to store the liquid or semi-liquid material.

The size of pit depends on many factors, the most important of which is the difficulty of spreading manure on the land at different seasons. Farmers in Northwestern Europe have the same problems arising from the smell of liquid manure as do farmers in the United States. They also have

the same kinds of difficulties with soil compaction if manure is spread with mechanical equipment when heavy soils are wet. Generally, farmers must spread during calm and humid weather to avoid major problems from people in surrounding urban centers.

While considerable publicity has been given to the spreading of liquid manure through stationary irrigation systems, this method is not widely used because of its high capital cost. There seems to be no question that liquid manure systems will preserve a larger proportion of the desirable nutrients for plants which are originally available. However, in many cases, the costs of handling manure are even greater than the costs of commercial fertilizer.

Labor Requirements. Some work studies have been done to determine the labor requirement associated with handling liquid manure. In a small study in Sweden (9) the time spent in cleaning out the barn was 1.3 minutes per cow per day using one liquid manure system which involved a small amount of bedding. The author estimated that this time could be reduced to 0.9 minutes per cow per day when no bedding was used. Some comparative statistics obtained in a relatively large study of farm operations by the same research institution indicated the following:

Method of Cleaning	Minutes Per Cow Per Day
Manual	3.2
Semi-mechanical	2.6
Mechanical gutter cleaner	2.1

It is probably reasonable to assume that the farmers studied, who were using conventional systems to clean their barns, were somewhat less efficient than the group of farmers who had adopted the liquid manure system. However, one should expect a saving of about an hour per day with a herd of 50 cows when a shift is made from conventional methods in a stall barn to the liquid manure system according to this study.

In a second study made in Sweden (10) the labor requirement calculated for barns with mechanical gutter cleaners was 2.1 minutes per cow per day. This was contrasted with the most efficient liquid manure system which required 1.2 minutes per cow per day. Again, this suggests a saving of about one minute per cow per day, or an hour per day for a 60 cow herd.

In a German farm management planning handbook (7) the labor requirements suggested for a 40 cow herd were quite different. With a mechanical gutter cleaner the labor needed was 1.1 minutes per cow per day and 0.85 minutes per cow per day for a liquid manure system. This study suggests the expected difference to be much smaller than the two Swedish studies. Moreover, the basic material on which the German bulletin is based involves larger numbers of herds, and more comprehensive studies over a longer period.

Based on farm observations and logical evaluation of the systems, as well as the research reports cited above, the difference in time saved is not likely to be as much as 0.5 minutes per cow per day. Perhaps 0.25

minutes per cow per day would be the more accurate estimate of the amount of time that might be saved. Since labor utilization is an important consideration, the liquid manure system has definite advantage both in terms of time saved on a daily basis and because of the convenience of not having to spread manure every day. However, the savings in labor on a daily basis must be converted to some alternative use, such as bringing more cows together in one location for one man to handle, if the savings are to be realized in fact.

Buildings. A liquid manure system requires a well ventilated barn if no accidents are to happen. The skill of the manager must be somewhat higher than for conventional systems to make the system work effectively. Some estimates of the associated building costs have been made. One Swedish study (10) indicates additional cost when a mechanical gutter cleaner is added to be $96 per cow. For a comparable sized liquid manure system a cost of $141 per cow was calculated. This includes the cost of the storage tank. No account is made in these two figures for special spreading equipment.

In a comparative study made in the Netherlands (3) the expected additional investment per cow for a 40 cow herd was indicated to be $118 for a mechanical gutter cleaner system and $170 for a liquid manure system for the same sized herd involving a pit with three months storage capacity. However, a system which required storage space for only one month in the pit was cheaper than the mechanical gutter cleaner and cost $102 per cow. The mechanical gutter system in this system was unusual compared to most American systems. Liquid material was collected separately from the solid material requiring a small storage system. Special transporting and spreading equipment was included in all three of the systems compared.

