Baltic Forum for Innovative Technologies for Sustainable Manure Management

KNOWLEDGE REPORT

Manure Handling Techniques on Case-Study Farms in Baltic Sea Region

By Erik Sindhöj and Lena Rodhe (Editors)

- WP3 Innovative Technologies for Manure Handling
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PREFACE

Baltic Manure (The Baltic Forum for Innovative Technologies for Sustainable Manure Management) is a Flagship Project in the Action Plan of the EU Strategy for the Baltic Sea Region (BSR), which is co-funded by the Baltic Sea Region Programme of the European Union. The work described in this report was performed within Work Package 3 (WP3) "*Innovative technology for animal feeding and housing, processing, storage and spreading of manure*" within Baltic Manure.

The overall aim of WP3 is to identify innovative and economically viable technologies for handling and processing manure in an environmentally friendly and user-friendly way on large-scale livestock farms in the BSR. Bottlenecks and barriers to implementing appropriate available technologies were also examined. Useful feeding strategies and technologies for reducing the nutrient content in manure were not included as much as planned, but will be highlighted in a separate Task 3 report.

This report presents an overview of manure handling techniques currently being used in practice on large-scale animal production farms in the BSR. On case study farms in Estonia, Finland, Latvia, Lithuania, Poland and Sweden, the entire manure handling chain from feeding and housing system to storage and on to land application to crops was examined. Data obtained through sampling and analysis of manure from these farms are not included in this report, but will be presented in a subsequent report produced by WP3.

The researchers responsible for the case studies were Allan Kaasik in Estonia, Ilkka Sipilä in Finland, Kaspars Vartukapteinis in Latvia, Sigitas Lazauskas in Lithuania, Ksawery Kuligowski in Poland and Erik Sindhöj in Sweden. Together with their co-authors, they were responsible for the farm descriptions and data from their specific country. Appendix 3 contains a contact list for the relevant authors. The farm characteristics were analysed and the other chapters were written by Erik Sindhöj and Lena Rodhe, with Allan Kaasik, Sigitas Lazauskas, Ksawery Kuligowski and coordinator Johanna Logrén (MTT) providing comments for the introduction and analysis. The section on feed in the introduction was improved by Allan Kaasik and Hanne Damgaard-Poulsen (Aarhus University).

The authors would like to thank all the farmers who opened up their farms and generously contributed valuable time and assistance to completing the surveys.

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The authors

CONTENT

1 Summary

This report describes manure handling techniques used in practice on case study farms with large-scale dairy, pig and poultry production in the Baltic Sea Region (BSR). In-depth studies were carried out with the aim of providing an overview of techniques currently used along the entire manure handling chain, from animal feeding to field application. The specific methods and techniques used for manure handling influence the physical and chemical properties of manure, including how well nutrients are utilised in plant production. An additional aim was to identify bottlenecks and barriers on farms to the use of manure as a fertiliser resource.

About five case study farms were chosen in each of six BSR countries, Estonia, Finland, Latvia, Lithuania, Poland and Sweden. At least two dairy farms, two pig farms and one poultry farm were included per country. The minimum size for the case study farms was set at the number of livestock units (LU) regulated by EU Directive 2010/75/EU (IED) on industrial emissions from pig and poultry farms, or the equivalent LU value for dairy farms. Farm surveys were conducted during 2011 and 2012 through personal interviews using a questionnaire for each of the livestock types.

The number of livestock on the case study farms ranged from about 400 to over 30 000 LU. The LU density was lowest for dairy farms (around 1 LU per ha), but five-fold greater for pig farms and six-fold greater for poultry farms. Several poultry and pig farms operated without any land and instead exported the manure to other farms. Manure on pig farms was handled as slurry, while poultry manure was mainly in solid form. On dairy farms, 62% of the total amount of manure was handled as slurry and the remaining 38% as solids.
For slurry, the dominant practices were daily manure removal with scrapers in primary channels, gravity flow in cross-channels and storage in tanks made of concrete panels, more than half of which were covered, mainly with an undisturbed crust. Mean slurry storage capacity was 7 months for dairy farms and almost 9.6 for pig farms (14 months including two farms with surplus capacity). The slurry was mainly band-spread (84%) on grassland (cattle farms) or before sowing of a cereal crop in spring or early autumn (pig and poultry farms). Application rates of 20 to 30 tonnes per ha dominated, but rates as high as 80 tonnes per ha were reported. About 7% of the slurry was spread with injectors, either with shallow disc tines in grassland or with cultivator tines in open soil before sowing a crop, often maize. For the solid manure, mobile manure removal technology was commonly used and the manure was most often stored on concrete pads, but also in field heaps. In most cases solid manure was stored without a cover, although on two farms poultry manure was either covered with peat or straw. Poultry manure was applied at rates of 2.5 to 10 tonnes per ha but with low spreading accuracy, as existing spreaders cannot cope with such low doses.

In general, manure handling after storage was the least well-described part of the manure handling chain. There for, emphasis should be placed on the responsibility of livestock farmers for the end-use of manure. It should be stressed on the importance of appropriate application rates and timing for achieving high nutrient uptake by plants and low leakage to water together with measures to minimize ammonia emissions. Farmers also identified a range of bottlenecks that make it difficult for them to fully utilise the resource potential in manure. These were classified into four categories: 1) Costs/economic factors, 2) technological limitations, 3) lack of knowledge of solutions, and 4) regulation or lack of incentives and support mechanisms for adopting best available technology (BAT).

2 Introduction

During past decades, livestock production has intensified with increasing herd sizes onto a fewer number of farms. Larger herds produce larger quantities of manure to be handled on farm. Collection, storage and spreading techniques for this manure can have significant impact on air, soil and water quality. Environmental problems typically associated with intensive livestock production include:

- The accumulation of nutrients in areas close to livestock operations
- Pollution of surface and ground water
- Odours and emissions of ammonia and greenhouse gases

The accumulation of nutrients in soils used for spreading manure can lead to excess nutrients that are lost through leaching and runoff to receiving waterways. Livestock production is also the greatest source of ammonia emissions in Europe (ECETOC, 1994; Misselbrook et al., 2000). Once in the atmosphere, gaseous ammonia can either be deposited again to the surrounding area depending on conditions, or it can cause the formation of fine particulate matter ($PM_{2.5}$) which in itself is a health risk and is also associated with the formation of photochemical smog (Renard et al., 2004). These particles will also eventually return to the surface through wet or dry deposition; however they can be transported over considerably longer distances. Deposition of ammonia contributes to eutrophication of surface waters, soil acidification, and fertilisation of vegetation and changes to natural ecosystems.

Eutrophication is the response of an aquatic ecosystem to excess nutrient loading (primarily nitrogen and phosphorus). Available nutrients stimulate excessive plant and algae growth. As the algae die, the decomposing organic matter depletes the dissolved oxygen in the water making it unsuitable for fish and other organisms. Eutrophication is a major problem in the Baltic Sea and the excess nutrients that are polluting the Baltic Sea enter via discharge from rivers and through atmospheric deposition. Nutrient losses from agriculture are responsible for a significant amount of the nutrient load on the Baltic Sea (HELCOM 2011).

As intensive livestock farming is placed under increasing pressures to minimize the environmental impact of their operations, attention is being focused on improving manure handling techniques. Livestock manure has a significant fertiliser value and energy potential and should be viewed as a resource to be conserved and utilised. However, manure is often considered a by-product of livestock production, associated with costs, handling difficulties and pollution risks. When viewed as a resource, management should strive to optimise the utilisation of the nutrient and energy resources and minimize losses to the surrounding environment. Minimizing losses will reduce the environmental impact. Manure management strategies should include overviews of farm-level manure handling chains including feeding, collection, storage, and field spreading systems as well as potentially including manure processing and treatment procedures to increase resource utilisation and economical profitability and in the same time decrease harmful environmental impacts.

As part of work package 3 (WP3) in the Baltic Manure Project, this report gives a review of current manure handling chains in large-scale intensive livestock production around the Baltic Sea. Countries around the Baltic Sea share common conditions for livestock farming that affect manure management and handling systems including cold winters with frozen soils, relatively mild wet summers, mostly flat land and an adequate amount of good agricultural land. Despite geographic and climatic similarities however, cultural and economic differences between countries has led to differences in farming and manure management systems across the BSR. Through this report, different solutions for manure handling on large-scale farms in the BSR region will be shown and communicated to all countries. It covers examples from three major livestock species including dairy cattle, pigs and poultry. It is a knowledge base for the project, and will be a help for identifying innovative and economically viable technologies for handling and processing manure in an environmentally-friendly and user-friendly way on big farms in the BSR. The purpose of conducting detailed examinations of specific farms in each country was also to give an entry way into determining reasons why there might be differences in manure characteristics between BSR countries. Manure sampling was also conducted on these farms to determine farm-level manure characteristics in countries in the BSR, the results of which are presented in a separate report. The case-studies covered feeding, animal housing systems, manure storage and spreading details. Bottlenecks and barriers for implementing available manure management technologies that would improve resource utilisation at the farm level were also identified and presented.

3 Manure handling systems

Specific manure handling systems are based on specific livestock and comprised of different components including: 1) Livestock (feed and feeding systems), 2) housing systems, 3) storage systems and 4) field application systems (see Figure 3.1). Within each system, there are a variety of systems and technical solutions available for manure handling in each component. This means that there are many potential configurations, depending on livestock type, for a manure handling chain on a particular farm. There is no single best system that will work everywhere. Instead, there are factors to consider when selecting solutions for each particular system component, which are discussed in further down. In the end, good manure handling system should:

- Maintain animal health
- Minimize environmental impacts (losses to air and water)
- Minimize odours to surrounding areas
- Maximize resource utilisation (integrated with the farm nutrient management plan)
- Improve the economy of the farm

In general within this report, we separate manure and manure handling into two categories:

1. Slurry or liquid manure, which is pumpable (generally referred to as slurry in this report)
2. Solid or semi-solid manure, which is non-pumpable.

Solid manure handling systems typically require handling systems for both the solid fraction and the liquid fraction which is sometimes called urine. There are numerous advantages and disadvantages of slurry and solid manure systems, which we will not go into here other than that slurry systems are generally considered less labour intensive and offer the best potential for effective farm-level utilisation of nitrogen in the manure (Burtonne and Turner, 2003).

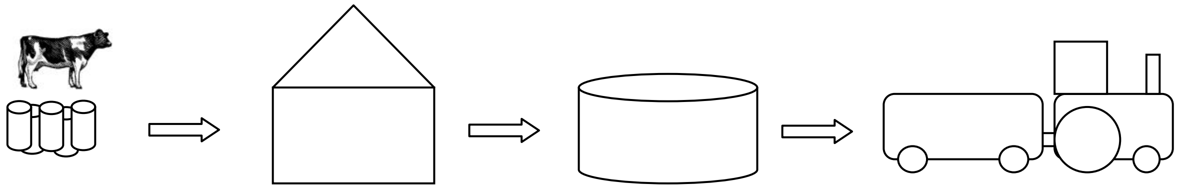


Figure 3.1. Model of basic manure handling chain for a particular livestock type. This is an adaption of the model used as a reference scenario for Life Cycle Analysis (LCA) of manure handling chains conducted by Baltic Manure WP5 (Assessing sustainability of manure technology chains).

3.1 Feed and feeding systems

Manure characteristics vary greatly between different livestock types, production levels, feeding regimes etc. Manure exiting the livestock is referred to as *ex-animal*.
Manure production and its nutrient content for a specific animal or herd are to a large part a function of input and output. Inputs are feedstuffs and feed additives as crystalline amino acids, minerals, vitamins etc., and output is production (milk, meat, eggs etc.), urine and faeces which together with other additives we refer to as manure. Therefore manure characteristics are closely related to feed quality and nutrient contents and production intensity like kg feed supplied per kg product (feed conversion ratio = FCR) for the particular herd.

Optimization of diets and feeding regimes to increase production has long been the focus of feeding technologies. In order to feed efficiently and economically, many feeding technologies have become common, such as phase and multiphase feeding which adapts diet and quantity to the animals' needs as they grow, reducing waste and excess production of manure. Thus it is now common in many countries to use crystalline amino and microbial phytase to increase the utilisation of nitrogen and phosphorus in the feeding of monogastric animals. Total mixed rations for dairy cows are another commonly implemented feeding technology that increases efficiency. More recently, however, feed and feeding technologies are being adapted to also reduce the environmental impact of manure. Increasing the uptake of nutrients in the feed can lead to decreased loss of nutrients into the manure. The improvements in feeding efficiency (FCR) due to enhanced feeding methods and genetic improvements (breeding) have made it possible to reduce dietary crude protein levels whereby also ammonia emissions were reduced without affecting production levels in dairy cows or milk quality and meat quality in pigs (e.g. Frank and Swensson, 2002; Li et al., 2012). Additives can be included in the feed which increase utilisation of phosphorus and nitrogen, such as the enzyme phytase. A newer technology that has gained focus is liquid feeding systems for mainly pigs which have been shown to increase the utilisation of plant phosphorus decreasing the need for extra supply of feed phosphates (e.g. Blaabjerg and Poulsen, 2010). The feeding topic will be handled in greater detail in a separate Baltic Manure report.

3.2 Housing systems

Housing systems are designed around various options for livestock keeping, manure handling and ventilation. Common designs of housing systems differ from country to country and are largely affected by local and national regulations as well as local traditions. Specific aspects of the housing systems will affect properties of the manure leaving the housing system. Choice of bedding material and quantity used, design of the manure collection system and frequency of manure removal, shape and form of manure channels are some aspects worth considering (Groot Koerkamp et al., 1998; Liang et al., 2003; Ngwabie, 2011; Ogink & Koerkamp, 2001). Type of watering systems for livestock can also affect manure properties by affecting water additions through spillage while the animal is drinking or playing with the water (Larsson, 1997; Borso & Chiumenti, 1999). Other sources for water additions to slurry will vary depending on livestock type and specific housing solutions but can included wastewater from cleaning the milking equipment and storage tanks, rinsing water from the milking pit, rinsing water from cleaning passages and stalls, and even showers and gray water from personnel areas.

Within the housing system there is the manure collection/removal system, which we divided into three main types for intensive production systems:

- Mobile scraping units
- Automatic scrapers
- Hydraulic removal (gravity flow, flooding, flushing, vacuum)

Mobile scraping units use a tractor or small motorized vehicle to manually remove the manure from hard passageways. Mobile units are also used to periodically remove deep litter beds, which are then directly transferred by the mobile unit to the storage area.

Automatic scrapers can be installed either in open hard passageways or in manure channels under slatted floor passageways. There are numerous types of automated scraper systems powered either mechanically or hydraulically that are suited for slurry and solid manure handling, and for either open or covered manure channels. In-house manure transfer with automatic scrapers typically occurs along parallel primary manure channels or passageways. Manure from the primary channels/passageways can be scraped into a cross-channel which leads to a temporary storage (pumping pit for slurry or pad for solid manure), or directly into the temporary storage depending on barn design. Various types of automatic scrapers can also be installed to remove manure from cross-channels.

Hydraulic transportation of slurry can be achieved by several methods and in colder climates commonly occurs in channels under grids or slatted floors. Gravity flow implies there is adequate slope in the channels for slurry to flow freely or a tip in the end of the channel. In flooding systems, slurry is collected for certain periods in channels under slatted floors and emptied regularly by opening a gate-valve or plug which allows the slurry to flow out or drain from the channel. Vacuum systems use a low pressure pump to create a vacuum in drain pipes to help remove the slurry from the manure channels. Flushing systems use wastewater or liquid manure fractions to help flush clean the channel in gravity flow systems and require large amounts of flushing water. Hydraulic transport can be used in primary manure channels, or in cross-channels that lead to the temporary storage. The outflow from the channel goes generally into a pumping pit which acts as a temporary storage.

Housing systems can also be combined with the storage systems, in which case slatted floors cover deep pits for manure storage. Due to risks of production of harmful gases to animals and human, storage of slurry below slatted floors is forbidden in some countries. Instead, the slurry must be removed and stored away from the housing system.

There are several methods that can be used to reduce the emissions of ammonia from livestock housing systems like ventilation systems, cooling of slurry, acidification, floor design e.g. slatted vs. solid floor, pen organization etc. These different approaches have been intensively described in general or for the individual species (e.g. Monteny & Hartung, 2007; Monteny & Erisman 1998; Ogink & Koerkamp 2001).

3.2.1 Dairy cattle

Housing systems for dairy cattle on intensive farms can be designed around solid or slurry manure handling with either indoor confinement year round, or a combination indoor – outdoor system. Open feedlot systems or outdoor confinement for intensive dairy cattle production are not common in the BSR. Tied stalls and loose housing systems are two options for indoor confinement. Loose housing allows the animals to range freely between different places for resting, eating and milking and is generally less labour intensive than tied stalls. Loose housing is becoming the common housing system for dairy cows in the BSR. Passageways between resting areas, loafing areas, and eating and drinking areas function often as the primary manure collection channel and are open and hard surfaced or covered in slatted floors. Loose housing can be further divided depending if the resting areas are large deep-litter pens or smaller individual cubicles (stalls) in which the animals may rest but are not restrained. Loose stall systems are becoming increasingly common in North America and Europe.

3.2.2 Pigs

Housing systems for intensive pig production are generally designed around slurry manure handling and indoor confinement year-round and the buildings are insulated and heated, although some solid manure systems still exist. The defecating behaviour of pigs differs from cattle in that they have separate places for resting and defecating. Most pig housing systems has either fully or partially slatted floors with either a deep pit or shallow manure channel underneath. Deep litter pens can also be used in conjunction with partially slatted floors over the manure collection channels. Production of finishing pigs and weaners generally occurs in smaller groups in pens, although large pens are used in some occasions. Breeding pigs can be kept individually or in groups (except when farrowing).

3.2.3 Poultry

Housing systems for poultry broilers commonly use litter beds covering large open floors in closed houses that are insulated and heated with forced ventilation. Removal of manure and the litter bed occurs at the end of the growing cycle.

Housing systems for laying hens can be either cage based, non-caged, or free-range systems. Manure from poultry is often handled as solid or semi-solid. Conventional battery cage housing systems for laying hens is banned in the EU from 2012, after a 12 year phase-out but furnished cages are still allowed. Cage systems can be stacked on top of each other with belts running underneath each layer to collect manure and transport it to the end of the house. Stair-step arrangements offset one tier of cages from the row underneath, so manure from all cages drops to the floor, or to a deep storage pit.

In free-range systems for poultry, the manure is often collected on conveyors for transporting out of the barn or stored in deep litter beds below the resting area with roosts. Free-range systems may have access to outdoor areas.

3.3 Processing/treatment

There are several reasons for processing manure and there are a wide range of different processing techniques available. Some of the reasons for processing manure are:

- Reduce the amount of manure to be transported and spread
- Increase the nutrient utilisation of the manure
- Utilize the energy potential of the manure
- Improve the handling properties
- Odour reduction
- Improve the economy of manure handling

Manure processing is still relatively uncommon in the BSR, possibly with the exception of anaerobic digestion which is gaining popularity. For a more detailed look at manure processing, a separate report from WP3 of Baltic Manure will soon be available. WP6 of Baltic Manure also has a number of detailed reports concerning anaerobic digestion and utilisation of the energy resource in manure (see Luostarinen et. al, 2011 and Luostarinen, 2011 for details).

3.4 Storage

Storage is essentially a buffer between manure production and utilisation. When manure is intended to be used as a fertilizer, storage is necessary in order to apply the nutrients when plants need them in order avoid losses and pollution. Manure application should be closely timed to crops nutrient uptake, so storage capacity will depend on the overall farm nutrient management strategy. Most often industrial-scale livestock production systems are regulated for minimum storage requirements. Storage systems can either be in-house or outdoors with several alternatives for both systems (Figure 3.2).

