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Research in liquid manure removal and storage technological versions on milk farms

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Abstract. Today loose housing of cows using boxes and a minimal amount of litter, resulting in liquid rather than litter manure is very common. However, there has not been much experience in manure utilization in Latvia.

In our research we have discussed the possible outcome of liquid manure considering the amount of sewage water in liquid manure, the most economically effective technological versions of liquid manure removal from cow barns and transportation to storage reservoirs as well as different storage reservoir building costs, depending on their capacity and building type.

It has been stated that the sewage water in the reservoir comprises 17% of the total amount of liquid manure. Practically speaking, the operational costs of liquid manure removal systems do not depend on the kind of boxes for cow recreation, but rather on the technological equipment costs. In addition, the lagoon-type liquid manure reservoirs are cheaper. Installing cylindrical reservoirs with reinforced concrete panel walls increases the specific building costs 1.8 times, and with metal plate walls – 2.0-2.5 times.

Key words: milk cows, liquid manure outcome, technologies, liquid manure removal, reservoirs, costs

INTRODUCTION

Production and utilization of liquid manure in Latvia started more than thirty years ago when the first experimental milk farming complexes were built. This technology was implemented more widely during the last ten years using loose housing of cows and at present it is applied on all large newly built farms.

Problems in removal and utilization of liquid manure remain. Scientifically founded methodology for calculation of liquid manure outcome considering the amount of sewage water it contains has not been developed, the most suitable technologies for liquid manure removal have not been sufficiently investigated, and the most economically efficient versions of liquid manure reservoirs have not been found.

Therefore, the aim of the present research was to clarify the above mentioned issues in order to use these research results practically as well as theoretically and to contribute to the development of the standard/norms in the corresponding legislative branch.

MATERIALS AND METHODS

The existing Latvian legislative acts and special literature were used for stating the outcome norms of liquid manure, but the viewpoint of the State Environment Protection Department was used to explain disputable issues. In turn, the amount of waste water resulting from washing milking equipment was investigated in operational conditions. For this reason three different farms were selected, including the research and training farm "Vecauce" of the Latvia University of Agriculture, where in total six different kinds of milking equipment were applied.

In order to determine the economically most efficient technologies of liquid manure removal, initially, 12 different technological versions of liquid manure removal were distinguished. After carrying out the analysis of the corresponding technological versions we suggest that in future research it is not advisable to include several less efficient/productive technologies. They are:

- Technologies with sand litter application; sand is an abrasive material causing rapid deterioration of the machinery;
- Technologies that are meant for transportation of liquid manure through self-flow channels which freeze in winter;
- Technologies for liquid manure removal with help of a tractor unit which is not appropriate for handling highly productive animals.

Accordingly, the total number of the discussed versions decreased (Table 1).

Table 1. Compared technological versions.

Kind of cow handling	Version No.	Liquid manure removal technological elements and equipment, not including reservoir
High boxes with mats	1.1	Delta type conveyer with cable drive + cross-channel + worm-type pump
	1.2.	Delta type conveyer with follower drive + cross-channel + worm-type pump
	1.3.	Delta type conveyer with cable drive + cross-conveyer + manure pumping pit with a piston type pump
Deep boxes with straw litter	2.1.	Delta type conveyer with cable drive + force-conveyer
	2.2.	Delta type conveyer with follower drive + force- conveyer

All of the liquid manure removal technologies in the table were compared for barns with a herd of 100, 200 and 400 cows. For each of these versions a corresponding version of barn planning was developed and the costs for construction and implementation of the chosen technology were determined.

The technological versions were compared according to the specific capital investments, Ls per cow, as well as according to the specific operational costs, Ls per cow per year. For calculations our own developed software programme was used

(Priekulis & Kuplis, 2007). The necessary initial data were obtained from our chronometrical results; the existing and valid norms, price lists and technical instructions, but in many cases the information available at the companies „DeLaval" and „Kesko Agro" was also used.

The economic efficiency of liquid manure reservoirs was evaluated according to their specific building costs, Ls per m^3, that were calculated according to the data given by the companies that supplied the necessary constructions. In turn, for the investigation of the lagoon-type liquid manure reservoirs and calculation of the costs, a special software programme was developed (Priekulis & Murikovs, 2007). This programme made it possible to calculate the building costs of the reservoir considering their necessary capacity, construction peculiarities as well as the costs of the used building materials and salaries for the workers.