Liquid Manure Systems in Loose Housing and Free Stall Barns

The use of slatted floors in the handling of livestock has been developed in the last 15 years. There are many different opinions about this kind of system. In general there is greater enthusiasm throughout Northwestern Europe for barns involving slatted floors for youngstock and calves than for the mature dairy herd. Experience has indicated that slatted floors will keep the youngstock clean with limited bedding. Larger numbers of animals are housed per square foot of floor space. Overall this is thought to be an efficient way of handling young animals. In most areas calves must be kept in insulated buildings; hence insulation is not an additional cost.

Much less experience has been obtained under commercial conditions with the use of slatted floors for milking herds either in free stall barns or cubicle barns, as they are called in England. Any building using slatted floors requires that a liquid manure system be associated with it. It also requires that the barn be warm and insulated. Freezing temperatures create major problems. The slatted floor becomes slippery. More important, manure will not move through the slats and quickly a physical problem exists which cannot be readily dismissed.

Because of the lack of experience under commercial conditions, few of the studies which have been conducted to date are comprehensive in the sense that they have looked at labor requirements for the whole system as well as capital costs. However, some basic data are now available for parts of this system.

Labor Requirements. The difference in the amount of labor required to handle manure when comparing a slatted floor system and a solid concrete floor for a free stall system is estimated to be from 0.2 to 1.1 minutes per cow per day according to two studies done in Sweden (11) and Germany (6). The labor requirement for manure handling is estimated to be practically zero for a slatted floor system. Hence, the saving is largely in the amount of time required to clean a concrete passway or floor in the standard free stall system. Here a great deal of variation exists from farm to farm depending on the efficiency of the layout and the skill of the individual operator. In the well-organized free-stall system, where buildings are carefully planned and equipment has been efficiently designed, it is possible to bring the labor requirement for manure handling down to 0.2 to 0.3 minutes per cow per day. As a result the saving in labor that can be expected from the use of a slatted floor would be this small number of minutes per cow per day.

Building Costs. One of the major issues in discussing additional costs associated with a slatted floor system has to do with the need for insulation. This, however, is almost a separate issue since both cold and warm housing units are now built regardless of the kind of floor, depending on the incidence of freezing temperatures. The cold, non-insulated building is obviously less costly to build than an insulated warm building which also involves a slatted floor and storage for liquid manure. The additional cost of insulation may be as important a consideration as the slatted floor and storage tank. Good comparative figures which might have application in the United States are diffieult to obtain. In one Swedish study (11) the increase in the original cost for the building unit was $217 to $230 per cow when a combination of slatted floor for liquid manure handling with a storage system was used. In another study (10) the increase was estimated to be only $93 per cow. Quite clearly the extra cost of the slatted floor and liquid manure handling system must be justified on the basis of labor saved and/or convenience in not having to spread the manure every day. The differences in the quantity of manure handled should not change, although more liquid material must be carried or handled with a liquid system. In general, differences in bedding for the two systems in free stall barns or loose housing is not an important issue.

General Conclusions

A review of the research experience in Northwestern Europe suggests that liquid manure handling systems can be operated in a technically efficient manner. There is some saving of labor. There is some advantage in terms of convenience of hauling manure occasionally rather than every day or every other day. The savings in labor and added convenience however, are hard to justify compared to the additional cost in terms of

capital for the liquid manure system. Justification of the systems on the basis of plant food nutrients saved do not seem to be very appropriate in the United States, considering the relatively low cost of these nutrients in standard commercial forms and the associated problems of timing of application relative to the crop grown. If the central concern is with efficient methods of waste disposal, the liquid manure system seems to have more disadvantages than gains in efficiency.

Brief Summaries of Research on Dairy Buildings and Dairy Systems

A series of nine articles or studies were reviewed. A brief review of some of the research presented in these studies is made in the following sections of the report. Tables have been translated and presented in as nearly the same form as they were originally presented as possible. Readers should consult the original materials listed in the bibliography for further details.