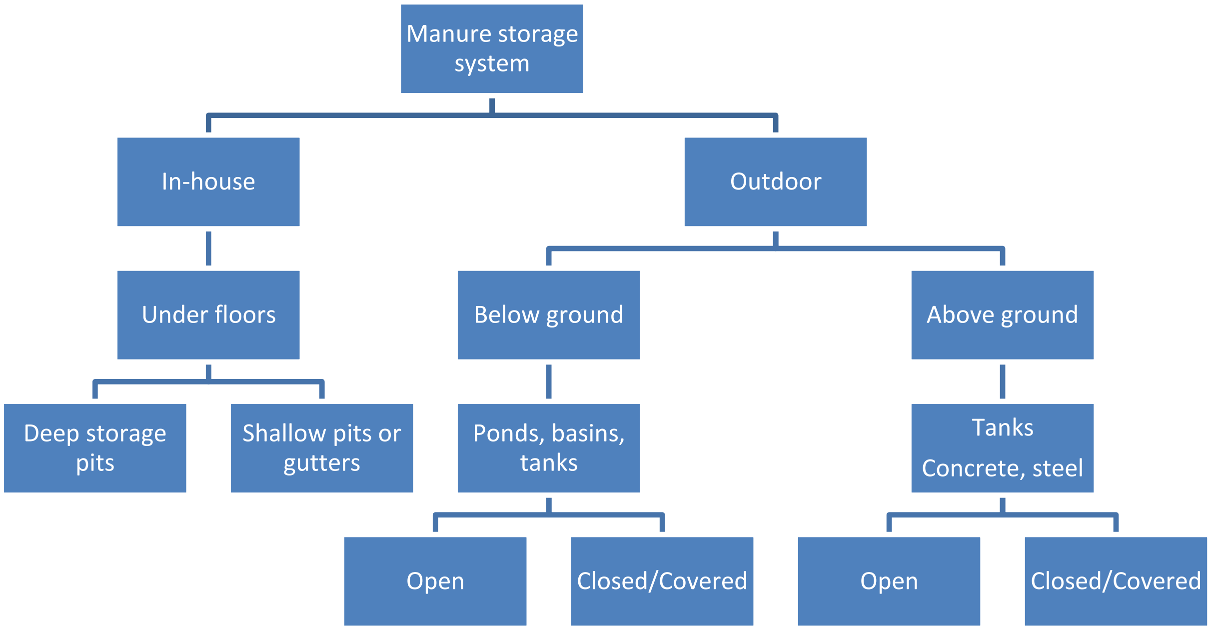


Figure 3.2. Various options for manure storage systems.

3.4.1 Slurry

Slurry stored under anaerobic conditions offers good opportunities for minimizing nitrogen losses during storage. Indoor storage systems under slatted floors must have well-designed ventilation system so gases do not adversely affect animal health.

With regard to minimizing nutrient loss from manure storage facilities, design considerations should include the following:

- Minimize surface area to volume ratio and restrict exposure to air
- Roofs or floating covers, prevents air flow at the manure surface
- Filling below cover or crust, which restricts fresh manure exposure to air and reduces ammonia losses
- Agitation should be minimized.

Floating natural crusts when straw litter is used can function well as covers against ammonia losses (Karlsson, 1996); however, they do not keep rain water from diluting the slurry. Roofs or other floating covers are available in a number of different designs and materials. A roof is also advantageous in that it keeps out rain water which otherwise further dilutes the fertilizer value of the slurry.

3.4.2 Solid manure

Solid and semi-solid manure storage facilities are hard manure pads, commonly made of concrete with one or more supporting concrete walls to increase the stackability of the manure. Leachate from the manure pile should be collected and piped to a urine or slurry basin, particularly if the pad is not covered. Solid manure can also be stored in field heaps, but these should not be located close to drainage ditches or waterways. During storage, solid manure has generous access to air and ammonia losses are much larger than from slurry. Different litter types have different abilities to bind ammonia and therefore choice of litter can affect ammonia losses (Andersson, 1996; Misselbrook & Powell, 2005).

3.5 Land application

Spreading manure on land as a fertilizer is the final step in the manure handling chain. The objectives here should be to maximize fertilizing potential and minimize losses to the environment with consideration to the following points:

- Time the application to when plants can utilize the available nutrients
- Apply a correct dose according to crop needs and the nutrient concentration in the manure
- Use appropriate spreading technology to spread evenly
- Use appropriate technologies that adjust the spreading rate depending on the speed of the tractor
- Incorporate the slurry as soon as possible after spreading, preferably immediately after spreading or within 4 hrs.
- Avoid spreading on environmentally sensitive areas (adjacent to waterways etc..)

3.5.1 Slurry

Trailer mounted tankers pulled by tractors are the most common used system for spreading slurry on fields. An umbilical hose system, where the slurry is pumped through a hose to the tractor that is equipped with distribution equipment significantly reduces the weight load and possibility of soil compaction compared to tanker systems. Irrigation systems, where the slurry is diluted and spread with broadcast techniques using typical irrigation systems. Tanks can be equipped with vacuum systems for filling and empting the tank or with a pump (centrifugal or positive displacement). There are various distribution mechanisms that can be attached to the slurry tank including:

- Broadcasting – mechanically simple, high ammonia and odour emissions, uneven spreading
- Band spreading (trailing hoses, trailing shoes) – consists of a low trajectory boom with trailed hoses so the slurry is applied directly onto soil surface leading to less splashing on leaves and lower ammonia emissions
- Injection – slurry applied directly into the soil and emissions are greatly reduced

3.5.2 Solid manure

Solid manure spreaders consist often of a trailer with an open container and a bottom bed conveyor, which transports the load to the spreading device. The spreading equipment is usually horizontal or vertical beaters with wings (one-step spreaders). Two-step spreaders typically use the vertical beaters to deliver manure to horizontal spinning discs, which gives a wide working width and the possibility for lower application rates. Spreaders intended for wetter solid manure or semi-solid manure may have a screw for transporting the manure to the spreading device, which could be one or two spinning discs.

4 European Legislation

In the European Union there are several agreements for reducing the impact from agriculture and other industries on water and air quality. The EU Nitrate Directive (EEC, 1991) requires member states to introduce measures to reduce water pollution caused or induced by $NO3^-$ from agricultural sources and to prevent further such pollution through a number of steps to be fulfilled by Member states, i.e.:

- Water monitoring (with regard to NO_3^- concentration and trophic status).
- Designation of nitrate vulnerable zones (NVZ).
- Establishment of national action programmes (a set of measures to reduce NO_3^- pollution).

The water framework directive (2000/60/EC) safeguards the sustainable use of water resources, and has introduced a river basin management planning system.

For controlling emissions of harmful gases, like ammonia, there is a directive (2001/81/EG) on national emission ceilings for certain atmospheric pollutants. Member states must make commitments to ensure the emissions do not exceed the ceiling numbers. As the main source of ammonia is from manure handling, the limitation of ammonia emissions concerns mainly the agricultural sector.

The HELCOM Baltic Sea Action Plan (BSAP) is an ambitious program to restore the good ecological status of the Baltic marine environment by 2021. In order to achieve a Baltic Sea unaffected by eutrophication, i.e., concentrations of nutrients (N and P) close to natural levels, countries have agreed on reduced nutrient loads from waterborne and airborne inputs. They will take actions no later than 2016 aiming at reaching good ecological and environmental status by 2021. Targets for P and N reduction are set per country.

The directive on industrial emissions 2010/75/EU (IED) sets out the main principles for the permitting and control of installations based on an integrated approach and the application of best available techniques (BAT) which are the most effective techniques to achieve a high level of environmental protection, taking into account the costs and benefits. The IED replaced the Industrial Pollution Prevention Control (IPPC) Directive in January 2011 (EUR-Lex, 2010). Agriculture was included in the IPPC and is also included in the IED concerning industrial sized livestock producers of pigs and poultry. Work is on-going to specify BAT for animal production and manure handling on IED regulated farms.

5 Methodology

Case study methodology was chosen, as there was no knowledge about the present situation how manure is handled on large-scale farms in the BSR. This knowledge is needed as a starting point, in order to be able to suggest changes by using innovative and economically viable technologies for handling and processing manure in an environmentally-friendly and user-friendly way on big farms in the BSR. Through such case study, you exchange knowledge, and get an understanding for the different conditions in different countries. The good examples could be identified, and later implemented on other farms, as well as in other regions or countries.

5.1 Choosing the case-study farms

In order to describe current manure handling techniques used on large-scale livestock farms around the Baltic Sea, detailed surveys were conducted on five case-study farms in each of the following countries: Estonia, Finland, Latvia, Lithuania, Poland and Sweden. Two dairy farms, two pig farms and one poultry farm were recommended for the case-studies in each country, depending on the dominate livestock systems in each country. Case-study farm descriptions were chosen as our methodology essentially to provide detailed background data that could give insights into differences in manure characteristics from repeated sampling events on the same case-study farms. Determining current farm-level manure characteristics on large-scale farms in the BSR by sampling and analysing is also a task in work package 3 of Baltic Manure; however the results of this sampling will be presented in a separate report. Each partner was free to decide, which farm to choose. It was implied it should not be farms with old-fashion handling technologies, instead good examples for finding innovative and economically viable technologies for handling and processing manure in an environmentally-friendly and user-friendly way on big farms in the BSR.

The minimum size of pig and poultry farms for the case-study farms was set to the size that requires regulation by the EU IED (described above) and can be seen in Table 5.1. Dairy farms are currently not regulated by the IED. In order to compare farms with various types of livestock and herd configurations, animal numbers can be converted into livestock units (LU) by multiplying with conversion coefficients for specific animal types. Conversion coefficients are usually based on 1 LU being equal to 1 lactating cow; however the relation to other animals is further dependent on the size of the cow and the production level. Numerous schemes have developed for calculating LU however most are intended for comparing grazing or feeding requirements. To maintain consistency in the analysis of the large-scale farms in this study, we defined the LU conversation coefficients (Table 5.2) according to the Official Journal of the European Union (L 391 15.12.2009, p. 3) and which can also be currently found at:
http://epp.eurostat.ec.europa.eu/statistics_explained/index.php/Glossary:Livestock_unit_(LSU)

Table 5.1. Minimum number of livestock places on farms included in the Case-studies. Limits for pigs and poultry are equal to that which is regulated by the EU IED.

Livestock species	Category	Number of places	LU
Dairy cattle	Milking cows	300	300*
Pigs	Finishers (over 30kg)	2 000	600
	Sows	750	375
Poultry	Broilers / laying hens	40 000	280 / 560

*not including additional LU for heifers, calves and bulls on farm.

Based on the range of LU calculated for the regulated pig and poultry farms, the minimum (recommended) size of the case-study dairy farms was set to 300 milking cows, since accounting for the total herd size, including heifers and dry cows, total LU would be even greater and fall within the LU ranges for pig and poultry farms.

Table 5.2. Coefficients for calculating general livestock units (LU) from various species and ages according to the European Commission (see link in text above).

Livestock species	Age or category	LU coefficient
Bovine animals	Under 1 yr.	0.4
	Between 1-2 yrs.	0.7
	Male, 2 yrs. and over	1.0
	Heifers, 2 yrs. and over	0.8
	Dairy cows	1.0
	Other cows, 2 yrs. and over	0.8
Pigs	Piglets under 20kg	0.027
	Breeding sows over 50kg	0.5
	Other pigs	0.3
Poultry	Broilers	0.007
	Laying hens	0.014

Livestock density for each farm was calculated by dividing the farms LU by the total agricultural area on the farm available for spreading manure, including owned and rented land.

5.2 Manure handling surveys

To ensure that comparative information on manure handling chains was obtained from all case-study farms in all countries, a survey form was drafted (see Appendix 1) with the goal of obtaining information concerning all aspects of farm-level technology and management that can impact manure characteristics. The manure handling surveys were based on the farm system model in Figure 5.1. The surveys covered general livestock information, production specifics, diet composition, a detailed description of the housing systems and in-house manure transport system, storage systems, manure treatment, manure application techniques and land area and crop information.

One of the objectives of this work was to identify barriers that are preventing farmers from implementing already available technologies and techniques for effective utilisation of nutrient and energy resources in manure. The owner or all manager of each case-study farm in each country was questioned about difficulties they encountered in managing their manure, what they would like to improve about their manure management system, and barriers they encountered to adapting new techniques.

The survey was to be conducted by a country expert in the form of an interview directly with the farmer. A draft survey was tested in Sweden on a finisher pig farm with approximately 3000 places. After testing, the draft was revised, and then modified for dairy and poultry farms respectively. See Appendix 1 for actual survey forms used.

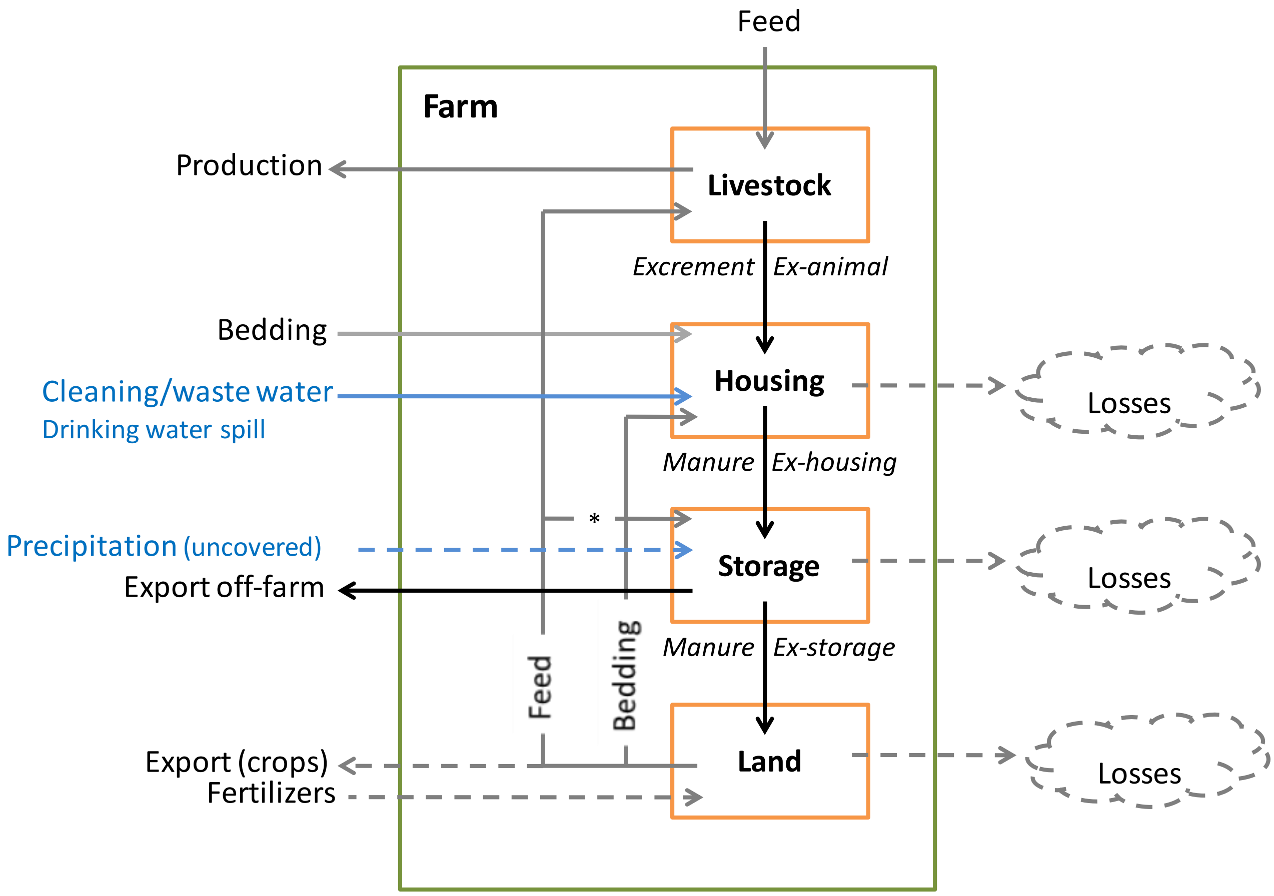


*Figure 5.1. Farm system (green). Major system components (brown) of a manure handling system. Other boxes for processing/treatment can be included either before or after storage. Black arrows are manure flows and blue arrows are water additions to manure that are relevant for determining manure characteristics. Gray arrows are other potential nutrient and mass flows which should be considered in an analysis of manure management. Broken arrows are significant in terms of farm management but are not accounted for in the surveys. * Flow from feed/bedding to storage can be silage leachate, dumping of bad feed, or addition of straw to form a natural crust. (This figure is modified from Poulsen et al., 2006).*

6 Description of case-study farms

Dairy, pig and poultry farm descriptions from Estonia, Finland, Lithuania, Latvia, Poland and Sweden are presented in detail here together with additional information in Appendix 2.

6.1 Estonia

Allan Kaasik and Hannelore Kiiver, EMU (Farms 1-5)
Kalvi Tamm, ERIA (Farm 6)

6.1.1 Dairy farms

6.1.1.1 Farm 1

Farm 1 is the experimental farm of the Estonian University of Life Sciences. The farm is located in the middle of Estonia (58 ° 36’ N) near Tartu. Farm data details are presented in Tables 1 – 7 for Estonia in Appendix 2. Farm 1 has 124 milking cows and a total herd size of 212 animals. The herd is 90% Estonian Holstein, 7% Estonian Red and 3% Estonian Native cattle and production average is 9 400 ECM per cow per year. Farm 1 has loose housing systems in semi uninsulated barns and manure handling is slurry based with a manure production of about 6 500 m^3 per year.

Feeding

The feeding is based on total mixed rations (TMR) for one group of cows and partially mixed rations (MR) plus feeding automats rations for the group milked by robots. The roughages are produced on farm. Grass silage (Gramineae, Leguminosae or theirs mix) is made in storages. Concentrates and mineral feeds are purchased off-farm.

Livestock housing

There are 2 animal housing units (see Figure 6.1.1) on the farm:

- Main barn for milking cows with 125 places with both a milking parlour and milking robot – H1
- Barn for calving, dry cows, heifers and calves 125 places – H2

The farm 1 was built in 2008. Both cowsheds are un-insulated loose housing buildings with 125 places for milking cows (H1) and 125 places for dry cows, calving and heifers (H2). The building is naturally ventilated by adjusting the roof ridge openings and wall curtains. The building has a DeLaval parallel milking parlour with 8 places and a DeLaval milking robot. Farm office and personnel room with toilets and showers are also inside. Reciprocating cable pulled scrapers remove manure from the 2 (H1) and 3 (H2) parallel main concrete passages covered with rubber mats and deposit it into a covered (slatted floor) cross channel at the end of the barn. The scrapers (Houle) operate once per hour in the summer and continually in the winter to minimize freezing risk. Approximately 270 m^3 of peat are used as bedding material per year. The cross-channel empties via mechanical removal into a 70 m^3 below-ground, concrete, manure pit (MP) just outside of the barn. The cross-channel is emptied 2 times per week. The volume of water added to the slurry is about 320 l per day (117 m^3 per year).

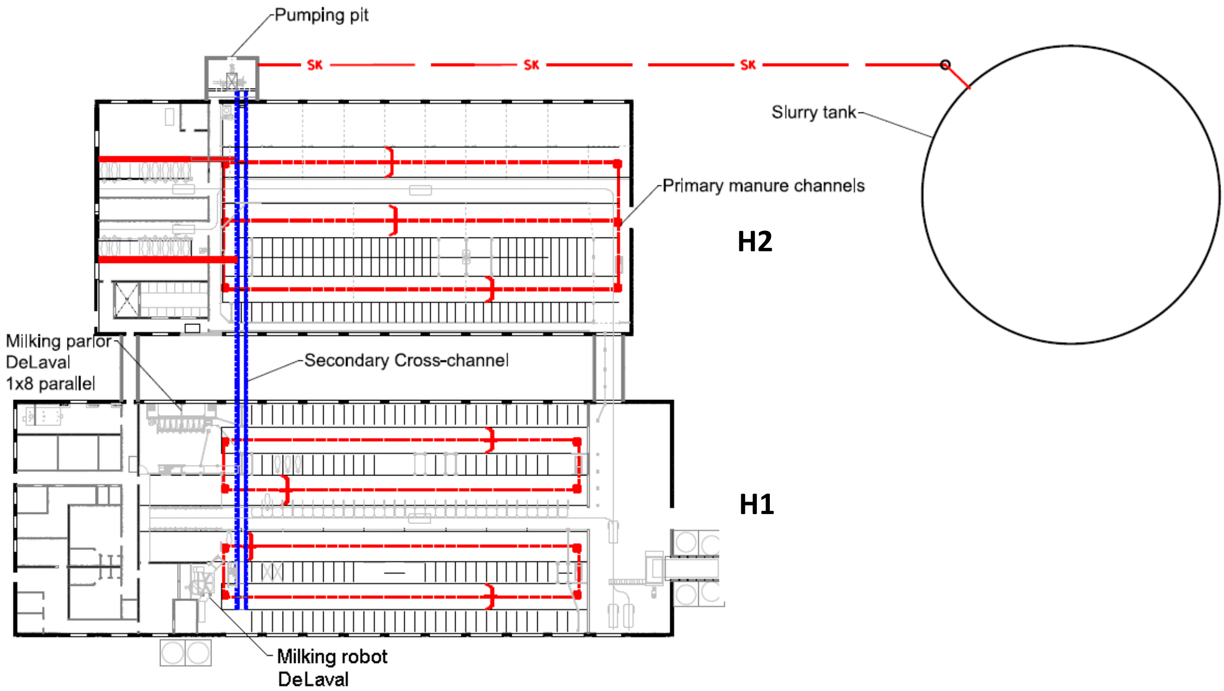


Figure 6.1.1. Cowsheds H1 and H2 on farm 1, including the manure pit (pumping pit) and the storage tank (slurry tank).