The estimate for the lagoon building costs was calculated according to an ordinary scheme, with separate categories showing the necessary building work operations, amount of work, salaries for the workers, costs of construction materials and machinery used. We also applied our software programme to investigate the optimisation of the lagoon-type reservoir geometric parameters..

RESULTS AND DISCUSSION

Liquid manure obtained in the barn as well as some cow barn sewage water are fed into liquid manure reservoirs. The liquid manure outcome norm determined in Latvia is 6.7 m^3 per day in a herd of 100 cows that, according to our investigations (Priekulis & Zujs, 2005), corresponds to the average liquid manure outcome advised in the specified literature. The main kinds of sewage water obtained on cattle farms and the possibilities for their use are given in Table 2.

Table 2. Main kinds of sewag e water.

No.	Kinds of sewage water	Possible versions of collection, storage and utilisation
1.	Water used for preparation of cow udder and washing of milking machines	Fed in the liquid manure reservoir
2.	Washing of dirty floors	Fed in the liquid manure reservoir
3.	Milking machine and milk tank washing waste water	Fed in the liquid manure reservoir
4.	Sanitary unit and shower waste water	Collected separately and regularly transported to the nearest water treatment devices
5.	Precipitation water from dirty areas on the farm territory	Infiltrates in the ground

The table shows not only that the liquid manure obtained in the barn but also waste water produced as a result of milking cows has to be fed into the reservoir.

The amount of water necessary for washing of cow udders, the outer rinsing of milking machines and for cleaning floors is indicated in special literature (First, 2000), but the necessary amount of water for washing of milking equipment is determined in our investigations (Zujs & Priekulis, 2004). Stand-type milking equipment used to milk 100 cows generates approximately 225 liters of water per one time of milking.

According to these data we have calculated that the total outcome of liquid manure obtained during 24 hours from a herd of 100 cows is 8.05 m^3. Its distribution according to separate kinds is shown in Fig. 1.

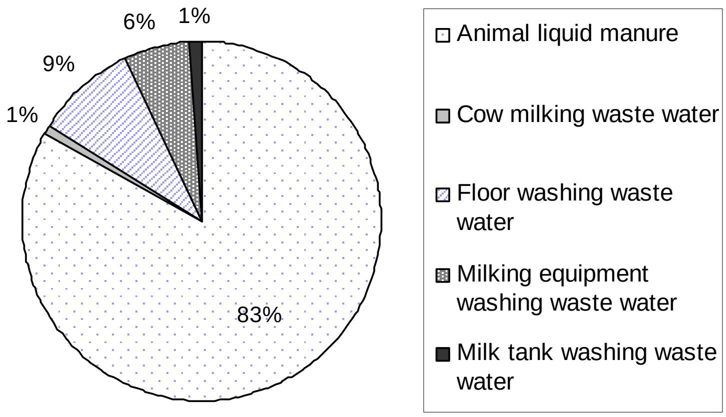

Fig. 1. Total liquid manure outcome structure including sewage water fed into the reservoir.

It can be seen from the figure that the liquid manure obtained in the barn comprises only 83% of the total amount of liquid manure. The other 17% is waste water obtained during milking of cows and in the process of washing milking machines. It should also be taken into consideration that in compliance with the regulations existing in Latvia (Regulations of the CM of the Republic of Latvia No. 628, 2004), silage juice can also be fed into liquid manure. Therefore, the following formula can be used to calculate the necessary capacity of liquid manure reservoirs

$$V_k = \frac{k_r \cdot T_{gl}}{12 \cdot \varsigma_k} \sum^{n} k_g \cdot k_p \cdot q_{dz} \cdot z_{dz} + V_{sk} \qquad (1)$$

where
V_k – necessary capacity of liquid manure reservoir, m^3;
k_r – capacity reserve coefficient, k_r = 1.1 to 1.2 (Berzina et al., 2003);
k_g – coefficient considering decrease of manure during the pasture period if animals are at grass (in summer), then k_g = 0.5, if not, then k_g = 1.0;

k_p – coefficient considering the increase of liquid manure outcome due to feeding of sewage water: in our example it is 1.2;
T_{gl} – normative length of liquid manure storage time, in months. According to the legislative acts existing in Latvia (Regulations of the CM of the Republic of Latvia No. 628, 2004), T_{gl} = 7 months;
q_{dz} – manure of slurry result from one animal of the corresponding group, tons per year;
z_{dz} – average number of animals in the corresponding group;
n – number of animal groups;
ς_k – liquid manure volume mass, approximately ς_k=1.05 t per m^3 (Berzina et al., 2003);
V_{sk} – amount of silage juice fed into the liquid manure reservoir, m^3 per year.