A. English Publications

Rejkenberg, G. J. (3) at the Netherlands Institute of Farm Buildings reports the results from research carried out in the field of manure handling and removal. The project started in 1958 and studies have been made both on commercial farms and at the experiment station as controlled experiments.

Five different types of manure removal systems were studied in stanchion or stall barns:

(1) cleaning by hand and wheelbarrow
(2) mechanical dung scraper
(3) fully automatic mechanical gutter cleaning systems
(4) sludge systems with a pit with storage capacity for one month
(5) sludge systems with a pit with storage capacity for three months

Total capital costs are given in dollars and represent the cost of the total manure handling system (transport from cow to storage, dung stead or pit, and from storage to land). The labor costs are based on wages of $1.12 per hour. Table 1 summarizes some of the more important figures presented in the report.

The investment figures indicate the outlays for only those items which are directly concerned with manure handling. Alternatives A, B and C are based on separate storage and handling for urine and solid manure, and transporting and spreading equipment for both. This is a factor raising both the original and the annual cost for this alternative compared to an alternative where the mixed manure is loaded on the spreader in connection with cleaning of the barn which was not studied.

Table 1. INVESTMENT AND ANNUAL COST OF COWSHED MANURE HANDLING
40 and 60 Cow Herds, Netherlands, 1965

Description	Invest-ment	Annual cost: Labor and haulage	Annual cost: Litter $14 a ton	Annual cost: Capital cost 1/	Total
40 Cows					
A. Cleaning by hand, wheelbarrow	$2814	$534	$201	$280	$1015
B. Push-type gutter cleaner	3528	484	201	380	1065
C. Automatic gutter cleaner	4704	372	201	563	1136
D. Sludge systems, pit storage for 1 month	4116	215	-	370	585
E. Sludge systems, pit storage for 3 months	6776	215	-	610	825
60 Cows					
A. Cleaning by hand, wheelbarrow	3458	784	302	330	1416
B. Push-type gutter cleaner	4256	705	302	448	1455
C. Automatic gutter cleaner	5628	534	302	664	1500
D. Sludge systems, pit storage for 1 month	5516	316	-	504	820
E. Sludge systems, pit storage for 3 months	9016	316	-	818	1134

1/ The annual capital cost is calculated on the following basis: 6% of the cost of dung stead, 8% of grids, 10% of urine tank, liquid manure tank and pump and rubber mats, 14% of dung spreader, and 15% on the cost of stirring unit and the mechanical gutter cleaner. These percentages represent charges for both depreciation and interest.

B. German Publications

The most important source of information in this field in Germany is from the major research effort carried out by the Max-Plank Institute for Work Study and Technology in Agriculture. Planning data based on their work studies are published in a planning data handbook (7). The figures for work requirements are based on controlled experiments and studies on commercial farms. Large numbers of observations are obtained from both sources. The figures seem to provide a very complete and accurate picture of the differences in efficiency between methods and equipment.

Labor requirements have been estimated for all of the major operations at the farmstead in handling a dairy herd. Times required for feeding green chop, silage and concentrates using different methods and different amounts of feed have been developed. Estimates have been made for both the milking herd and youngstock and for different herd sizes. The following tables are some of the more important ones selected from the complete report.

Table 2. LABOR REQUIREMENTS FOR FEEDING GREEN CHOP
Germany, 1964

Ration per animal per day	Wheelbarrow: Herd size 20	Wheelbarrow: Herd size 40	Unload from wagon by hand: Herd size 20	Unload from wagon by hand: Herd size 40	Self unloading wagon: Herd size 20	Self unloading wagon: Herd size 40	Self unloading wagon: Herd size 80
kg.	minutes per animal per day						
20 (1 ration)	0.7	0.7	0.32	0.32	--	0.13	0.11
30 (2 rations)	1.1	1.1	0.55	0.55	0.26	0.22	0.18
40 (2 rations)	1.4	1.4	0.65	0.65	0.30	0.26	0.22
50 (2 rations)	1.7	1.7	0.75	0.75	0.34	0.30	0.26