Manure storage

There is 1 primary storage facility on Farm 1 (Figure 6.1.2). The storage is a round concrete tank with a capacity of 4 630 m^3. Storage is partially below-ground and made with pre-fabricated concrete panels. Storage is covered with armed concrete roof. Slurry is pumped from MP about 100 meters to the storage and filled below the surface. Slurry mixing in storage tanks takes place immediately prior to spreading is done with a three stationary propeller mixers.

Figure 6.1.2. Picture of liquid manure storage tank (S) with stationary propeller mixers and unloading pipe.

Manure end-use

Farm 1 has 130 ha of grassland available for spreading manure. All manure spread with band spreading techniques. Grasslands receive of 40 t/ha of manure. Soils range from heavy clay to loam. Manure left from own use is given to contracting farmer (cereals).

The farm does not have its own equipment for slurry transportation and spreading so all manure spreading is hired in from a local contracting company with its own equipment.

6.1.1.2 Farm 2

Farm 2 is located in middle Estonia (58 ° 22’ N) near Tartu. Farm data details are presented in Tables 1 – 7 for Estonia in Appendix 2. Farm 2 has 520 milking cows and a total herd size of 1088 animals. The herd is 61% Estonian Holstein and 39% Estonian Red cattle and production averages 10 470 ECM per cow per year. Farm 2 has loose housing systems in un-insulated barns and manure handling is slurry based with a manure production of about 14 000 m^3 per year.

Feeding

The feeding is based on total mixed (TMR) rations. The roughages are produced on farm. Grass (Gramineae, Leguminosae or theirs mix) and corn silage is made in storages. Cereals, mostly barley are also produced on farm. Concentrates (for example rape seed cake) and mineral feeds are purchased off-farm. Special feed additive “Optigen” is used in farm 2 which improves nitrogen use-efficiency for rumen microorganisms. Feeding strategies are not considered as a part of farm-level manure management practices.

Livestock housing

There are 7 animal housing units (see Figure 6.1.3) on the farm:

- New barn for milking cows with 520 places with milking parlour – H1
- Barn for calving and dry cows, 80 places – H2
- Barn for calves, 100 places – H3
- Barns for heifers, 260 places – H4, H5
- Barns for young bulls, 160 places – H6, H7

Farm 2 was built in the 1960’s. During the most recent decade all cowsheds have been renovated (H2-7). In 2008, a new uninsulated loose housing cowshed with 520 places for milking cows (H1) was built. The building is naturally ventilated by adjusting the roof ridge openings and wall curtains. The cowshed has DeLaval Cascade parallel milking parlour with 2 x 10 places. The farm office and personnel room with toilets and showers are located in milking parlour building (Figure 6.1.4). Reciprocating cable pulled scrapers remove manure from the 4 parallel main concrete passages and deposit it into a covered (slatted floor) cross channel at the middle of the barn. The scrapers (Houle) operate 8 times per day. Approximately 58 tonnes of sawdust and 4.8 tonnes of slaked lime ($Ca(OH)_2$) are used as bedding material per year. The cross-channel empties via hydraulic removal into a 70 m^3 below-ground, concrete, manure pit (MP) just outside of the barn. The cross-channel is emptied 2 times per day in summer and 8 times per day in winter. The volume of water added to the slurry is about 1680 l per day (613 m^3 per year).

Other cowsheds (H2, H3, H4, H5, H6, and H7) are renovated insulated loose housing buildings with natural ventilation and pens with bedding. The pens are cleaned weakly with a tractor mounted front loader. Straw bedding is used all the year. The solid manure is deposited temporarily into the storages (S2, S3, S4, S5, and S6) located at the ends of the barns. Two times per month the solid manure are removed to the field heap.

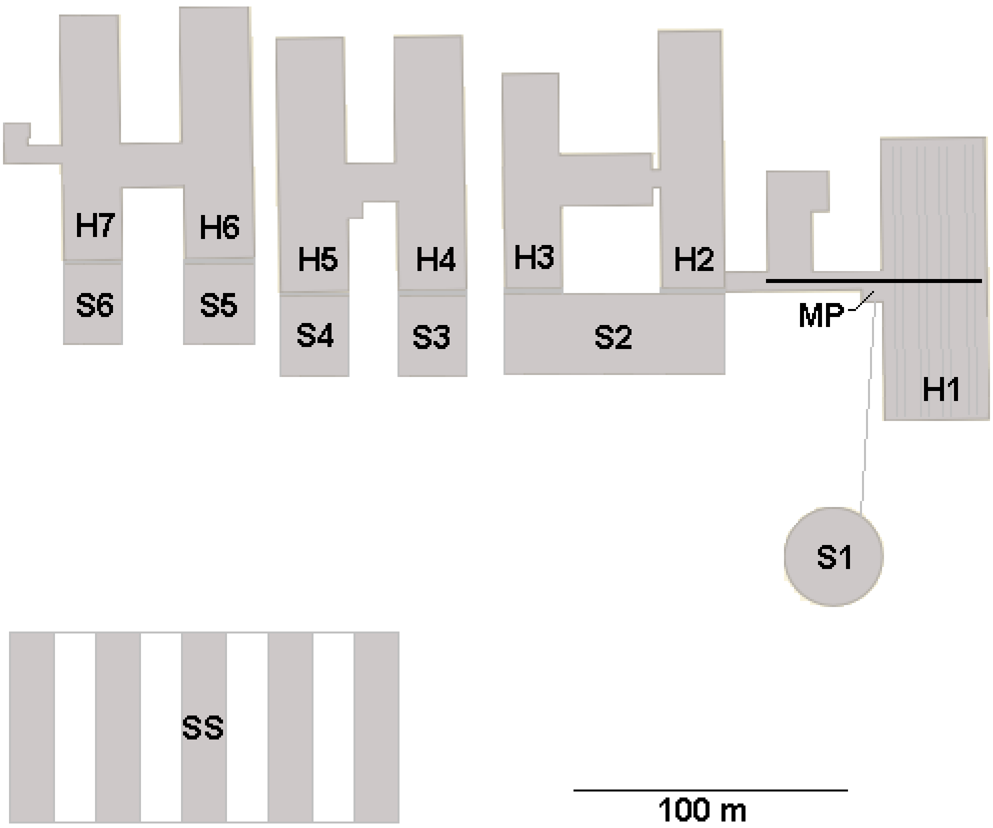


Figure 6.1.3. Layout of animal housing units (H1, H2, H3, H4, H5, H6, H7), manure pit (MP), liquid manure storage tank (S1), solid manure storages (S2, S3, S4, S5, S6) and silage storages (SS) on Farm 2.

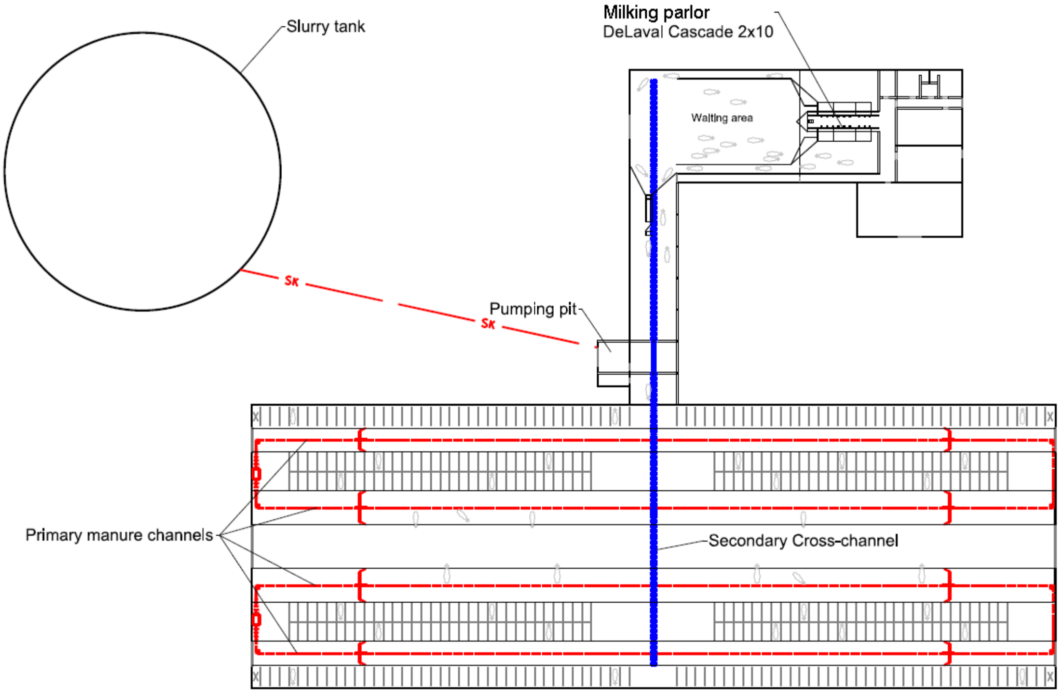


Figure 6.1.4. Cowshed H1, including the milking parlour, manure pit (pumping pit) and the storage tank (slurry tank).

Manure storage

There is 1 primary storage facility on Farm 2 for liquid manure. The storage (S1) is a round concrete tank with a capacity of 6000 m^3. Storage is partially below-ground and made with pre-fabricated concrete panels. Storage is uncovered but has well-formed natural crusts and is filled below the surface. Slurry is pumped from MP about 100 meters to storage. Slurry mixing in storage tanks immediately prior to spreading is done with a tractor mounted propeller mixer.

Manure end-use

The company that owns farm 2 has 3200 ha of arable land for manure spreading. The company also has two additional animal production units that are not included in this case-study description, one dairy and one pig farm. There is a total of 4400 LU including all three production units, one of which is Farm 2. All manure is spread on land owned by the company. The company has some equipment for manure transportation and spreading (band spreaders with trailing hose applicators) but they use also spreading service in time of intensive spreading of manure.

6.1.1.3 Farm 3

Farm 3 located in east Estonia (58 ° 49' N) not far from Lake Peipsi. Farm 3 is conventional. Farm data details are presented in Tables 1 – 7 for Estonia in Appendix 2. Farm 3 has 585 milking cows and a total herd size of 1 135 animals. The herd is 100% Estonian Holstein cattle with production average 10 133 ECM per cow per year. Farm 3 has loose housing systems in uninsulated barns and manure handling is slurry based with a manure production of about 14 000 m^3 per year.

Feeding

The feeding is based on total mixed (TMR) rations. The roughages are produced on farm. Grass (Gramineae, Leguminosae or theirs mix) and corn silage is made in storages. Cereals, mostly barley are also produced on farm. A concentrates (for example rape seed cake) and mineral feeds are purchased off-farm. General description of the feeding system presented in Table 3 for Estonia in Appendix 2.

Livestock housing

There are 3 animal housing units (see Figure 6.1.5) on the farm:

- New barn for milking cows with 600 places with milking parlour – H1
- Barn for calving and dry cows – H2
- Barn for calves and heifers – H3

The farm 3 was built in seventies of last century. During the last decade all cowsheds are renovated. 2003 was built new un-insulated loose housing cowsheds with 600 places for milking cows (H1). The building is naturally ventilated by adjusting the roof ridge openings and wall curtains. The cowshed has a 2 x 10 places parallel milking parlour Strangko. The farm office and personnel room with toilets and showers are located in milking parlour building. Reciprocating cable pulled scrapers remove manure from the 4 parallel main concrete passages and deposit it into a covered (slatted floor) cross channel at the middle of the barn. The scrapers (Houle) operate multiple times per day. Approximately 4t disinfection material Delta sec are used per year, bedding are not used. The cross-channel empties via hydraulic removal into a 20 m^3 below-ground, concrete, manure pit (MP) just outside of the barn. The cross-channel is emptied 2 times per day in summer and multiple times per day in winter.

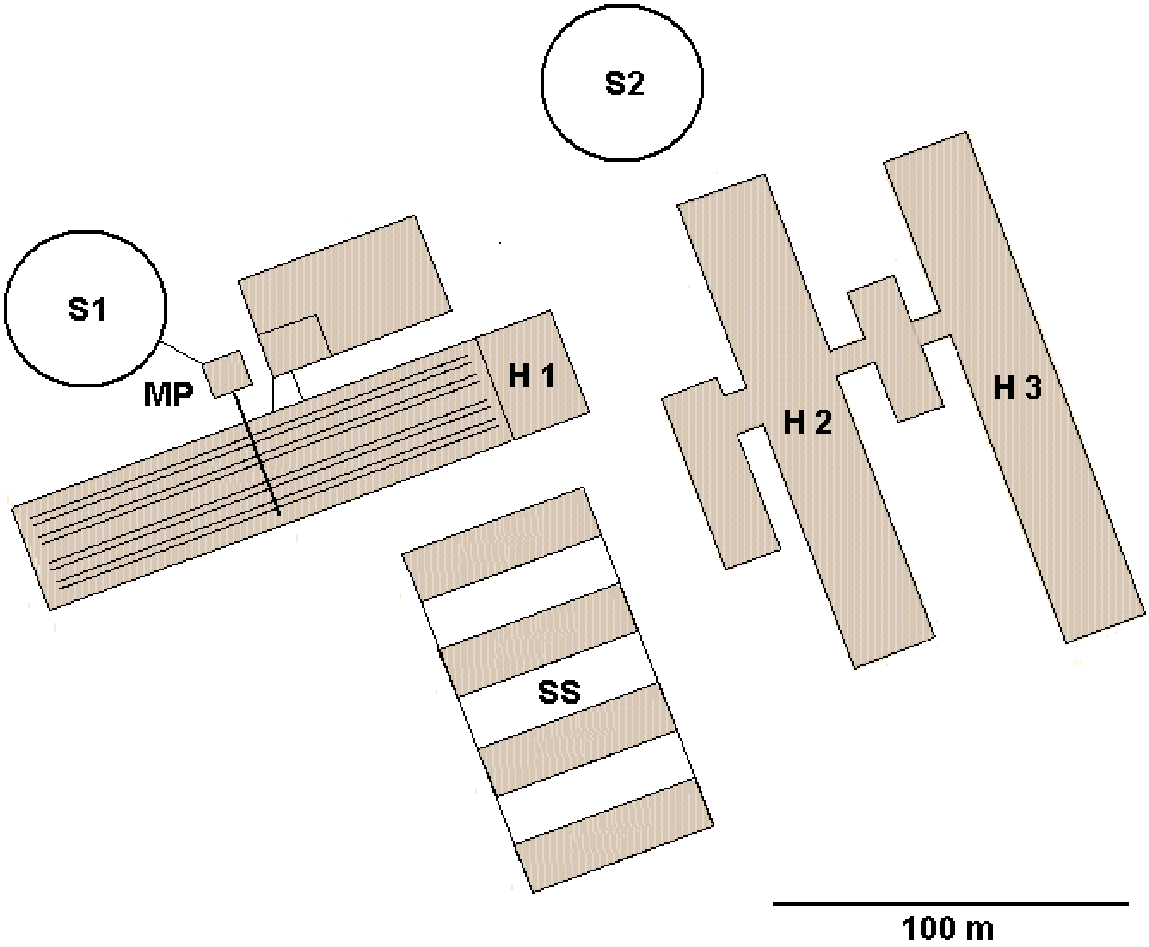


Figure 6.1.5. Layout of animal housing units (H1, H2, H3), manure pit (MP), liquid manure storage tanks (S1, S2) and silage storages (SS) on Farm 3.

Other cowsheds (H2, H3) are renovated un-insulated loose housing buildings with natural ventilation and pens. Reciprocating cable pulled scrapers remove manure from the 4 parallel main concrete passages and deposit it into a covered (slatted floor) cross channel at the middle of the barn. The scrapers (Houle) operate multiple times per day. The liquid manure is deposited into the storage (S2) located on top of barns. Small quantity of straw is used as bedding material in calving area.

Manure storage

There is 2 primary storage facilities on Farm 3 for liquid manure (S1 for barn H1; S2 for barn H2 and H3). Both storages (S1, S2) are round steel tanks with a capacity of 8 900 m^3. Storages are partially below-ground. Storages are uncovered but have well-formed natural crusts and is filled below the surface. Slurry is pumped from MP about 50 meters to storage. Slurry mixing in storage tanks immediately prior to spreading is done with a tractor mounted propeller mixer.

Manure end-use

Company has 2300 ha arable land for manure spreading and only one animal unit (farm 3). All manure is used on its own land. All manure is spread with band spreading techniques. The company has a 15 m^3 “Samson” band spreader with trailing hose applicators and 17 m^3 “Zunamer” open slot injector spreader. Grasslands receive of 20 t/ha of manure during vegetation period. For cereals and rapeseed the liquid manure consumption rate per hectare is also 20 tonnes per ha.

6.1.2 Pig farms

6.1.2.1 Farm 4

Farm 4 is largest pig producing unit in Estonia. The farm is located in the middle of Estonia (58 ° 20' N) near the town of Viljandi. Farm 4 is conventional. Farm data details are presented in Tables 1 – 7 for Estonia in Appendix 2. Farm 4 has 36 000 places for fatteners and 10 500 places for breeding and young sows. Total number of fatteners produced per year 65 000. Starting weight of fattening is 7 kg and delivery weight 113-115 kg. Time from start to delivery is 165-170 days. Manure handling is slurry based with a manure production of about 60 000 m^3 per year.

Feeding

All feeds are purchased off-farm in the form of concentrates. The concentrates for all pig groups are produced in company "Farm Plant Estonia". Liquid feeding technology is used.

Livestock housing

There are 4 animal housing units (see Figure 6.1.6) on the farm:

- Facility for finishers – H1
- Facility with section for sows before farrowing and section for lactating sows – H2
- Facility with sections for gestation and young sows – H3
- Facility with sections for gestation sows and farrowing section –H4

This farm uses an indoor batch pen housing system with partially slatted floors. The buildings were built in seventies of last century and renovated during the last decade. Buildings are closed with forced ventilation and heating. Buildings are divided into identical sections (see figure 6.1.6). Bedding material is not used. The boxes are scrapped manually once a day. Each section has one primary manure channel covered by the slatted floors. Primary manure channels are emptied once per day (gravity, vacuum). The manure transports by gravity flow from the cross-channel to the manure pits (MP1, MP2, MP3, and MP4) just outside the building, from there manure pumped once per day to the main MP. The main MP is 250 m^3 which has a storage capacity of 1-2 days. Cleaning of the sections is done by a washing once per month. Approximate water amount for cleaning is 5000m^3 per year.

Manure storage

There is primary storage area (S1-S10) with 10 liquid manure storages. The storage tank is round, partially below-ground and made of pre-fabricated concrete panels with a capacity of 6000 m^3. Slurry is pumped from main MP about 800 meters to S1. The pump in main MP also has the possibility to pump slurry from farm area to a satellite storage area (S11-S13, lagoon) 1.5 km away that has a capacity of 40 000m^3. The primary storages are covered with floating cover (floating Leca pebbles) to reduce ammonia emission, and filling occurs below the cover.