The comparison of liquid manure removal technologies according to the specific capital investments is given in Fig. 2.

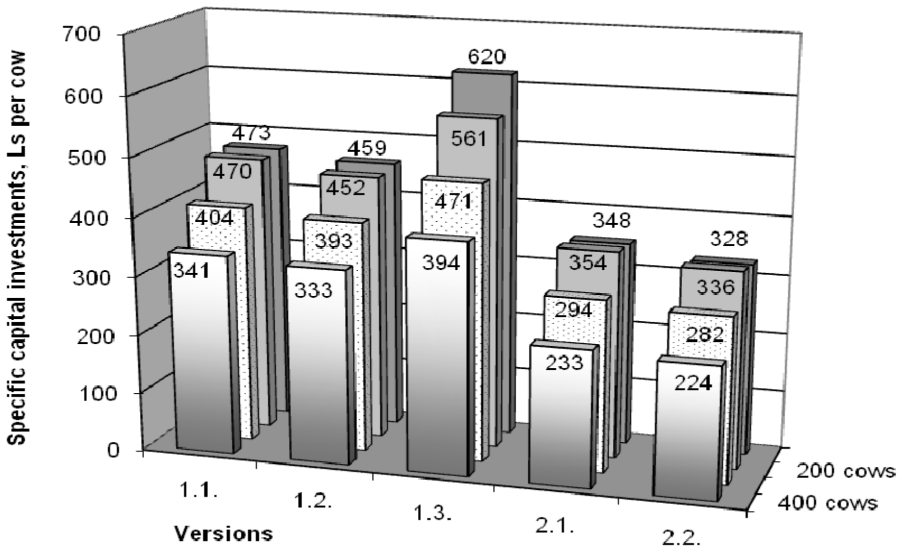

Fig. 2. Comparison of specific capital investments for different technological versions of liquid manure removal, Ls per cow place (stand). In the first column – capital investments for a herd of 400 cows, in the second, third and fourth – 300, 200 and 100 cows, respectively.

As the figure indicates, the specific capital investments depend on the chosen technological version as well as on the number of cows in the herd. If it is assumed that with a herd of 100 cows, the specific capital investments (including also the installation costs of boxes) are 100%, then, with a herd of 400 cows they are approximately 70%.

1.00 EUR = 0.702804 Ls

The changes of these costs are not proportional to the changes in number of cows: in our case, the design of the barn also changed. In one case, the feeding table for 100 cows was located at one side of the barn; in other cases, it was in the centre.

The figure also shows that the capital investments are considerably larger if high boxes are used: these boxes include special mats costing up to 100 Ls per m^2. In these calculations we have considered the average price of the mats, i.e., Ls 50 per one square meter. Increased capital investments are required also for the introduction of version 1.3, as in this case, for mechanization of work, cross-conveyers and the piston type pump of the company *HOULE* are used.

More objective evaluation of the liquid manure removal technological versions can be obtained according to the specific operational costs that include salaries for the workers (Fig. 3).

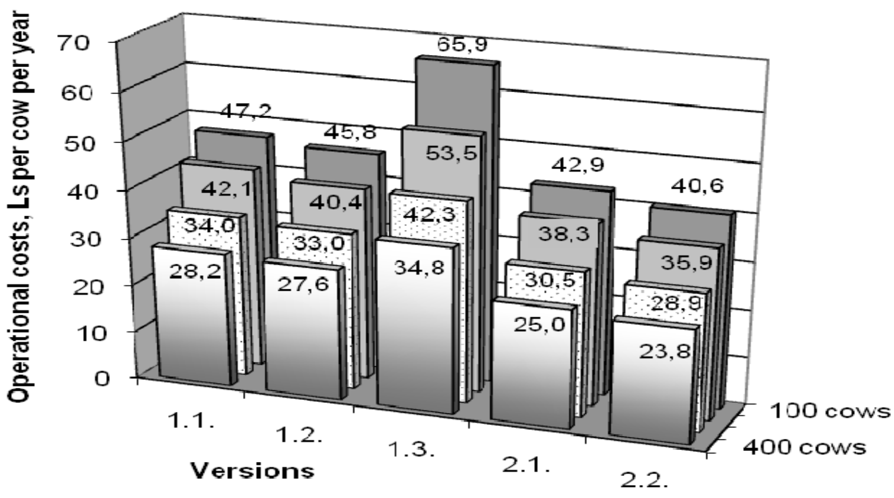

Fig. 3. Comparison of the technological versions of liquid manure removal according to the specific operational costs, Ls per cow per year. In the first column the costs are given for a herd of 400 cows, in the second – 300 cows, in the third – 200 cows and in the fourth – 100 cows.