Source: Kuratorium für Technik....(7)

Table 6. TOTAL CHORE TIME -- STANCHION BARNS AND LOOSE HOUSING
10, 20, 40 and 80 Cow Herds, Germany, 1964

Description of system	Herd size 10	20	40	80
	minutes per cow per day			
1. Stanchion barn				
Milking: 2 bucket units and cooler	10.3	9.0	8.3	
Silage feeding: 50 kg. from horizontal silo into 300 kg. wagon	1.2	1.2	1.2	
Hay feeding: 2 kg. per cow	0.35	0.35	0.25	
Concentrate feeding	0.25	0.25	0.2	
Manure handling, gutter cleaner	1.1	1.1	1.1	
Bedding	0.4	0.34	0.3	
Cleaning cows and barn	2.05	2.05	2.05	
Miscellaneous tasks	0.5	0.5	0.5	
	16.3	14.8	13.9	
2. Loose housing				
Milking: 3 units, double 3 walk through parlor, pipeline, tank, 1 person			6.4	
Milking: double 6 herringbone, 6 units, pipeline, tank, 2 persons				6.0
Silage feeding 50 kg., mechanical distribution			0.65	0.65
Concentrate feeding in parlor			0.4	0.4
Manure removal from paved outdoor area			0.1	0.1
Bedding			0.45	0.45
Miscellaneous tasks			0.6	0.6
			8.6	8.1

Source: Kuratorium für Technik....(7)

Table 7. TOTAL CHORE TIME INCLUDING MANURE REMOVAL --
CALVES IN LOOSE HOUSING (PENS)
Germany, 1964

Description	Solid floor	Slatted floor
	minutes per head per day	
Calves, up to 4 months		
Pen size - 3	6.95	6.76
6	5.20	5.03
12	4.75	4.62
25	4.60	4.47
Calves, 5-6 months		
Pen size - 1-3	1.35	1.15
Calves, 7-12 months		
Pen size - 1-2	1.90	1.35
5-10	1.70	1.25

Source: Kuratorium für Technik....(7)

Table 8. TOTAL CHORE TIME -- YOUNGSTOCK 1-2 YEARS IN ALTERNATIVE HOUSING SYSTEM Germany, 1964

Description of chores	Stanchion barn, Herd size 2	Stanchion barn, Herd size 5	Standard loose housing, solid floor, Herd size 2	Standard loose housing, solid floor, Herd size 5	Standard loose housing, solid floor, Herd size 9	Standard loose housing, solid floor, Herd size 18
	minutes per head per day					
Hay and straw, feeding	0.70	0.70	0.70	0.70	0.50	0.50
Concentrate feeding from buckets	0.15	0.15	0.15	0.15	0.15	0.15
Feeding beets 20 kg.	0.40	0.40				
Silage feeding, 20 kg manual handling			1.00	1.00	1.00	1.00
Bedding	0.40	0.35	0.90	0.80	0.80	0.80
Manure removal	1.30	1.20				
Miscellaneous tasks	0.70	0.70	0.60	0.60	0.60	0.60
Total	3.65	3.50	3.35	3.25	3.05	3.05

Description of chores	Slatted floor, Herd size 2-5	Slatted floor, Herd size 9-18	Separate feeding and resting areas, Herd size 9	Separate feeding and resting areas, Herd size 18
	minutes per head per day			
Hay feeding 4 kg.	0.70	0.50		
Hay feeding 4 kg. in bunk			0.30	0.30
Concentrate feeding from sack	0.15	0.15	0.15	0.15
Silage feeding 20 kg. from horizontal silo with tractor and front loader	0.50	0.45		
Haylage feeding, mechanical distribution			0.25	0.20
Bedding			0.40	0.40
Cleaning the slats	0.05	0.05		
Cleaning paved feeding area			0.30	0.25
Miscellaneous tasks	0.60	0.60	0.10	0.10
Total	2.00	1.75	1.50	1.40

Source: Kuratorium für Technik....(7)

Rübrich, W. (8) discusses labor requirements for daily cleaning, straw collecting and manure transporting to field in four types of barns. The figures given for labor requirement are based on work studies and calculated for herds of different sizes. The figures in table 9 report comparisons made for a herd of 30 cows.