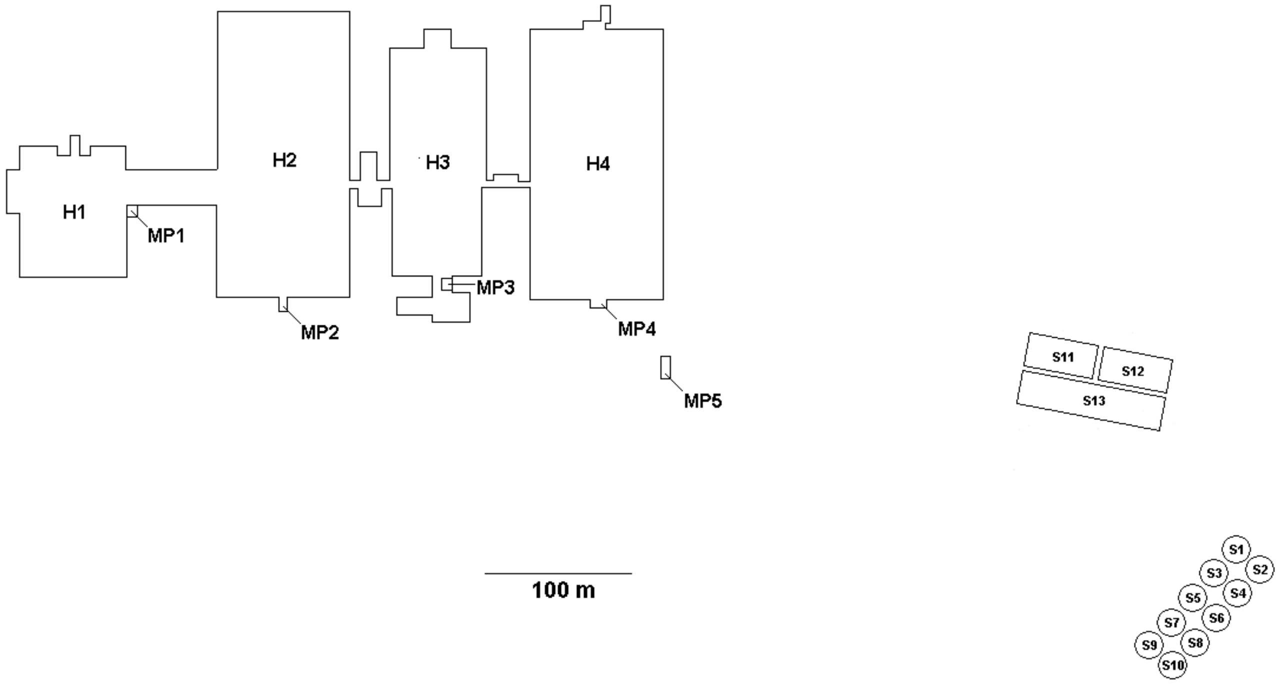


Figure 6.1.6. Layout of animal housing units (H1, H2, H3, H4), manure pits (MP1-5), primary liquid manure storage tanks (S1-10) and reserve manure storage lagoons (S11-13) which are 1.5 km from the primary storage.

Manure end-use

Farm 4 has over 46 000 ha of arable land available for spreading manure (Contracts with cereal growers). All manure is used on these farms as fertilizer and all fields for spreading are within 0-35 km of the storage facilities. Spring cereals receive 20-25 t/ha slurry during the spring and winter cereals receive between 10-15 t/ha during the autumn. Manure incorporated to the soil within 4-24 h after spreading.

Farms 4 have all manure spreading equipment: 8 band spreaders, 4 slurry tankers with 16 m^3 capacity (short distance, 0-7 km), 4 slurry tankers with 15 m^3 capacity (on field) and 6 slurry tankers with 22 m^3 capacity (long distance).

6.1.2.2 Farm 5

Farm 5 is a contractor farm of unit 4. Farm located in southeast Estonia (58 ° 3’ N) near town Põlva. Farm 5 is conventional. Farm data details are presented in Tables 1 – 7 for Estonia in Appendix 2. Farm 5 has 12 212 places for fatteners. Total number of fatteners produced per year 24 850. Starting weight of fattening is 7 kg and delivery weight 113-115 kg. Time from start to delivery is 165-170 days. Manure handling is slurry based with a manure production of about 18 000 m^3 per year.

Feeding

All feeds are purchased off-farm in the form of concentrates. The concentrates for all pig groups are produced in company “Farm Plant Estonia”. Liquid feeding technology is used.

Livestock housing

There is one animal house (see Figure 6.1.7) on the farm:

- Facility for finishers – H1

This farm uses an indoor batch pen housing system with partially slatted floors. The building was renovated some year ago. Building are closed with forced ventilation and heating. Building is divided into identical sections. Bedding material is not used. The boxes are scrapped manually once a day. Each section has one primary manure channel covered by the slatted floors. Primary manure channels are emptied once per day (gravity, vacuum). The manure transports by gravity flow from the cross-channel to the manure pit (MP1) just outside the building. The MP is 25 m^3 which has a storage capacity of 1-2 days. Cleaning of the sections is done by a washing once per month. Approximate water amount for cleaning and spill from drinking system is 600m^3 per year.

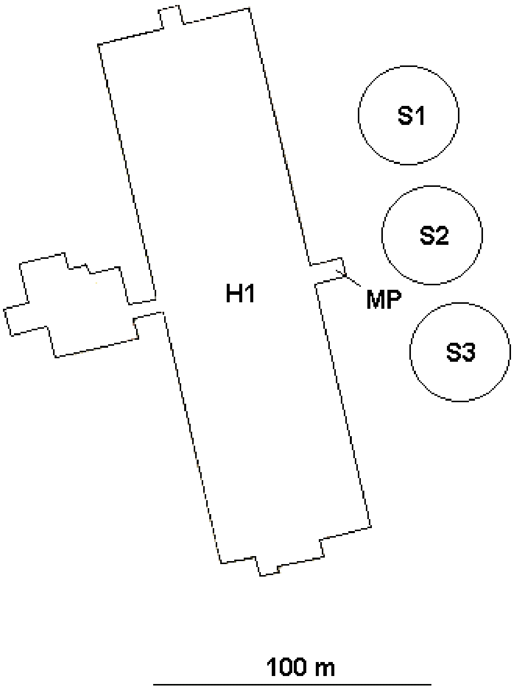


Figure 6.1.7. Layout of animal house (H1), manure pit (MP) and liquid manure storage tanks (S1-3) on Farm 5.

Manure storage

There are 3 primary liquid manure storages (S1). The storage tank is round, partially below-ground and made of pre-fabricated concrete panels with a capacity of 6000 m^3. Slurry is pumped from MP about 50 meters to S1. Storages are filled from the bottom. Storages are covered with floating cover (floating gravel) to reduce ammonia emission.

Manure end-use

Farm 5 has over 5500 ha of arable land available for spreading manure (Contracts with cereal crowers). All manure is used on these farms as fertilizer.

6.1.3 Poultry farm

6.1.3.1 Farm 6

Farm 6 is largest poultry farm in Estonia which has 11 operating production units and 1 is under reconstruction at the moment. Most of production units are located near to the Baltic Sea (Figure 6.1.8). Farm data details are presented in Tables 1 – 7 for Estonia in Appendix 2. Farm 6 has places for 1 200 000 broilers and 350 000 laying hens. The production is 74 000 000 eggs and 9 600 000 broilers annually. Farm 6 has loose housing systems and solid manure based manure handling system for broilers. The cages and slurry based manure handling system is used for laying hens. Farm produces 25 000 m^3 solid manure and 15 000 m^3 slurry annually. Currently, the farm makes reconstructions in the production units for laying hens. Bigger cages and solid manure based manure handling system is built for laying hens. Slurry based system is kept only in reproduction unit.

Figure 6.1.8. Location of production units of Farm5 in Estonia (Red dots and labels). Base map source: Estonia / cartographer Krista Mölder / Source: Based on Regio map data (KL-134) (http://www.estonneica.org/en/Topographic_map_of_Estonia/?max).

Feeding

The feeding is based on wheat and compound feed concentrate. All the feed is imported to the farm. Number of feeding days:

- Broilers 405 527 889
- Laying hens 101 463 930
- Chicken 45 142 500
- Breeding stock 19 292 000

These numbers are used to calculate amount of the compound feed per bird.

Feed	Kg per bird per day	P%
Wheat for broilers	0.016	0.35
Concentrate for broilers	0.088	0.7
Concentrate t for laying hens	0.098	0.65
Concentrate for starters	0.063	0.65
Concentrate for breeders	0.142	0.65

Annual amount of feed additives (kg) used on Farm5:

- Monocalciumphosphate 680 550
- Lysinsulphate 224 920
- Methionine 166 580
- Treonin 71 830
- Na_2CO_3 85 150
- NaCl 118 150
- Kolinchlorid 55 800

Livestock housing

There are 11 poultry housing units (see Figure 6.1.9) on the farm. Data source: IPPC reports

No.	Unit	Poultry type	Production capacity
1	Loo	Broilers	2 106 000 birds/yearly
2	Saha	Broilers	624,000 birds/yearly
3	Saha	Breeding stock chicken	82 500 birds/yearly
3	Ülgase	Breeding stock	18 500 birds/yearly
4	Kumna	Broilers	12 barns, 262 200 places, 1 704 300 birds/yearly
5	Rannamõisa	Broilers	20 barns, 490 000 places, 3 185 000 birds/yearly
6	Laabi	Broilers	14 barns, 305 900 places, 1 988 350 birds/yearly
7	Martna	Breeding stock	26 000 places
8	Koonga	Breeding stock	13 000 places
9	Pääsusilma	Breeding stock	13 500 places
10	Tellivere	Young birds	522 192 birds/yearly
11	Kulli	Laying hens	415 400 birds/yearly
12	Ebavere		1 664 000 birds/yearly (planned)

About 1 200 broilers are in one barn. There are about 16 starters per m^2. The delivery weight is 2.34 kg, number of days from starter to delivery is 38-42. There are 18 000 birds in delivered batch in average. Number of batches is 6.5-7.5 per year. The average weight gain is 58g per day. Feeding efficiency is 1.75.

For laying hens is used cage with size 3m x 1.5 m=4.5 m^2 and there are 60 hens. All 330 000 are purchased as starters. Production period is 9 months. Old hens are not sold but used in own slaughterhouse.

Units based on solid manure are after every delivery (38-42 days) fully cleaned with a tractor mounted front loader so that all deep-litter beds are changed before new portion of birds. Depth of bedding material is about 1-2 cm. 2500-3000 m^3 peat is annually used as bedding material. The tractor lifts the material to a tractor-pulled wagon which transports the manure to the storage. The storage is located away from farm.

		
Laabi unit	Saha unit	Ülgase unit
		
Kumna unit	Martna unit	Koonga unit
		
Rannamõisa unit	Kulli unit	Tellivere unit
		Ebavere unit is under reconstruction
Loo unit	Pääsusilma unit	

Figure 6.1.9. Housing production units of Farm 6.Source:Tallegg homepage http://www.tallegg.ee/kontakt/asukoht; Maaamet, http://xgis.maaamet.ee/xGIS/XGis Äripäev http://www.toostusuudised.ee/default.aspx?PublicationId=8e344abc-1566-4518-bce6-fa146c5664a3

In the units based on slurry have gridfloor and the basefloor under grid is cleaned by scrapers. Daily scrapers push the slurry to the collector channel. From collector channel the slurry is pumped to a collector tank located in the barn. The tank is emptied by pump mounted on a tractor-pulled slurry tank. 250 m^3 water is used to wash barns once per year.

Figure 6.1.10. Inside the Pääsusilma farm (built in 2011). Source Tallegg http://www.tallegg.ee/firmast/pildialbum-pressile/paasusilma-farm

Manure storage

Storages for solid manure. There is 1 primary storage facility in Saha. Farm 5 has contracts with service providers who transport the manure from barn to the Saha storage or own storages.
Saha solid manure storage has concrete pad for 8 month manure, partially periphery from concrete blocks (Fig 7.1.11) and precipitation water collector. Actually is stored about 20% from annual production because contractors transport most of the material from barn to the field or own storages.

Figure 6.1.11. Solid manure storage in Saha. Source Kalvi Tamm

Storage for slurry. Slurry storage locates in Loo and consists 4 tanks each 3500 m^3 and without cover. Slurry is agitated with stationary electrically driven mixer before delivery. Slurry is spread with broadcast distributor. Due to high dry matter content of slurry the spreading with any hose system is complicated. Farm5 has own slurry distributor used to spread slurry to the clients fields. After distribution the slurry is incorporated to the field.

Manure end-use

Solid manure is distributed by contractors to the fields belonging to local farmers. The distribution amount is 5-10 t/ha. Fertilised crops are oilseed rape, barley and wheat. Manure is distributed before seeding as well as on winter crops in spring time. Most of manure is distributed in 130 km radius around Tallinn. Contractor uses Fliegl and Samson solid manure spreaders.

Figure 6.1.12. Loading of solid chicken manure from field heap to the spreader. Source Kalvi Tamm

Figure 6.1.13. Solid chicken manure distribution in Mid-Estonia. Source Kalvi Tamm

6.2 Finland

Illka Sipilä, Pellervo Kässi, Tiina Kortelainen and Maija Karhapää (MTT)

Manure storage regulations for large-scale livestock farms:

- Storage capacity of 12 months for cows, minus pasture period and 12 months for pigs and poultry.
- Slurry storage must be covered with a stabile natural crust or some other method for reducing ammonia losses.
- Filling must occur below the cover.

Regulations that affect manure spreading on agricultural fields include:

- Land application from October 15th through April to February
- Must be incorporated to at least 10 cm within 12 hours of application
- Maximum 22 kg phosphorus (P) per ha and year or 110 kg P per ha over a 5-year period.

Since Finland as a whole is stated as nitrate vulnerable zone, following rules are applied:

- Land application on bare soils must be incorporated within 4 hours.
- Maximum 170 kg nitrogen (N) per ha and year. Maximum 60 kg N per ha on winter oilseed crops and maximum 40 kg N per ha on other winter cereals.
- Land application between August and October is only permitted in growing crops or just before sowing winter crops.
- No land application from October 15th through April 15th (in dry field conditions application is permitted until November 15th and can be started at April 1st).
- No land application on water saturated areas or on frozen or snow covered soils.
- No land application on slopes > 10% if the slope is facing a waterway.

6.2.1 Dairy farms

In Finland, year-round confinement is not allowed and if the cows are not loose housed the milking cows must have access to pasture during summer months. Housing systems with fully slatted floors and indoor manure storage in pits under the floors is not allowed. For detailed farm data see Tables for Finland in Appendix 2.

6.2.1.1 Farm 1

Farm 1 is a large dairy farm in Lammi County, and is located in southern Finland (60° 02' N). Farm data details are presented in Tables 1 – 7 for Finland in Appendix 2. Farm 1 has 215 milking cows and a total herd size of 430 animals. Average milk produced is 9100 kg/cow/year ECM. Farm 1 has loose housing systems and manure handling is slurry based with a manure production of about 5800 m^3 per year. There is a small amount of solid manure, approximately 180 m^3 produced in the service barn from the deep-litter bed calving stalls.

Feeding

The feeding is based on grass silage produced on farm. The 1st and 2nd cuts are made bunkers, the 3rd cut in large round bales. A full-mix ratio is made of silage and feed concentrate, which is purchased off-farm. Cows in milk receive about 33 kg silage from 1st and 2nd cut, 7,8 kg feed concentrate (Opti Maituri 15), 2.3 kg rapeseed cake, 0.1 kg yeast based feed additive (Optimelli) and 0,1 kg protected lipids. Young cattle are fed with whole crop silage of spring rye+peas or spring rye+alfalfa. Harvesting is done by a contractor.

Livestock housing

There are 2 animal housing units (see Figure 6.2.1) on the farm:

- Main barn for milking and dry cows with 300 places and milking parlour – H1
- Heifer barn 120 places

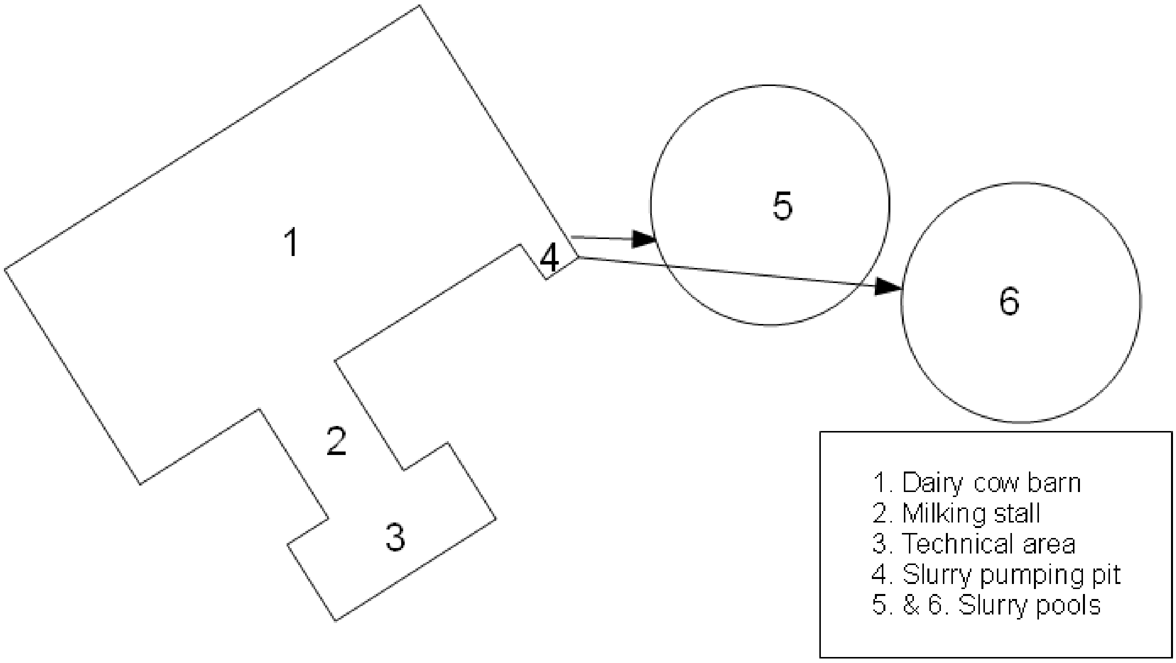


Figure 6.2.1. Layout of animal housing units 1, manure pumping pit (4) and manure storage tanks (5 and 6) on Farm 1.

The main housing (H1) was built in 2010-2011 in loose cubicle (freestall) design with 260 places for milking cows (Figure 6.2.2). The building is open sided, naturally ventilated by adjusting the roof ridge opening and side openings. The building has a 2x12 milking parlour, as well as the farm office and personnel room with toilets and showers. Manure is removed twice a day with a small loader from the 4 parallel main concrete passages and deposit it into a cross channel at the end of the barn. The main concrete passages slope about 1 % towards the cross channel. Approximately 1.5 m^3 of wood shavings or saw dust are used as bedding material per day (600 m^3 per year). The cross-channel empties via gravity flow into a 70 m^3 below-ground, concrete, manure pit (MP1) just outside of the barn. The milking parlour area is flushed once daily with wastewater collected from the milking parlour. The storage capacity of MP1 is 75 m^3 and it is emptied every 3rd day.

The first rinsing water from the milking parlour is pumped straight to slurry channel, rest of the rinsing and washing water is used for flushing the milking parlour floors. There is a separate, closed container for toilet waters.

There are five deep-litter calving pens. The deep-litter is removed 2-3 times a year. The used bedding material is straw and about 250 big round bales are used yearly.

Manure storage

There are 2 storage facilities on Farm 1. The main storages (S1 and S2) are round concrete tanks with a capacity of 4500 m^3 each. They are partially below-ground and made with pre-fabricated concrete panels. Slurry is mixed in MP and allowed to flow by gravity about 50 meters to S1, or about 80 meters to S2. Both S1 and S2 are uncovered but have well-formed natural crusts and are filled below the surface. Slurry mixing in storage tanks immediately prior to spreading is done with a tractor mounted propeller mixer.

An old, open silage bunker is used for storing the solid manure, about 150 meters from the barn. The storage capacity is 200 m^3. It is emptied once a year. In spring and fall the solid manure removed from the barns is spread directly on the fields.

Figure 6.2.2. Pictures of dairy farm 1.

Manure end-use

Farm 1 has 160 ha of arable land available for spreading manure. About 300 m^3 of manure is exported from the farm. All manure is used as fertilizer and spread with a 16 m^3 Veehuis Eurojects 3500 rolling coulterblade-based slurry injector in about one cm deep. The average distance to the fields is 1 km. The crop rotation in general is a 3-year ley followed by 1 or 2 years of cereals. The slurry is spread after the first silage cut and the leys receive 30 t/ha slurry. The leys are renewed by harvesting whole crop silage (spring rye+peas-ley or spring rye+alfalfa-ley). The farm yard manure is spread on these spring cereals with a Bergman 18S two stage manure spreader.

All slurry spreading is hired in from a local contracting company with its own equipment. The contractor uses Veenhuis slurry tanker with 16 m^3 tank, equipped with a Eurojects 3500 rolling coulterblade-based slurry injector.

6.2.1.2 Farm 2

Farm 2 is located in northern Pirkanmaa region (62N, 24E). There are 120 milking cows, 100 heifers and 43 calves situated in two barns. 80 % of the cattle are Holsteins and 20 % Ayshire breed. Average milk produced is 10 500 kg/cow/year ECM. 3000 m^2 of slurry is produced by the milking cows. Manure from young cattle is handled as dry manure.