The comparison of operational costs confirms the profitability of large farms. The operational costs of the liquid manure removal systems for a 400-cow barn are 1.5–2 times lower than in a 100-cow barn. This difference in costs is especially clearly seen in technologies using expensive equipment. It can be seen also that there are no big differences concerning the specific operational costs between the technologies with high and deep boxes. If high boxes are used, costs are slightly increased, especially with a small number of cows. Nevertheless, with use of deep boxes the litter material has to be supplied regularly; that requires manual labour and therefore higher compensation of work.

The specific building costs of liquid manure reservoirs depending on their constructive version, material and capacity are given in Fig.4.

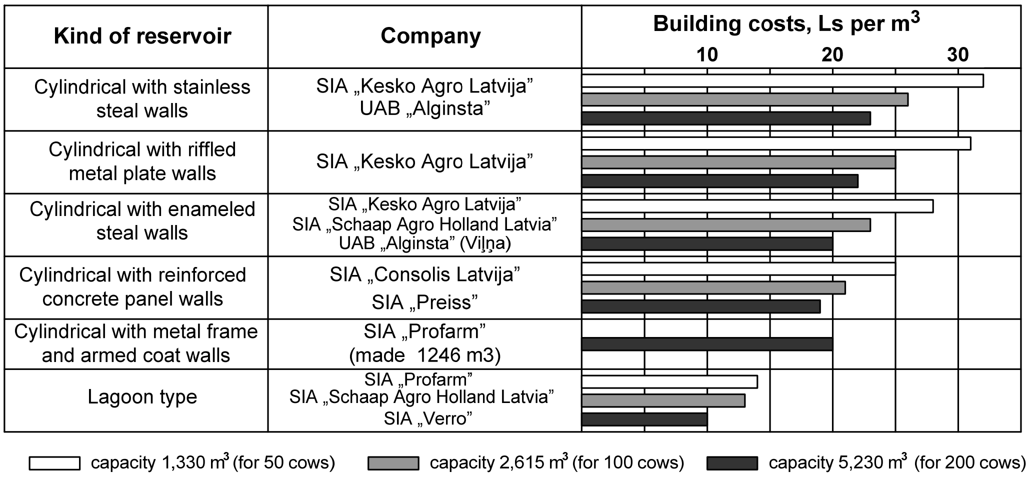

Fig. 4. Liquid manure reservoir specific building costs, Ls per m^3, depending on the number of milk cows in the herd and the type of the reservoir.

As it can be seen from Figure 4, for barns with 50–200 cows the specific building costs of liquid manure reservoirs range from 32 to 10 Ls per m^3. The bigger the capacity of the reservoir, the smaller the specific building costs (calculating per one cubic meter of the capacity). The light-type reservoirs with armed coat walls and a capacity of 1.245 m^3 are an exception. In our case, two such reservoirs would be needed for a barn with 100 cows, four, for a 200-cow barn, etc.

The lagoon-type liquid manure reservoirs are the cheapest but, compared to other versions create a comparatively higher risk of environmental pollution. Therefore, with a small herd of cows (up to 50), the light-type reservoirs with armed coat walls could be economically profitable, but for a larger number, reservoirs with reinforced concrete block walls as well as enamelled steel plate walls.

CONCLUSIONS

When calculating the necessary capacity of liquid manure reservoirs, the amount of waste water fed into the reservoir should be taken into consideration as, for instance, it comprises 17% of the total volume of liquid manure for a 100-cow barn.

When comparing different liquid manure removal technologies, the corresponding costs of installation of cow recreation boxes should also be taken into account as these costs vary.

If high boxes with rubber mats are used, compared to the deep boxes, the specific investments for construction work and purchasing of mats increase 50–100%.

On farms with 400 cows the specific operational costs of the liquid manure removal system are 1.5–2 times lower than on farms with 100 cows.

The lagoon-type liquid manure reservoirs are cheaper. Installing cylindrical reservoirs with reinforced concrete panel walls increases specific building costs 1.8 times, but reservoirs with metal plate walls – 2.0-2.5 times.

The bigger the capacity of the reservoir, the smaller the specific building costs are. For instance, for a reservoir with the capacity 5230 m^3 the specific building costs amount to 60% of costs for a reservoir with a capacity of 1330 m^3.

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