Table 9. LABOR REQUIREMENT FOR MANURE HANDLING IN DIFFERENT TYPES OF HOUSING 30 Cow Herds, Germany, 1965

Thirty cow herds	Cleaning per cow	Cleaning	Straw collecting and manure transporting
	minutes per day	hours per year per cow	
Loose housing, open	0.5	3.1	6-7
Free stall, slatted floor	0.3	1.8	6-7
Free stall, concrete in passways	1.4	8.5	6-7

Source: Rübrich, W.(8)

Franz, Otto Karl (6) discusses the same problem in free stall barns which make use of concrete in the passways. Most of his figures for labor requirements are based on a herd of 50 cows. His figures for cleaning and bedding the barn per cow are in minutes per cow per day.

Job	Time
Bedding	0.12 minutes
Cleaning passways	0.13 minutes
Feeding area	0.08 minutes
Preparation time, once per day	0.10 minutes
Total	0.43 minutes

Some data are also provided on expected building costs, but there are difficulties in interpreting these data as they refer to so many different situations from those common in the United States.

Forster, A. (5) gives figures for building cost of free stall barns with slatted floor and free stall barns with concrete in the passways. He estimated the cost for a 30 cow barn insulated and with slatted floor to be $400 per cow. The cost for a cool (non-insulated) free stall barn with concrete floor was calculated to be $160 per cow.

C. Publications in Swedish

In Sweden the Employer's Association in Farming and Forestry, with a central office and research center in Stockholm, has made an important contribution in the areas of work simplification and labor requirements.

Jonson, B. (12) a staff member in this association, reports the result from work studies of 128 dairy herds with a total of 4,665 cows. The range in herd size was from 7 to 207 cows. Half of the herds had less than 25 cows.

Table 10. LABOR CONSUMPTION, FEEDING ALL FORAGES AND CONCENTRATES 128 Dairy Herds, Sweden, 1964

Herd size	Average labor consumption	Average labor used by most efficient 1/4 of herds
	minutes per cow per day	
Less than 20 cows	3.2	2.2
More than 20 cows	2.9	2.2

Source: Jonson, B.(12)

Using these farm data, estimates were made of the time used to feed a ton of different feeds:

Feed	Minutes per ton
Concentrate	100
Hay	100-150
Silage (manual)	50

Labor used in milking was divided into minutes for preparation and finishing, actual milking time with machines, hand stripping and cleaning of equipment. Average yield per cow was 14.8 kg. per day. The milker in herds larger than 20 cows used 3.2 units and 3.6 units respectively for bucket milking equipment and pipeline equipment. The average times spent for all milking tasks were 11.0 and 7.9 minutes per cow milked per day when using bucket milking equipment in herds with less than 20 cows, and in herds with more than 20 cows respectively. The equivalent figures using pipeline equipment were 8.8 and 7.5 minutes per cow per day.

An average of 26 cows were milked per hour on farms with herds larger than 20 cows, where pipeline milkers were used. An average of 22 cows were milked per hour with bucket milking equipment. Under good

management the numbers of cows milked per hour were increased to 35 and 25, for pipeline and regular milking equipment respectively.

The reduction in labor associated with the introduction of bulk tank facilities was calculated on work studies in 30 barns. The average gain in efficiency was 40 and 60 minutes per ton of milk in herds of 30 and 50 cows respectively. A gain of 0.5 and 0.8 minutes per cow per day was obtained in these respective herd sizes based on average milk production of 12 kg. per cow per day (26.7 lb.).