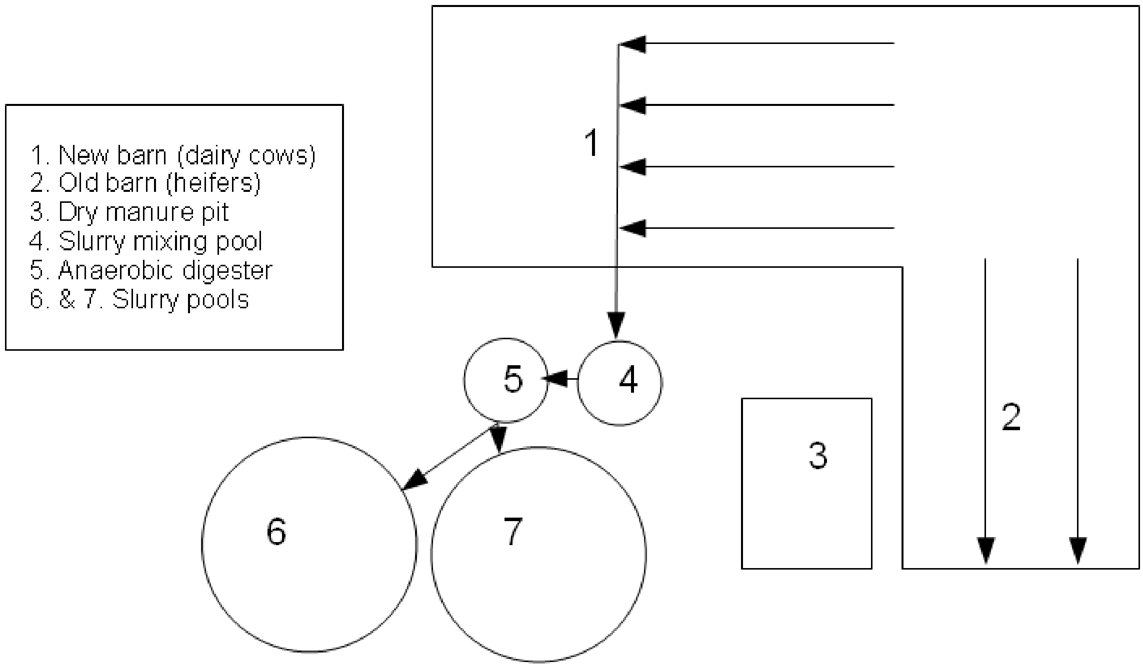


Figure 6.2.3. Layout of barns (1&2), dry manure pit (3), slurry mixing pool (4), anaerobic digester (5) and slurry storage tanks (6 & 7) on Farm 2.

Feeding

Feeding is based on TMR which is based on in farm produced grass silage that is mixed with whole grain silage, rapeseed meal, barley and concentrates feed. TMR consists of 54 % of grass silage. Some of the barley is produced on farm. The silage is harvested by contractor.

Livestock housing

The stall has been built in two phases: cold loose housing stall with deep litter was built in 1997. This barn serves for housing the young cattle and dry cows. Warm dairy cow stall with loose cubicles and slurry system with open manure channels was built in 2005. The manure is constantly being removed by a cable operated scraper. The stall is of 2+2 type with feeding aisle in the middle of the barn. Four primary manure channels are scraped empty to a deep cross channel that leads to the 300 m^3 mixing pool. The 8 m^3 slurry is pumped every day to anaerobic digester.

Beside manure, rinsing waters from two Lely A2 milking robots and waste milk are being flushed into the slurry pool.

Calving pens and small calves are housed on deep litter system. Deep litter is being removed once a year and spread directly to fields in the spring. Dry manure is cultivated into soil before tillage of barley. Aisle next to the feeding aisle is emptied once a week and the manure is store in roof covered pit. Peat (1800 m^3) and barley straw (400 round bales) are being used as bedding material in the deep litter barn. In dairy cow barn, peat (200 m^3 / year) is used as an additional bedding material on the rubber mats. All animals are permanently confined.

Manure storage

Slurry is stored in two 1500 m^3 subsoil concrete slurry pools that are being filled from the bottom. No cover is applied. Dry manure is stored in the barn as deep litter manure. Manure removed from the aisles of the cold barn is stored in a roof covered concrete pit.

Manure end-use

Slurry is processed in an anaerobic digester. The proceeding dung is then spread to grass fields in June and July after the first silage harvest. On grass fields the manure is spread with a shallow injector system with two disks and a 17 m^3 tanker. The slurry is spread by a contractor. Dry manure is applied to winter cereals. It is being spread with a spreader owned by the farmer together with another farm. Dry manure spread on the field is cultivated within four hours from the spreading.

6.2.2 Pig farms

6.2.2.1 Farm 3

Farm 3 is a fattening pig producer in Huittinen County and is located in Varsinais-Suomi (N 61° 3'). The farm has 3000 places for finishers, or fatteners, and a yearly production of 10 800 pigs. The manure handling system is slurry based with a yearly manure production of 6371 m^3**.** The initial body weight of arriving piglets is about 32 kg and pigs are slaughtered in the targeted body weight of 120 kg (slaughtering weight of 86 kg). The rearing time is about 100 days.

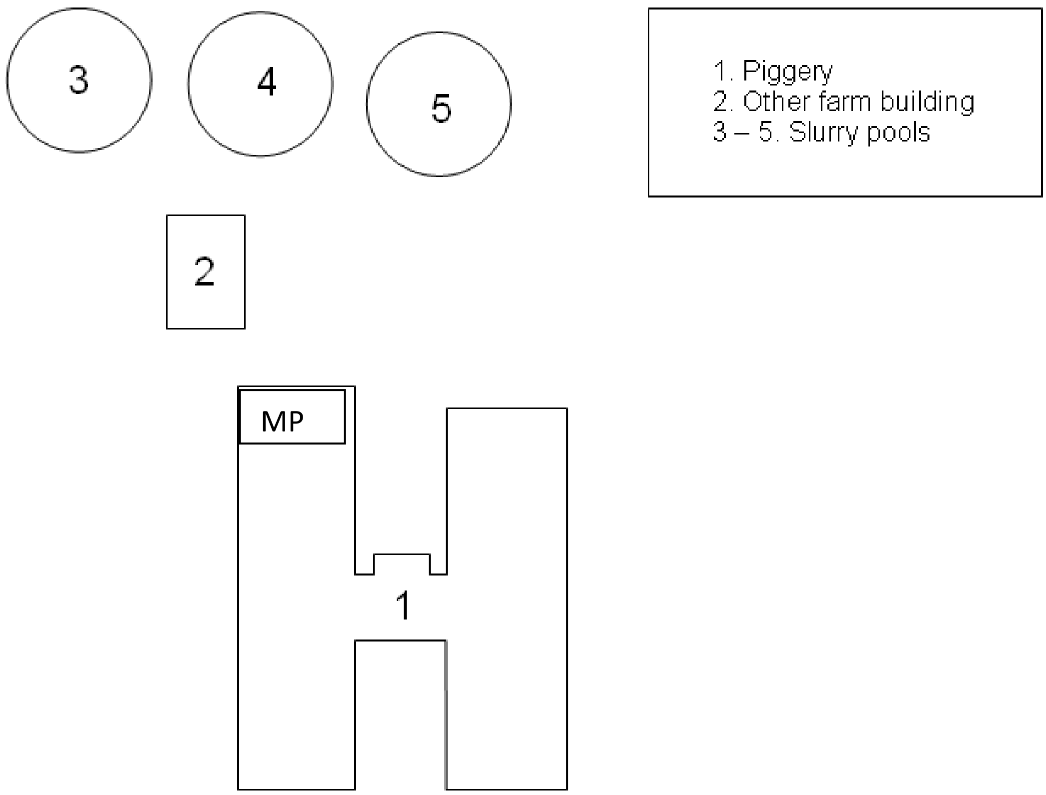


Figure 6.2.4. Layout of animal housing unit (1), manure pit (MP) and primary manure storage tanks (3, 4 and 5) on Farm 3.

Feeding

In Finland, pig diets are typically based on either barley and soybean, or barley and different protein-rich liquid by-products from food and starch-ethanol industry for example wet barley protein (WBP). For the fattening pigs the liquid feeding is the most common in Finland. Liquid feeding has many advantages over the dry feeding as improved growth and feed conversion ratio, better phosphorus digestibility and palatability. Anyhow, the amount of water provided to pigs using liquid feeding is higher than used in conventional dry feeding systems. As a result, manure volume can be increased along with increased humidity and moisture levels in swine facilities.

In farm 3 all fodder is purchased off-farm. During the first 5 days the piglets are fed with dry complete feed (Tervepossu 4, contains phytase 500 FTU/kg and mixture of organic acids 5 g/kg) and after that with liquid feed. Fattening pigs have 2-phase feeding (below and over bodyweight of 60 kg). The major feed ingredients in fattening pig feed are barley (37-50 %), WBP (15-22 %), concentrate for WBP feeding, (Sian-Herkku OVR Tiiviste, 12-14 %, no phytase), wheat (9-13 %), whey (about 8.5 %) and rapeseed oil (about 5 %). Vitamin-B, vitamin-E and selenium are added to WBP-liquid before feeding. In WBP the potassium sorbate and in milk rinsing leftover formic acid is used as preservative.

Livestock housing

This farm uses an indoor batch pen housing system with partially slatted floors. The building is closed with forced ventilation and heating. There is only one housing unit (see Figure 6.2.4) which is divided into 15 identical sections. Each section has 20 boxes and 10-11 pigs per box. The boxes are 10.12 m^2, which includes 3.37 m^2 slatted floors. Bedding material is a mixture of wood shavings and hay, 800 small square bales and 800 kg wood shavings are used per year. Each section has one primary manure channel covered by the slatted floors. The openings in primary manure channels are opened every 3rd week and the manure transports by gravity flow from the primary-channel to the manure pit (MP) via 315 mm piping. MP is 70 m^3 which has a storage capacity of 3-4 days and emptied twice a week. Each section is emptied and cleaned by washing every 100 days. The estimated water quantity used is 15 m^3 per washing per section.

Manure processing and storage

From the manure pit the slurry is pumped twice a week via a 125 mm and 500 meter long piping to a nearby biogas plant which takes care of the processing, storing and end use of the slurry. At the biogas plant pig slurry is processed with municipal sewage sludge and industrial waste materials. The 3 primary storage facilities in close proximity to animal house are rented by the biogas company and used for storing the processed slurry. The storage tanks are round, partially below-ground and made of pre-fabricated concrete panels with a capacity of 2500 m^3 each. Slurry is pumped straight from biogas plant via same pipeline that is used to transport the raw slurry to the biogas plant. The tanks are filled from the bottom but no natural crust seems to develop. Since the manure processing at the biogas plant took place, the 500 meter long pipeline has been plugged twice due to mineral sedimentation.

Manure end-use

Once the slurry is drained to pumping pit the biogas company is in charge of transporting, processing, storing and end use of the slurry. Of the 60 000 tonnes of yearly processed slurry 20 % is dewatered with a decanter centrifuge. The liquid fraction is returned to the biogas process for dilution and solid fraction is transported into field heaps. Farmers have received permission from the authorities to store the solid fraction in field heaps based on the dry matter content of the material and that specific placement of the heaps is far from either waterways or drainage ditches. Peat is spread underneath of the heaps and heaps are covered with a peat layer. 80 % of the processed slurry is transported by a 30 m^3 truck to rented storage facilities. The biogas company has 40 000 m^3 of capacity within 40 km radius from the plant.

Figure 6.2.5. Pictures of slurry tanker with injection boom and nurse tank for transport.

All transportation and manure spreading is hired in from a local contracting company with its own equipment. The contractor uses 2 or 3 slurry trucks 30 m^3 each to move the slurry from the biogas plant to storages and also for longer distances during spreading. The trucks are equipped with loading system. Most of the spreading is done by 2 or 3 Terragator spreaders equipped with disc cutter injectors. About 50 % of processed slurry is spread in spring time to fertilize spring cereals. In summer time 20 % is spread on leys and during autumn 30 % is spread to fertilize winter cereals.

6.2.2.2 Farm 4

Farm 4 is a fattening pig producer in Koski TL County and is located in Varsinais-Suomi (N 60° 39')**.** The farm has 3300 places for finishers, or fatteners, and a yearly production of 11 700 pigs. The manure handling system is slurry based with a yearly manure production of 8 000 m^3. Recruited pigs are 25-30 kg when they arrive and 128-130 kg when they are finished. The rearing time is about 100 days.

Feeding

In farm 4 about 30 % of barely in pig feed is produced on farm and all the rest of the fodder is purchased off-farm. A liquid feeding technology with three phases is used, live weight less than 50 kg, from 50 to 80 kg and live weight over 80 kg. The major feed ingredients in fattening pig feed are barley (19-33 %), WBP (27-40 %, DM about 17 %), milk rinsing leftover (34-37 %, DM about 15 %) and concentrate for WBP feeding (Farmi OVR-tiiviste, 3.2-3.5 %, no phytase). The potassium sorbate in WBP and formic acid in milk rinsing leftover is used as preservative**.**

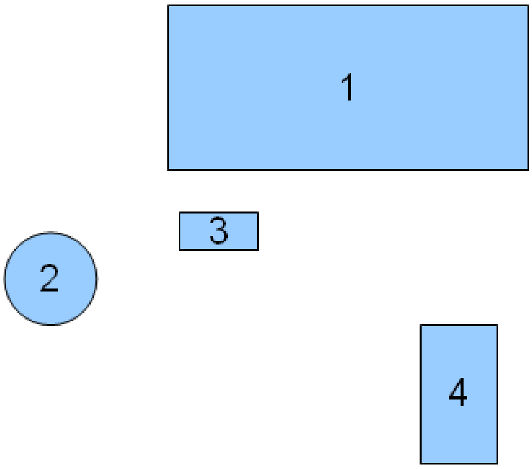


Figure 6.2.6. Layout of animal housing unit (1), and primary manure storage tank (2) on Farm 4.

Livestock housing

This farm uses an indoor batch pen housing system with partially slatted floors. The building is closed with forced ventilation and heating. There is only one housing unit (see Figure 6.2.6) which is divided into 15 identical sections plus a section for loading and a section for sick animals. Each identical section has 20 boxes and 10-11 pigs per box. The boxes are 11.2 m^2, out of which 30 % is slatted. Straw is used as bedding material, 800 kg per week. While taking the pigs in, 2.5 kg of peat is spread in each box. Each section has one primary manure channel covered by the slatted floors. The openings in primary manure channels are opened every 2^{nd} week and the manure transports by gravity flow from the primary-channel to the manure pit (MP) via 160 mm piping. MP is 6-7 m^3 equipped with grinding pump. Each section is emptied and cleaned by washing every 100 days. The estimated water quantity used is 10-12 m^3 per washing per section.

Manure storage

From the manure pit the slurry is pumped via a 160 mm and 40 meter long piping to the bottom of the primary storage of 2200 m^3. The 4 other storage facilities are located from 4.7 to 7.5 km from the piggery. The storage tanks are round, partially below-ground and made of concrete with a capacity from 1100 m^3 to 1500 m^3 each. The primary tank is filled from the bottom; the other ones are top filled with tanker. The filling of the 4 separate storages requires about 4000 km of transportation yearly.

Manure end-use

About 80 % of the manure is used to fertilizer farm´s own crops. The total spreading area on the farm is 300 ha; 100 ha of winter wheat, 80 ha of spring wheat, 60 ha of barley, 30 ha of peas and 30 ha of rape seed. The 21 m^3 Samson spreader is equipped both with trailing hoses (for winter wheat in spring time spreading) and disc injector for fertilizing other crops before seeding. All transportation and manure spreading is done by the farm personnel with its own equipment. All slurry is spread in spring time.

6.2.3 Poultry farm

Broilers in Finland must be raised free range on litter covered floors with maximum stocking density of 42 kg live weight or 23 chickens per m^2.

6.2.3.1 Farm 5

Farm 5 is a poultry broiler farm located in Huittinen County in Varsinais-Suomi (N 61° 13'). The farm has approx. 7800 m^2 available for raising broilers, split among 4 buildings and altogether 8 sections. Currently they raise approximately 137 000 chickens per batch at 1720 g after 37.5 days, with 6 batches per year. Chick mortality rate is 3.7-3.8 %.

Feeding

Most of the feed is purchased as a complete feed for broilers. Daily rations are split and given twice a day. Farm-grown wheat is mixed into rations in linearly increasing proportions from 5 % on day 5 to 30 % on day 30 onwards. The feeding strategy is divided into 4 phases each with a specific complete feed composition. Phase 1 is up to day 7, phase 2 is until day 21, phase 3 is until 34, and phase 4 feed is used until slaughter. Most feed is consumed during phase 3. Of the total amount of feed, about 17 % is home grown wheat.

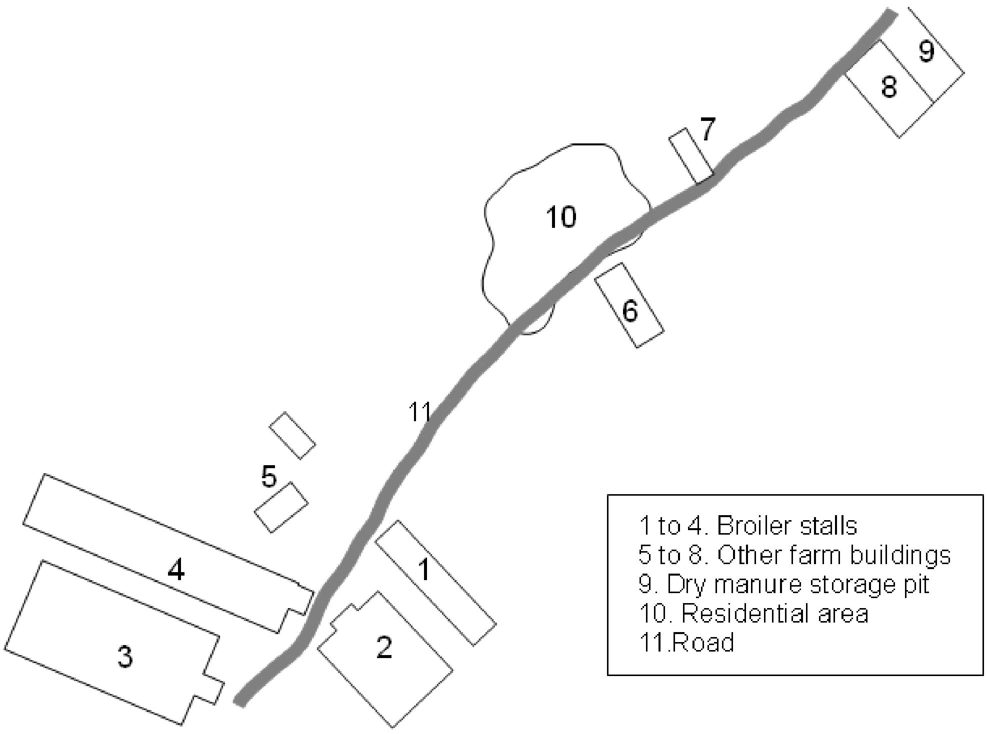


Figure 6.2.7. Layout of broiler stalls and dry manure storage pit.

Livestock housing

This farm has 4 buildings for raising broilers. All houses are closed with forced ventilation and heating. The newer buildings are divided lengthwise into 2 separate sections. Sections are approximately 1600 m^2 with an open floor-plan and hard asphalt floors. About 150 m^3 litter peat is spread evenly in the buildings with a self-made spreader making up about 2 cm deep bedding. Manure removal occurs after the chickens leave the barn for slaughter. Then the feeding trays and drinkers are raised up and the manure is scraped and removed with a small loader. The manure is loaded onto a trailer and transported 300 meters to storage. The manure typically has moisture contents of about 20 %. When the barns are washed and cleaned, the water is collected in a 55 m^3 underground tank. The tank is emptied after each batch and wastewater is transported to the municipal waste water treatment plant.

Manure storage

All manure produced on the farm is stored on a 700 m^2 concrete manure pad with 2.5 meter high support walls and drainage collection. Due to work technical reasons, some of the stored manure is transported in early spring into field heaps. Farm 5 has received permission from the authorities to store manure in field heaps based on the dry matter content of the manure and that specific placement of the heaps is far from either waterways or drainage ditches. Peat is spread underneath of the heaps and heaps are covered with a peat layer.

Figure 6.2.8. Pictures of solid manure removal and storage from Farm 5.

Manure end-use

Approximately 40 % of the manure produced on the farm is given to a nearby farmers producing wheat for the broiler farm. The rest of the manure, approximately 1440 m^3, is used on the farm as fertilizer.

Farm 5 has 140 ha of arable land available for spreading manure. All of the manure is applied in the spring, 120 ha of spring wheat and 20 ha of rapeseed. The manure is spread with an own 25 m^3 Bergmann 2-phase spreader and immediately incorporated prior to sowing for wheat or rape seed. The targeted application rate is 10 m^3 per hectare based on the P fertilisation limits.

6.3 Latvia

Kaspars Vartukapteinis, Juris Priekulis and Jānis Latvietis, LLU

6.3.1 Dairy farms

6.3.1.1 Farm 1

Farm 1 the dairy farm "Līgotnes", Latvia, region Auce, district Auce which is located in the south of Latvia, 100 km southwest from Riga. The farm data details are presented in Table 1 and 2 for Latvia in Appendix 2. The farm has 453 cows (323 dairy and 130 pregnant cows). The average annual milk yield in 2011 was 7050 kg per cow. The farm has loose housing with bedding, a cold type of barn which is confined year round. Manure handling system is slurry based and the farm produces around 8800 m^3 per year. All slurry is treated with anaerobic digestion for biogas production and the digestate is spread on agricultural land.

Feeding

The feeding is based on grass-silage, corn-silage, barley and bale silage which are all produced on the farm. Rapeseed cake and sunflower siftings are purchased, along with chalk, soya, molasses and yeast which are used as additives. For feeding there are 4 separate cow groups: milking cows in three groups: robotic milking cows (92), milking cows with a higher yield (106) and with a lower yield (125); pregnant cows (130). Cows in the robotic milking group are fed partly mixed rations and they receive the additional concentrates and additives in the milking robot. The rest of the cows receive total mixed rations.

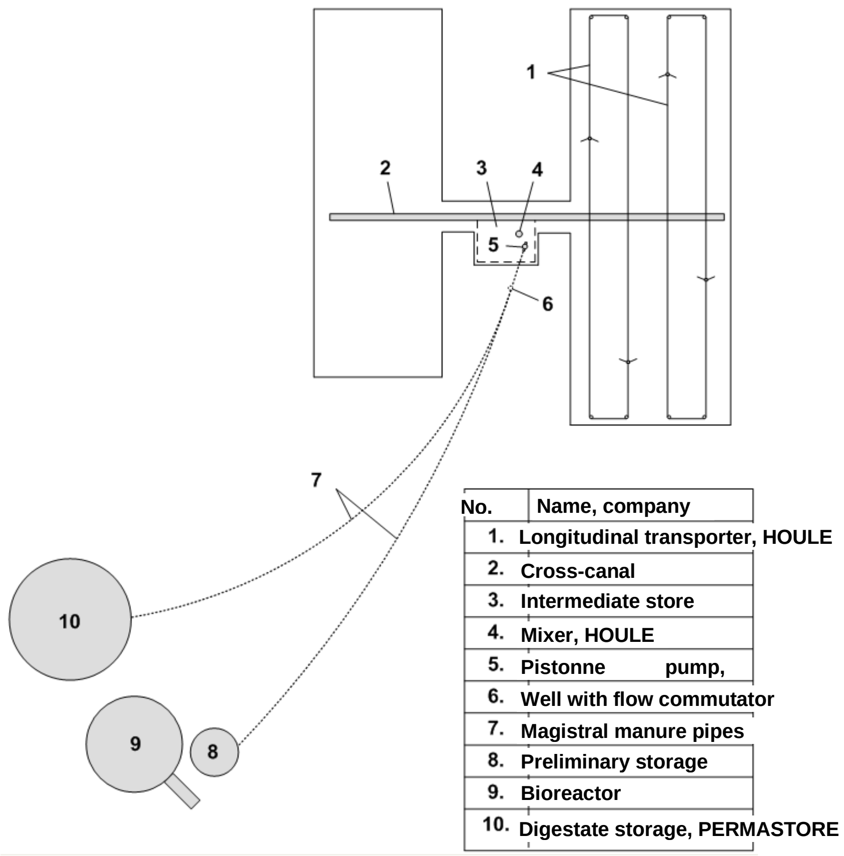


Figure 6.3.1. Layout of the animal housing units and manure handling system at Farm 1, Līgotnes.

Livestock housing

There is a loose animal handling system with slurry-based manure handling (Figure 6.3.1). The whole herd is divided into four groups: group 1 – robotic milking cows (92), group 2 – cows with a higher yield (106), group 3 – with a lower yield (125) and group 4 – pregnant cows (130). Manure is scraped from the passageways every half hour and is discharged in a cross-canal. Slurry in the cross-canal is removed to an intermediate manure pit using a rod conveyor four times a day. From the manure pit slurry is pumped daily using a pistonne pump to the preliminary storage of the bioreactor. Waste water enters the cross-canal rely on gravity.

Manure processing

Slurry is first pumped daily from the housing unit to the preliminary storage, which is located about 110 m from the barn. All of the manure is then processed through anaerobic digestion together with corn silage, since November, 2008 (Figure 6.3.2). The biogas plant for anaerobic digestion includes:

- Temporary storage tank for receiving raw slurry
- digester (2000 m^3) with mixer and heating unit
- plant biomass input tank
- digestate storage (4000 m^3)
- cogeneration unit
- excess biogas combustion torch

Electrical output of the biogas plant is 260 kW and thermal power is 356 kW. Intensification of production processes can achieve 400 kW electric power. In 2011, the revenue from electricity sales was 201 thousand LVL (141 thousand EUR).

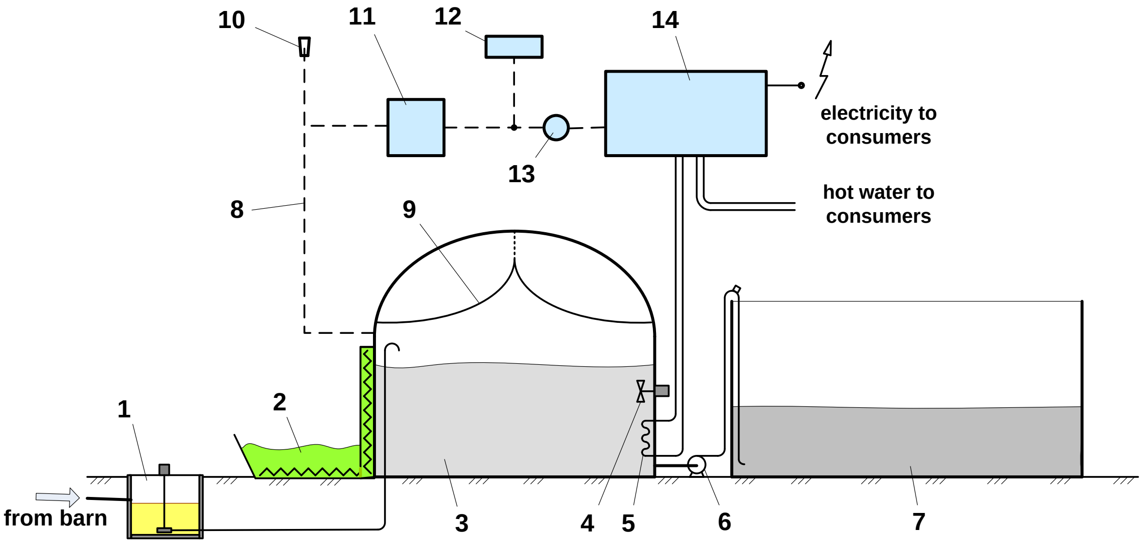


Figure 6.3.2. Scheme of biogas plant on farm Līgotnes: 1 – intermediate store, 2 – plant biomass input tank, 3 – digester (2 000 m^3), 4 – mixer, 5 – heating unit, 6 – pump, 7 – digestate storage (4 000 m^3), 8 – pipeline for biogas, 9 – membrane, 10 – excess biogas combustion torch, 11 – filter, 12 – reservoir, 13 – pump,14 – cogeneration unit.

Manure (digestate) storage

A 4000 m^3 storage tank is the primary storage for the digestate. The tank is covered with a natural crust.

Figure 6.3.3. Biogas plant in dairy farm Līgotnes: (A) Anaerobic digester (2000 m^3) on the left; (B) anaerobic digester and digestate storage tank (4000 m^3).

Manure end-use

Digestate slurry is used on farm fields with application rates between 20-40 t/ha/yr. The total field area available for manure spreading is 1 700 ha. Digestate is spread with broadcast spreading techniques using the equipment *HTS 100*. The arable fields are within 5 km from the farm. Digestate is used primarily on winter wheat (240 ha), winter rape (60 ha), maize for digestion (30 ha) and before autumn ploughing (130 ha).

6.3.1.2 Farm 2

Farm 2 is a dairy farm "Rāvas", Latvia, region Brocēni, district Blīdene, which is located in the western part of Latvia, 100 km southwest from Riga. The farm data details are presented in tables for Latvia in Appendix 2. The farm has 463 cattle (262 milking cows, 48 dry cows, 128 heifers, 5 calves and 20 young bulls). The average annual milk yield in 2011 was 7500 kg per cow. The farm has two barns (Figure 6.3.4): one newly built cold type barn for milking cows, and a renovated barn for calves and young cattle. The barn for cows has loose housing with cubicles and slurry based manure handling. The calf/heifer barn has solid manure handling. Milk cows, calves and young cattle are confined in the barn; however, dry cows are put to pasture during the summer. About 9300 tonnes of slurry and 1770 tonnes of solid manure are produced per year.

Feeding

Total mixed rations is used for feed based on grass-silage, corn-silage, milled grains (barley 75 %, wheat 25 %), feed-bean flour (produced on the farm); rapeseed cake and soya siftings (purchased). Feed chalk / lime, soya, molasses and Gelamin Typ R55 Plus Biotin are used as additives. For feeding there are four separate groups: productive cows (160 cows), unproductive cows (100 cows), heifers before insemination and dry cows, and pregnant heifers. Feed is mixed and distributed with a Euromix 1 by Kuhn.

Livestock housing

The farm has two barns (Figure 6.3.4): one newly built cold type barn for milking cows, and a renovated barn for calves and young cattle. Both barns have a loose housing with bedding. Milk cows, calves and young cattle are confined in the barn; however, dry cows are put to pasture during the summer. In the new barn for milking cows, there is a slurry manure handling system.

Manure is removed from the passageways with reciprocating scrapers and deposited in the cross-canal in the centre of the passageways (Figure 6.3.4). The slurry is gravitationally flowing in the cross-canal to a belowground, concrete manure pit (40 m^3) just outside the building for temporary storage. A centrifugal pump is used once a day to transport the slurry to long-term storage.

No	Name	No	Name
1.	Slurry storage	7.	Cross-canal with recirculation
2.	Magistral manure pipe	8.	Auxiliary room
3.	Intermediate store	9.	Barn for calf and young stock
4.	Centrifugal pump	10.	Sections with straw bedding
5.	Longitudinal transporter	11.	Feeding rack
6.	Barn	12.	Storage for solid manure

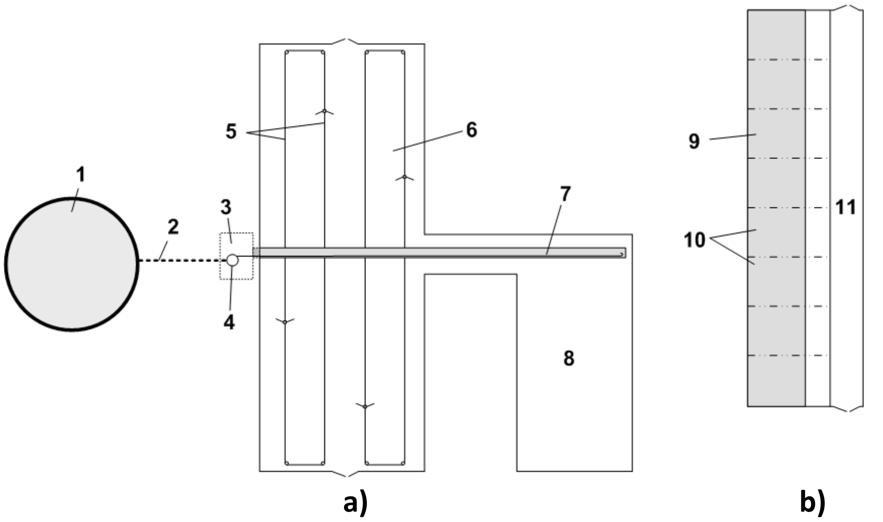


Figure 6.3.4. Scheme of the dairy farm “Rāvas”: a – new barn for milking cows; b - renovated barn for calves and young cattle.

Manure storage

The primary storage for slurry is an aboveground metal tank (5600 m^3) that is located very close to the barn. The storage tank is covered by a floating natural crust. Solid manure is stored on a concrete pad with 3 walls and a capacity for 1000 m^3.

Manure end-use

All of the slurry is used in the farm fields with application rates ranging between 30-40 t/ha/yr. The total field area available for manure spreading is 1200 ha. The slurry is spread using a tractor drawn tanker (20 m^3) with a broadcast applicator. The arable fields are within 5 km from the farm. The solid manure is spread using a tractor pulled broadcaster (*PTU-6.0/14A* (10 t)).

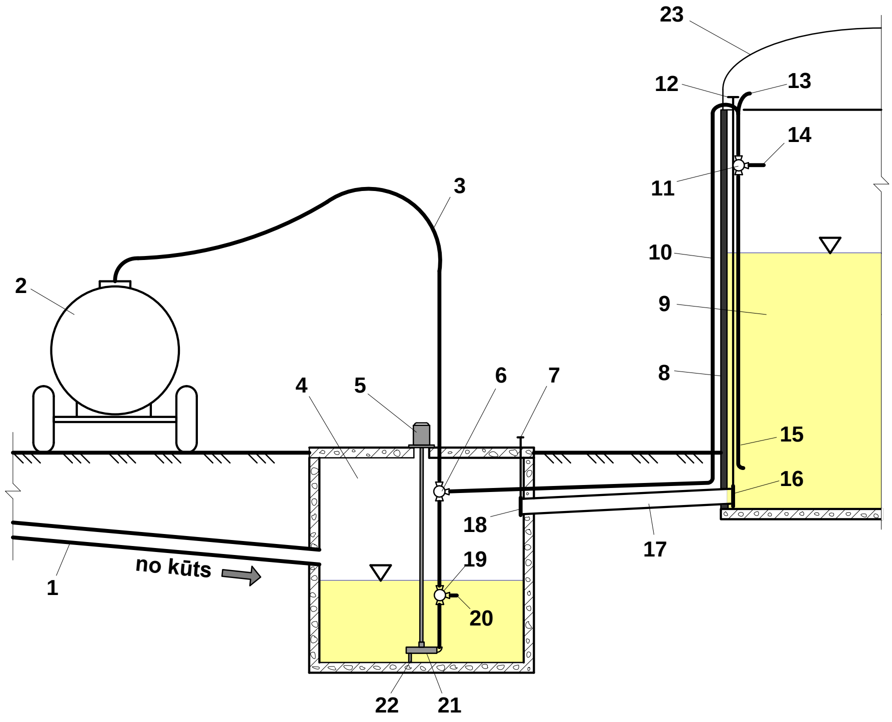


Figure 6.3.5. Slurry transport scheme on dairy farm "Rāvas": 1) slurry pipeline from the barn; 2) transport tank; 3) penstock; 4) intermediate store; 5) pump drive electric motor; 6) 11) 19) three-way valves; 7) 12) shutter adjustment handle; 8) the main storage wall; 9) slurry; 10) slurry penstock; 13) air inlet valve; 14) 20) slurry outlet nozzles, working in recirculation mode; 15) pipeline for slurry input in storage; 16) operational shutter; 17) pipeline for liquid overflow from the main storage to intermediate store; 18) flow control gate; 21) centrifugal pump; 22) pump support toe.

6.3.2 Pig farms

6.3.2.1 Farm 3

Farm 3 is an IPPC swine farm "Ulbroka Ltd", located in the outskirts of Riga in the district Stopiņi. The farm data details are presented in Tables 1 – 7 for Latvia in Appendix 2. The farm has integrated production with 1060 sows that produce about 27 000 pigs per year which are finished at an average weight of 107 kg. This farm exists since the Soviet times and was founded in 1973. The farm has a housing system with pens with slatted floors and manure handling is slurry based with manure production of about 22 000 tonnes per year. Solid manure is not produced. The farm also has a certified slaughterhouse.

Feeding

The feeding system is dry feed based. All feed is purchased as complete mix with special diets for gilts (also dry sows) and farrowing sows. Separate mixes are purchased for weaned growers (until 41 days) and finishers between days 42-62 and finishers after day 63.

Livestock housing

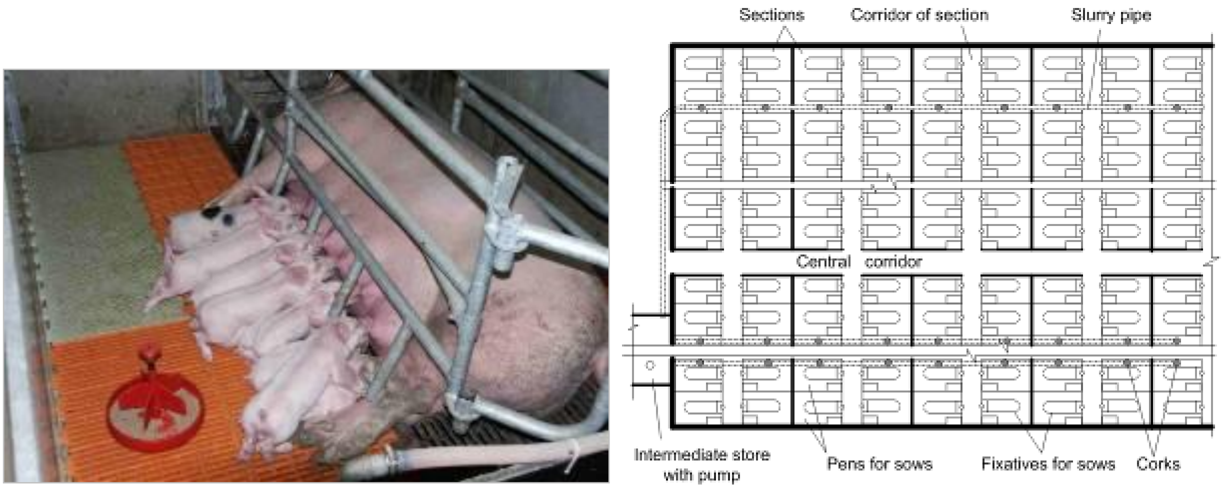


Figure 6.3.6. Housing system for suckling sows and piglets. Pen size – 4.08 m^2

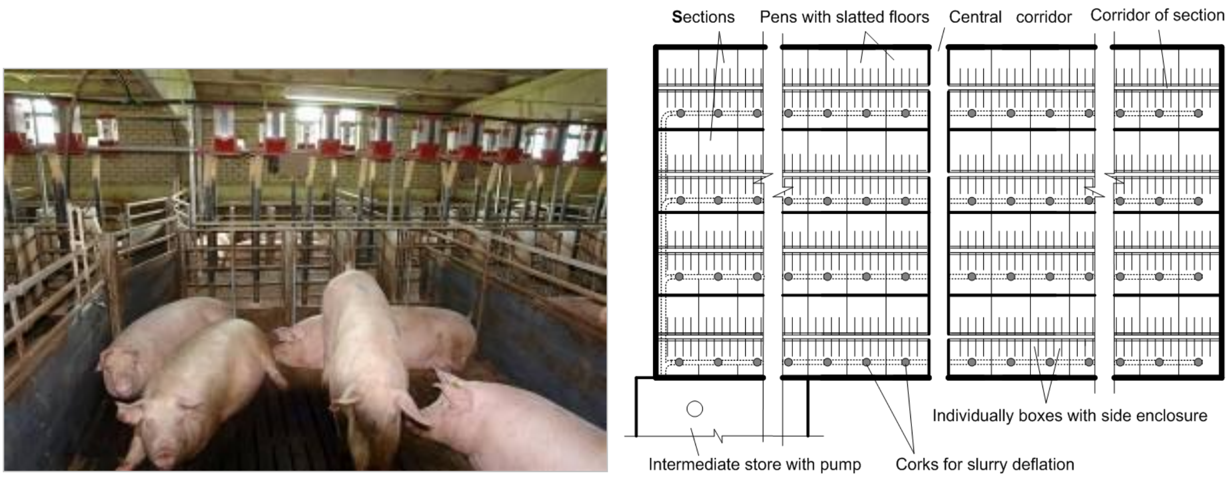


Figure 6.3.7. Housing system for pregnant sows. 5 sows per pen (18.8 m^2).