Work studies were also made under farm conditions of time spent in cleaning the barns and bedding the herd. The average time used for cleaning and bedding in the sample was:

Method of cleaning	Average minutes per cow per day
Manual	3.2
Semi-mechanical	2.6
Mechanical gutter cleaner	2.1
Liquid manure system	1.3

Very few studies have been done in barns with liquid manure handling. The average labor consumption in these barns was 1.3 minutes per cow per day. The author estimates the labor requirements for cleaning in barns with liquid manure and no bedding to be 0.9 minutes per cow per day.

In addition, the report gives information about time spent in doing chores for calves and heifers in different types of barns at different levels of mechanization.

Olle Malmqvist (11) in his research for the same association discusses four different possibilities for increasing herd size when a farmer starts with a technically good stanchion barn holding 48 cows. In the first stage (etapp) the building is increased to hold 60 cows. In the second stage (etapp) the move is to 120 cows.

The alternative types of building changes considered are:

1. Stanchion barn, mechanical unloader of silage, manual distribution of silage and concentrate, liquid manure, pipe milker.

2. Stanchion barn as 1 but with mechanical unloading and distribution of silage.

3. Free stall for cows, not insulated, floor scraped by tractor. The old stanchion barn utilized for parlor, double 5 herringbone, room for calves and heifers on slatted floor. Mechanical unloading and distribution of silage, concentrate given during milking.

Table 12. HERD SIZE FOR ONE MAN WORKING EIGHT HOURS EACH DAY
Work Study Experience, Sweden, 1960-64

Type of barn and mechanization	Only cows	Cows + 75% more youngstock
1. Stanchion barn, bucket milkers, manual distribution of fodder and manual cleaning	32	27 + 21
2. As 1 but pipeline and gutter cleaner	37	31 + 22
3. As 2 but liquid manure	40	33 + 24
4. As 3 but mechanical distribution of fodder	48	38 + 29
5. Loose housing, pipeline, side opening parlor, manual distribution of fodder	51	44 + 33
6. As 5 but herringbone, self-feeding of silage	60	50 + 38
7. As 6 but mechanical distribution of silage, free stall	64	54 + 40
8. As 7 but with slatted floor	74	60 + 45

Source: Joelsson, B. (9)

The Swedish Institute of Agricultural Engineering (10) has studied the layout, management and cost of liquid manure handling. The report presents information about four different systems for handling liquid manure in stanchion barns: (1) pump from pit system, (2) sluice gate system, (3) combined sluice and recirculation system, and (4) continuous flow system. Estimates of added building cost, differences in labor costs associated with handling manure, and suggested layouts are discussed for stanchion barns, free stall barns with concrete passways, and free stall barns with slatted floors. The investments and operating costs presented only represent additional outlays associated with handling manure.

The risks associated with a gas that develops as a by-product of liquid manure are stressed in the bulletin. This problem can be solved by proper ventilation of the buildings.

Additional investment costs and annual operating costs for manure handling for a herd of 75 cattle units are presented.

Table 13. ADDED INVESTMENT AND ANNUAL COST PER COW FOR MANURE HANDLING 1/
Sweden, 1965

	Added investment per cow	Annual cost per cow
Stanchion barns		
a. Sluice gate cleaning out	$152	$27
b. Combined sluice gate and recirculatory system	166	30
c. Continuous flow cleaning out	141	26
d. Mechanical gutter cleaner	96	41
Free stall barns		
e. Free stalls and slatted floor in passages	260	34
f. Free stalls and concrete in passages	167	29

1/ The depreciation period for buildings is 20 years, for equipment 7 years. Labor cost $1.60 per hour. Distribution of liquid manure is supposedly done by entrepreneur. The building cost represents only building parts in direct connection with the manure handling.

Source: Jordbrukstekniska Institutet, Medelande No. 310 (10)

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