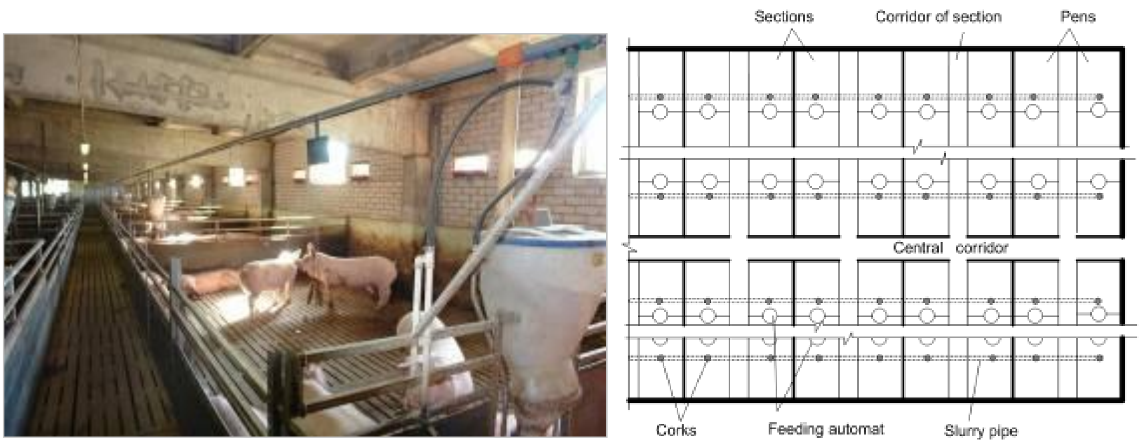


Figure6.3.8. Housing system for weaned piglets. 20 piglets per pen (21.2 m^2).

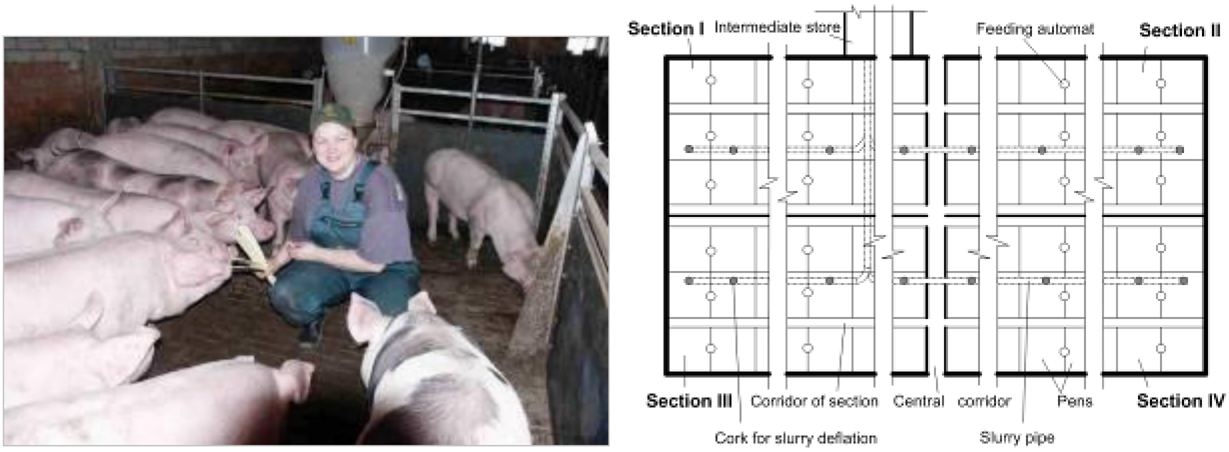


Figure 6.3.9. Housing system for fatteners. 20 piglets per pen (21.2 m^2).

Figure 6.3.10. Air filtration system: 1) water supply pipes with sprinklers; 2) plastic cell wall; 3) ventilators; 4) wall of barn; 5) wood shavings filling; 6) plastic cell wall.

Manure storage

There are three LDPE (low-density polyethylene) covered concrete tanks for long-term manure storage, each with a capacity of 4000 m^3 (Figure 6.3.11).

Figure 6.3.11. Covered slurry tanks.

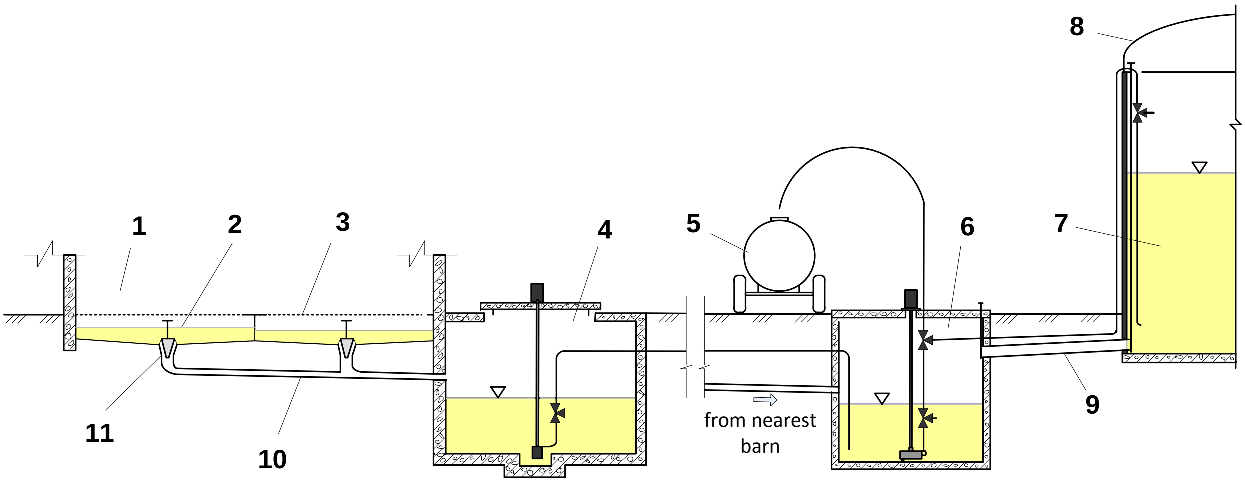


Figure 6.3.12. Sheme of collection, transportation and storing of slurry: 1) barn; 2) tub for collection of slurry; 3) slatted floor; 4) between-reservoir with centrifugal pump (firm Eisele); 5) transport unit for transportation of slurry; 6) central between-reservoir with centrifugal pump (firm Eisele); 7) slurry reservoir (type Acontank); 8) roof; 9) backpipe; 10) slurry pipe; 11) cork for emission of slurry.

Manure end-use

Manure is used for fertilizing purposes with the application rate of 30-40 tonnes/ ha/ year. The farm has about 1000 ha of arable land available for spreading slurry. All manure is used on the farm as fertilizer and spread with band spreading techniques using the equipment of Mayer (18 m^3). The arable fields are within 10 km from the farm.

6.3.2.2 Farm 4

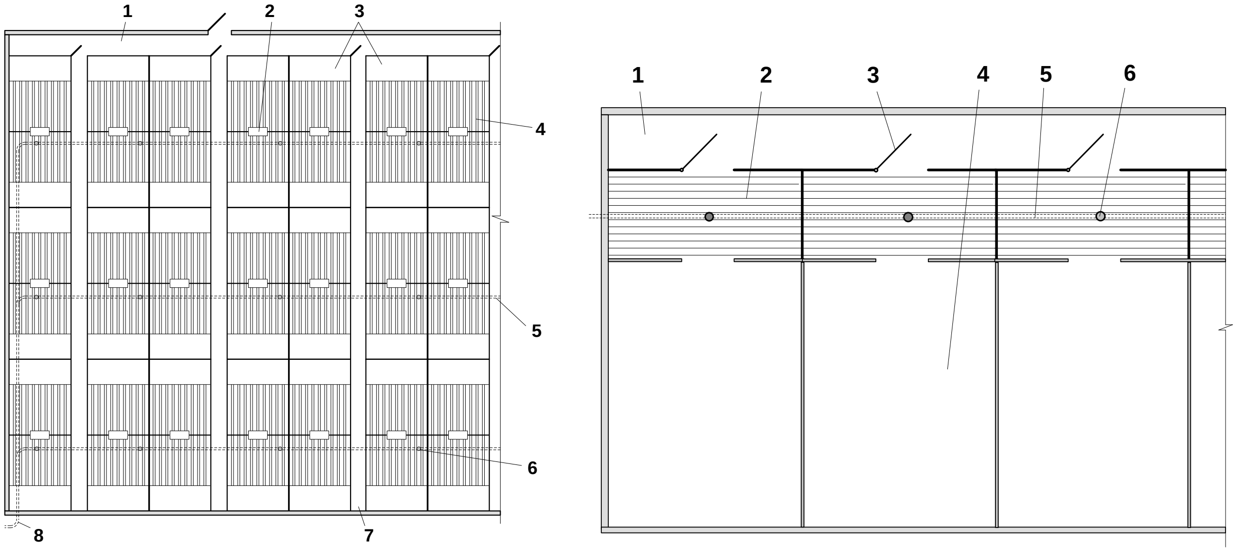
Farm 4 is the IPPC swine farm "Latvi Dan Agro Ltd" in the region Dobele, district Jaunbērze, which is located in the central part of Latvia, 61 km southwest from Riga. The farm data details are presented in Tables 1 to 7 Latvia in Appendix 2. The farm has about 2350 sows which produce 56 100 piglets per year with a delivery weight of 21-30 kg. In addition, Latvi Dan Agro also has 1685 young pigs and 48 boars. Manure handling system is slurry based and manure production of about 15 600 tonnes per year. Solid manure is not produced.

Feeding

Feeding is based on dry complex feed produced on-farm. Premix is fed as feed additives.

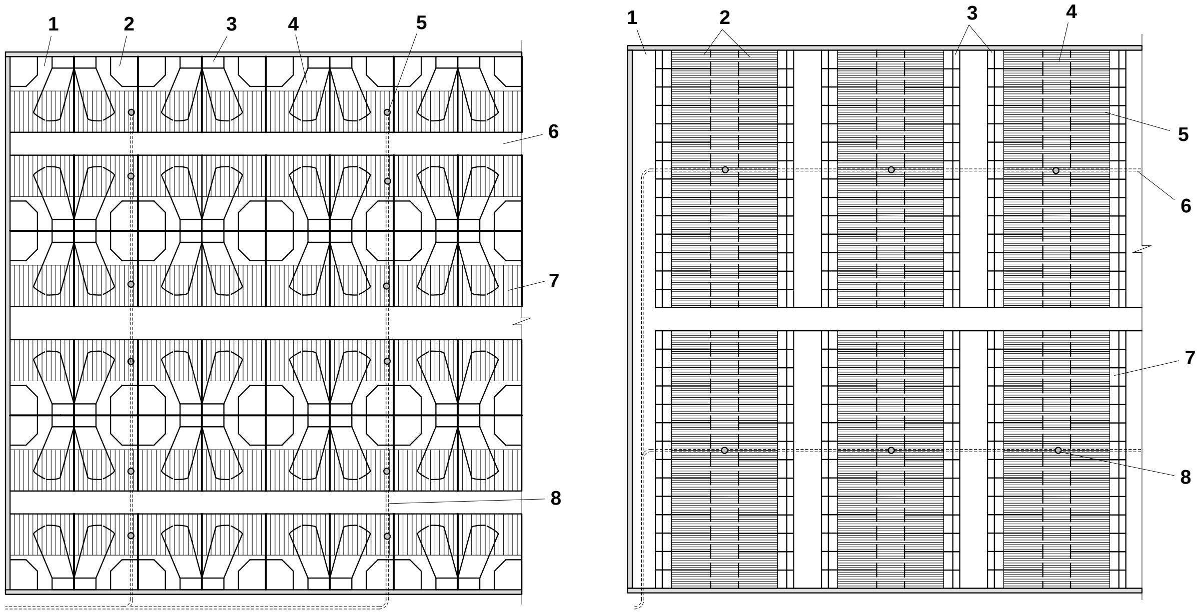
Livestock housing

The farm has a housing system with pens with slatted floors and slurry based manure handling. There are four barns.



(A) (B)

Figure 6.3.13. Scheme of barns for: (A) weaned piglets 1) corridor, 2) feeding automate, 3) warm concrete floor, 4) concrete floor, 5) slurry pipe, 6) cork, 7) corridor, 8) main slurry transport; and (B) young pigs 1) corridor, 2) slatted floors, 3) gate, 4) concrete floor, 5) slurry pipe, 6) cork.



(A) (B)

Figure 6.3.14. Scheme of barn for: (A) suckling sows 1) sty, 2) piglets den, 3) sow's manger, 4) sow's fixing device, 5) – cork, 6) passage, 7)concrete floor, 8) slurry pipe; and for (B) pregnant sows 1) corridor, 2) individual cages, 3) feeding area, 4) passageway, 5) concrete floor, 6) slurry pipe, 7) solid concrete floor zone, 8) cork.

Slurry is collected and temporarily stored under the slatted floors of the pens. This storage capacity totals 6540 m^3 and manure is removed twice a month in the gestating and young pig barns, once a month in the farrowing barn, and once a week in the weaned piglet barn. Slurry is drained through pipes running from under the pens to a manure pit outside the buildings (Figure 6.3.15). The manure pit has a capacity of barns to the central channel and on to the between-reservoir. To the main store they are transported by a pump once a week.

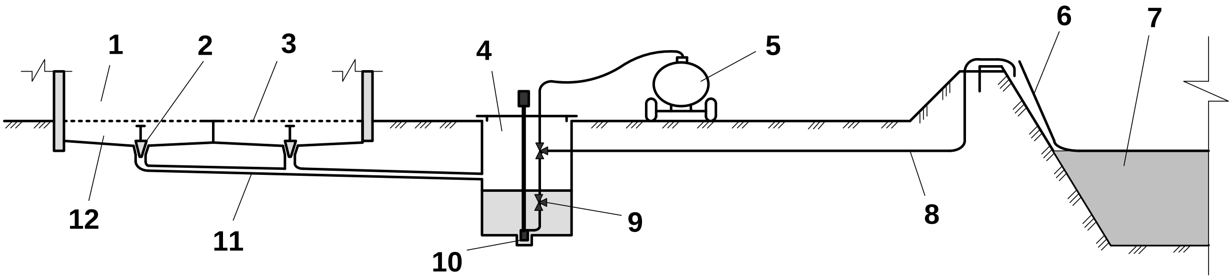


Figure 6.3.15. Manure transportation and management scheme. 1) barn; 2) cork-type valve; 3) slatted floors; 4) manure pit; 5) transport unit for slurry; 6) floating low-density polyethylene (LDPE) cover; 7) slurry storage lagoon (10 000 m^3); 8) pressure main; 9) output for mixing; 10) centrifugal pump; 11) slurry main transport; 12) under floor storage.

Manure storage

The main storage facility is a pond with a capacity of 10 000 m^3 (Figure 6.3.16). The lagoon is 78 x 45.5 m and 5-6 m deep. The slope of the storage sides is 37°. The bottom of the lagoon also slopes in towards the centre with a depth difference of 1 m. To avoid unpleasant odours, the storage surface is covered with a 1 mm thick geomembrane equipped with valves for gas discharge. The geomembrane is made of high density polyethylene pellets (97.5 % polymer and 2.5 % stabilizer).

Figure 6.3.16. Covered storage pond for slurry.

Manure end-use

Before land application, slurry is well mixed using a pump to supply the manure to 14 mixer tubes, which are located along the edges of the storage 0.4 m away from the main of the store. The same pump is also used to fill a transport tank with slurry. All manure is used for fertilizing purposes with the application rate of 30-40 tonnes/ ha/ year. The farm has about 3 400 ha of arable land available for spreading slurry. Arable fields are within 10 km from the farm.

For slurry transportation to fields the following equipment is used: a *Scania* truck (mass 7665 kg) with tank *Tranders* (mass 10 200 kg, capacity 27 m^3); a *DAF* truck (mass 7970 kg) with tank *Madyar* (mass 10 450 kg, capacity 30 m^3); and a *MAN* truck (mass 7800 kg) with tank *Tranders* (mass 11 780 kg, capacity 30 m^3). All slurry is spread with tractor drawn slurry tankers equipped with booms and trailing hose applicators for band spreading. Both a *Kimadan* slurry tanker, 24 m^3 with 24 meters working width and a *UM-25000* slurry tanker, 25 m^3 with 18 meters working width are used.

6.3.3 Poultry farm

6.3.3.1 Farm 5

Farm 5 is the poultry farm "Balticovo" in the Lecava region of Lecava district, which is located in the central Latvia, 45 km south from Riga. The farm data details are presented in Table 1 to 7 for Latvia Appendix 2. The farm has 1 960 000 laying hens with egg production of 510 million per year and 660 000 chickens they are purchased from outside. In year 2010 60 % of all AS Balticovo egg products are exported to other European countries. Farm 5 has housing system based on cages including 14 buildings for laying hens and 6 buildings for chickens. Total manure production amounts for about 190 000 t per year. Balticovo does not have arable land available for spreading manure.

Feeding

All feed components are purchased but are mixed and blended on the farm. Wheat and barley are milled on the farm and mixed with sunflower siftings, chalk, monocalcium phosphate, salt, premivit, L. Lysine, rapeseed oil and DL-methionine.

Livestock housing

There are housing systems located in 20 buildings:

- 6 buildings with cages (0.92 m^2 each, 25 chickens per cage) for purchased starters
- 14 buildings with cages (1.488 m^2 each, 24 laying hens per cage) for laying hens

Cages has a sieve floor below it is located manure conveyor belt. No bedding is used and manure is mechanically removed twice with the conveyor belt located directly under the cages and deposited in a trailer outside the buildings (Figure 6.3.17).

Manure storage

The farm has a solid manure pad with walls and seepage collection system but since 2010 it is no longer used. Since then, Balticovo has coordinated the timing of manure collection with the company that buys the manure. Manure is loaded directly onto a trailer which is then transported off-farm to the company.

Manure end-use

All manure is exported off-farm. Since 2010, all manure is sold to a company that takes responsibility for its disposal. Currently packages it as a fertilizer for gardens, and also uses a portion as substrate for a biogas plant.

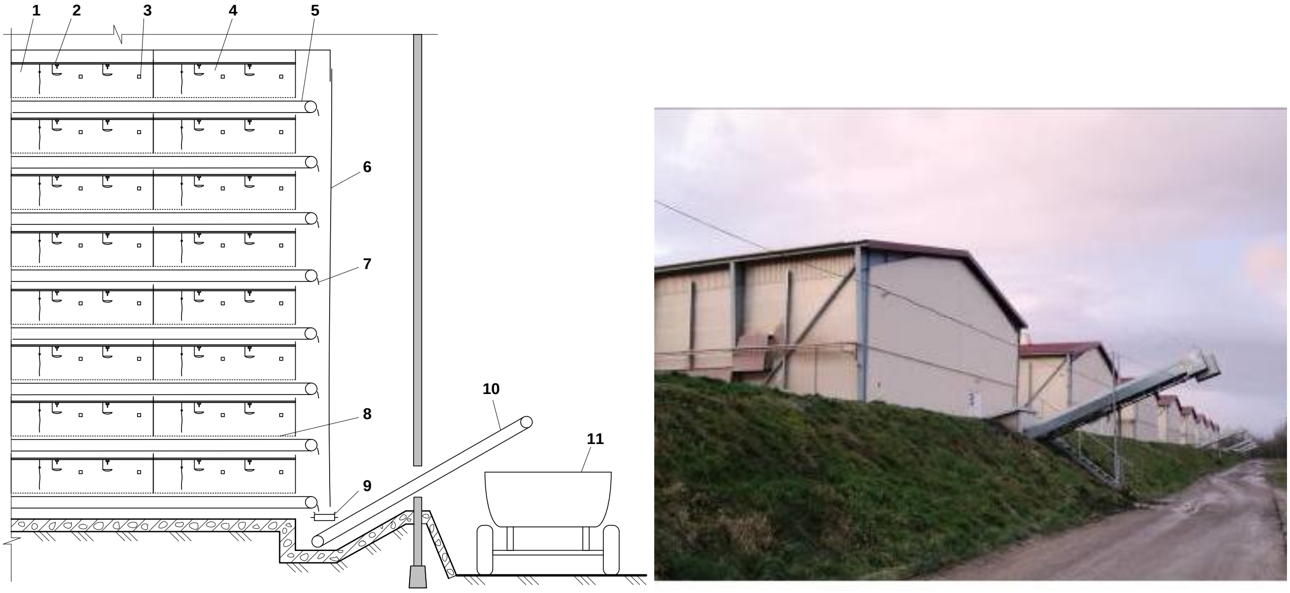


Figure 6.3.17. Manure handling in the animal housing units. 1) nest for egg laying, 2) water bowls, 3) roost, 4) cage, 5) manure removal belt, 6) curtain, 7) scraper for cleaning bands from manure, 8) grated floor, 9) belt type cross conveyor, 10) sloping conveyor, 11) trailer.

6.4 Lithuania

Sigitas Lazauskas, Virmantas Povilaitis and Vita Telvikiene, LRCAF

Recent changes in Lithuania's legislature reflect increasing attention to animal welfare and environment concerns. Details concerning these regulations can be found at the Lithuania Ministry of Agriculture website www.zum.lt, and the website for the Agricultural Advisory Service www.lzukt.lt. Additional specific requirements and/or restrictions for animal husbandry and manure handling can be applicable in some areas due to area status and location. In addition, large scale animal producers should have permits for potential impact on environment from the regional Environmental Agency.

Manure storage regulations (in force since autumn 2011) for large-scale livestock farms include:

- Storage capacities - minimum for 6 months (this requirement is not applicable to farms with animals housed on deep-litter bed systems)
- Farms processing manure into compost, biogas, etc. can get adequate reduction in requirement for storage capacities
- Slurry storage must be covered with stabile natural crust, chopped straw or some other material (for producers with more than 500 LU – required from 2014-01-01)

Major requirements provided in this regulation that affect manure spreading on agricultural fields include:

- Maximum of 170 kg of N can be applied (with manure, slurry and grazing) per ha and year
- Spreading of manure is forbidden from November 15 until April 1, as well as on frozen, waterlogged or covered by snow soil
- Spreading of manure and slurry from June 15 until August 1 is allowed only on meadows, pastures, fallow and fields under preparation for winter crops
- Land application of slurry on bare soil must be incorporates within 24 hours
- Application of manure should be based on a fertilizer plan

6.4.1 Dairy farms

Forecasts performed in 2011 by the Lithuanian Institute of Agrarian Economics for the period until 2020 suggests that number of dairy cows in Lithuania will decline, although, production per cow and total production will increase due to intensification of production. Increasing herd size and a reduction in the number of farms with small herds can be expected. Despite this, it is not likely that very large milk producers (equivalent to IPPC levels for pigs and poultry) will be typical of Lithuania in a nearest future.

6.4.1.1 Farm 1

Dairy farm 1 is situated in south west part of Lithuania, in the river Mituva watershed. Farm is owned by the farmer and is relatively large for the region. At the time of visit in farm there were 230 milking cows and 270 dry cows and heifers. Dairy cows are confined year round and manure handling is primarily slurry based with a manure production of about 6400 m^3 per year. The cow's weigh on average 700 kg and milk production is about 7000 kg per year per one cow. Milk contains on average 3.3% of milk protein and 4.6% of milk fat so about 7450 kg ECM is produced per cow per year.

Feeding

The feeding of cows is based on grass and corn silage produced on farm. The quality of silage is shown in Table 1 for Latvia in Appendix 2. Mineral additives and salt is also included into cow ration. The rate of mineral additives and salt is 200 g per adult animal per day. In relation to feeding cows are divided into four groups according productivity, with different feeding for milk and dry cows. All feed is produced on a farm, farmer buys only mineral additives.

Livestock housing

The barn is loose stall housing system and the passageways are covered by slatted floors. Passageways are cleaned with automatic scrapers twice a day. Manure in the primary channel under the slatted floors flows by gravity to a cross-channel at the end of the building. There are additives of water (2 times per day, total 100 l per day) to manure from wastewater from cleaning milking lines. There is a manure pumping pit at the end of the building which helps to transport manure and other residues to the manure storage tank.

Calves are kept in a separate building that has solid manure handling (Figure 6.4.1). Straw is used as bedding material, but only for calves. Calves are kept in pens for about one month. After that pens are cleaned and all solid manure is removed by hand. The farmer put solid manure to the concrete manure pad and spread it on the fields in autumn, before soil cultivation. The amount of straw used in pens depends on the number of calves.

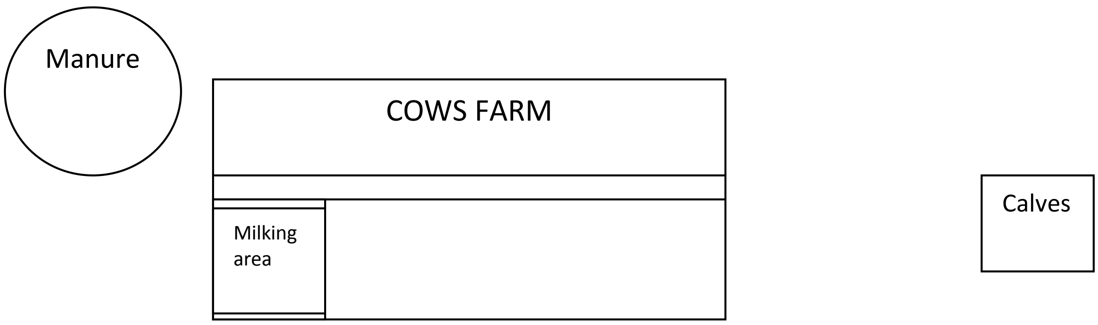


Figure 6.4.1. Layout of animal housing units liquid manure storage tanks on Farm 1.

Manure storage

The manure storage reservoir volume is 3220 m^3. Reservoir is constructed 25 m from the barn, aboveground on the strong concrete pad of ferroconcrete blocks. There is no roof – floating natural crust serves as a cover. Mixer and pump with mixer is installed in reservoir.

Manure end-use

Farm 1 has 400 ha area of arable land and 200 ha of grasses (Including owned and rented land) for manure spreading located up to 15 km away. Farmer owns slurry spreader with disc injector. Mixed liquid manure is spread with band spreading techniques with a trailing hose applicator in spring for winter and spring cereals, and in autumn for grasses. Manure to distant fields is transported by a truck and 18 m^3 tanker. The application rates depend on the soil characteristics. Farmer periodically takes soil and manure samples to the laboratory and makes analysis of the main components. Average application rates are approx. 30-35 t/ha. Solid manure is spread with a broadcasting techniques in late summer before sowing winter wheat at a rate 25 t/ha and incorporated into the soil by ploughing.

6.4.1.2 Farm 2

Farm 2 is a dairy farm located in the middle of the Lithuanian lowlands, in the watershed of the river Nevezisd. There are currently 300 milking cows, 50 dry cows, 180 heifers (recruitment is 61 %), 40 pregnant heifers, 15 young bulls, 1 mature bull and 45 calves. The breed is 100% Lithuanian black and white cattle. The cow's weigh is on average 650 kg. Milk production is about 7 844 kg per year of one cow. The milk contains 3.5% of protein and 3.8% of milk fat so the ECM production is 7750 kg per cow per year. Only solid manure handling systems are currently implemented on the farm and manure production is about 11 400 tonnes per year.

Feeding

Feed is based on grass and corn silage and cereals (barley, wheat and maize), which are all produced on farm. Rapeseed cake, mineral feed, malt draff and salts are purchased off-farm and included in their rations.

Livestock housing

Cows are confined indoors in a loose housing system with straw deep-litter pens. Cereals straw is used as a main litter, with occasional application of hay. The manure from hard-surfaced concrete passageways is removed using mobile scraping units and transported directly to storage about 4 – 6 times per month.

Manure storage

Solid manure is stored on a concrete pad without a roof. It is approximately 3800 m^2 and is about 1 km from the barn. The storage capacity is about 7 months. Part of manure is stored in a field heaps.

Manure end-use

The dairy Farm 2 has 1000 ha area of arable land and 200 ha of permanent grasses available for manure spreading which are all within a maximum distance of 3-4 km from the farm. Manure is applied mainly for arable crops - winter wheat, maize, sugar beet at a rate 25-30 t/ha. Broadcast solid manure spreaders are used for application of solid manure after which the manure is incorporated into the soil by ploughing.

6.4.2 Pig farms

Large producers dominates pig husbandry and are important economically for Lithuania. However, attitude of local rural citizens to such production is often rather negative, due to odour complains and other pressures on environment. Thus innovations and improvements in animal welfare and manure handling are crucial for sustainable development of pig production.

6.4.2.1 Farm 3

Farm 3 is one of the largest pig farms in Lithuania. The farm is located in former Marijampole region, in the middle of the Nemunas river watershed. The farm is owned by a company. The farm has 2400 places for sows and 13 300 places for finishers, or fatteners, and yearly production levels are over 50 000 pigs. Recruited pigs are 32 kg upon arrival and 108 kg when they are finished. The manure handling system is slurry based with yearly manure production of 85 000 m^3.

Feeding

Feeding is based on rations providing different mixtures for different group of pigs which the farmer did not want to elaborate on.

Livestock housing

The Farm uses an indoor batch pen housing system with partially slatted floors. The buildings are closed and insulated with forced ventilation and heating. In total there are 44 housing units and each is 648 m^2. Manure is collected in channels under slatted floor section of the pens. The channels are emptied once daily by a hydraulic system and collected in a manure pit just outside the building. The slurry in the manure pit is pumped directly to the storage lagoons.

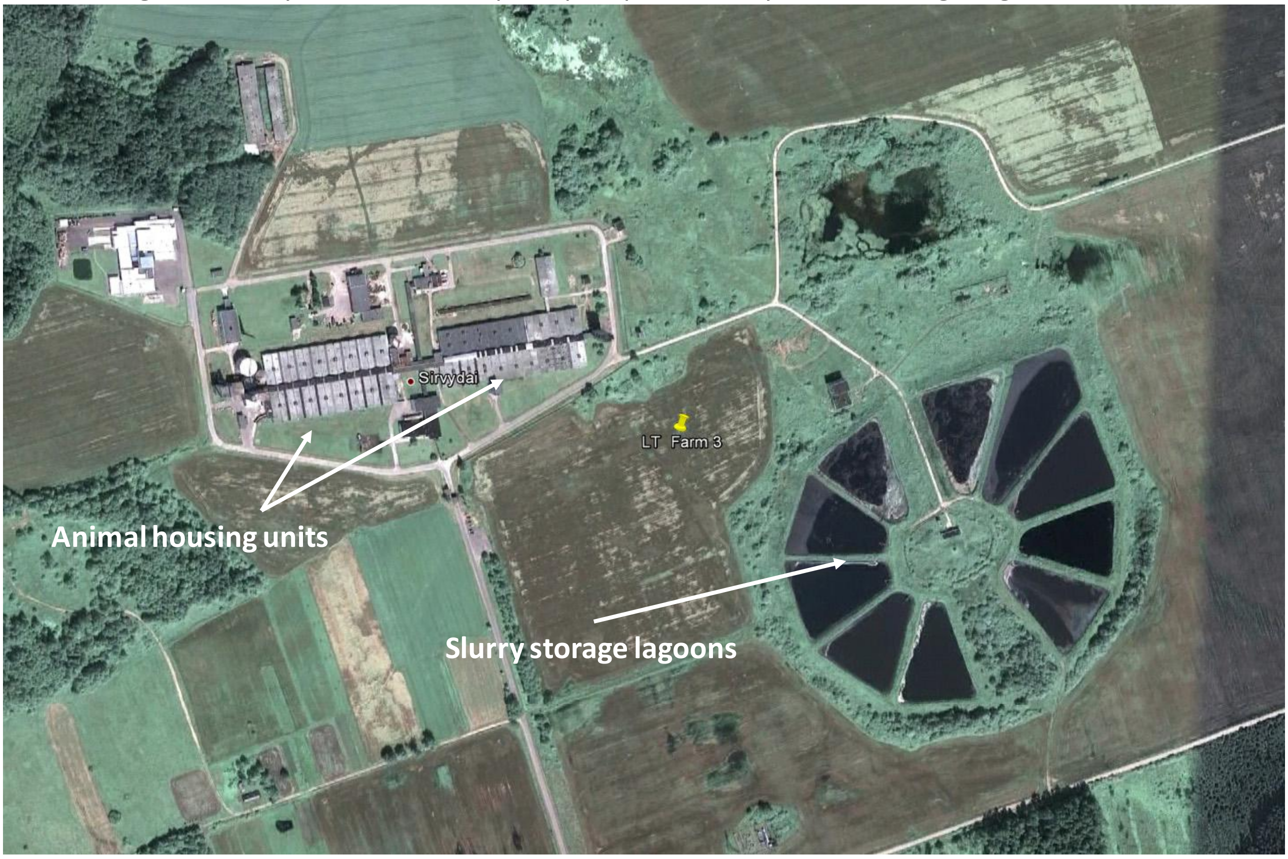


Figure 6.4.2. Layout of pig farm 1 and manure storage lagoons.

Manure storage

There are 10 lagoons for liquid manure storage approximately 0.5 km from the farm (Figure 6.4.2). Size of one lagoon is 16 000 m^3 so the total storage capacity is 160 000 m^3. The lagoons are lined with concrete and covered with a plastic material to prevent seepage. The lagoons are also used to store digestate from a neighbouring biogas plant. Earlier, the number of pigs was higher, which explains the rather high storage capacity of today compared to calculated slurry production (Table 6 for Lithuania, Appendix 2).

Figure 6.4.3. Mobile slurry pumping station used to pump slurry from the storage lagoons to the umbilical distributing spreader.

Manure end-use

A part of the mixture of slurry and digestate is used in own fields. On the other hand the farm has agreements with neighbour farmers for 2300 ha of arable land for spreading of manure and digestate mixture. Farmers do not pay for the fertilisation and the mixture. The owner of pig farm and biogas plant has to utilize digestate, but he does not have enough fields, so he spread the mixture in other fields for free. All fields are within 0 - 5 km distance from the manure storage facilities. Liquid manure is pumped through mobile pipes to the fields (Figure 6.4.3), and an umbilical delivery system with a boom and trailing hose applicators is used to spread manure on the fields (Figure 6.4.4). All manure produced in the pig Farm is used on these farms as fertilizer. The maximum amount of liquid manure applied per ha is 80 t.

Figure 6.4.4. Umbilical distributor with boom and trailing hose applicators.

6.4.2.2 Farm 4

Farm 4 is another one of the largest pig farms in Lithuania and is located in the Taurage region in the river Mituva watershed. The farm has integrated production with 2250 sows. The sows produce about 30 000 piglets per year. The piglets are grown to 35 kg and then moved to the finishing facilities where they stay until they reach 107 kg. Manure handling is slurry based but all manure is processed with separation technology into solid and liquid fractions with an annual production of 3100 and 11 000 tonnes per year respectively.

Feeding

A major part of feed is purchased off-farm in the form of a single complex feed type. Other purchased feedstuff includes rapeseed cake, minerals and additives.

Livestock housing

The Farm uses an indoor pen housing system with partially slatted floors (30-80%), part of which are grids. The recently renovated buildings for sows, growers and fatteners were equipped with new water-troughs, feeding, ventilation and manure removal systems all provided by 'Big Dutchman' (www.bigdutchman.de). Manure channels under the slatted floors have corked drains, which when opened, drains the manure to a main collector channel which then flows to a manure pit outside the buildings. From these pits, manure is pumped to the processing and storage facilities described below.

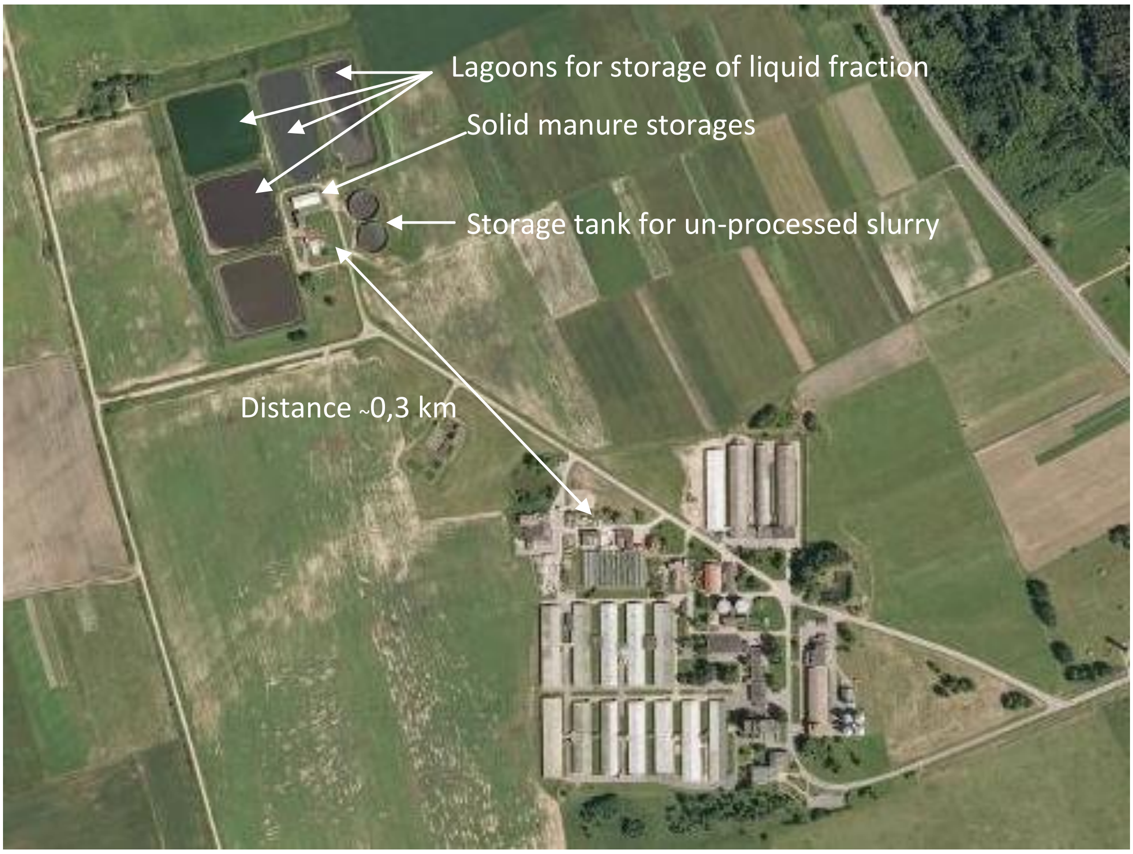


Figure 6.4.5. Layout of pig farm 2 and manure storage lagoons.

Manure processing

All of the slurry produced from the growers and finishers is separated into liquid and solid fractions using Bauer S650 and DODA 2000 separators, while the slurry from breeding pigs is unprocessed. See table 6.4.1 for fraction characteristics.

Table 6.4.1. Quality and quantity of manure from the finishers after separation, and the quality and quantity of the slurry from the breeding pigs which is not separated. Data provided by the farm company.

Type of manure	Amount (t annual)	DM %	N kg/t	P kg/t
Untreated slurry	11 000	1.0	2.8	0.54
Solid fraction*	3 100	27.7	5.9	13.6
Liquid fraction*	31 000	0.8	1.9	0.33

** After separation*

Manure storage

Untreated slurry from the breeding pigs is stored directly in the 2 steel tanks which each have a volume of 4400 m^3. After separation, the solid manure fraction is stored in covered manure storage and the liquid fraction is stored in uncovered lagoons (4 lagoons are actively used for storage and 1 is for reserve).

Manure end-use

The farm, together with agreements with neighbouring farms, has 1487 ha of arable land for spreading of manure. All amount of manure is used as fertilizer. In total 25 000 t of manure are used outside the Farm. The solid fraction is applied in spring before plant growing or in autumn (in September) for field crops. The liquid fraction from the lagoons is used for irrigation of grasses (240 ha, distance from farm 5 km) at the rate 84 t/ha. The unprocessed slurry is spread at a rate of 37 t/ha for cereal (on the fields in 1 – 8 km distance from farm). The farm has 4 broadcasters, 2 EISELE FW 240 and 2 HTS100.27.

6.4.3 Poultry farm

6.4.3.1 Farm 5

Farm 5 is one of the largest poultry farms in Lithuania. It is located in the Elektrenai district near Lake Ausieniskiai, which belongs to river Neris watershed. The farm has a maximum of 705 000 laying hens and produces about 17 million eggs per month. There are an additional 350 000 young hens.

Feeding

The feed consists of wheat, corn, barley and premix concentrates.

Livestock housing

In this farm chickens live in cages. In one cage are 39 chickens. Slurry and manure are removed mechanically 2 times per week. Spilled water from the drinking system is added to the manure.

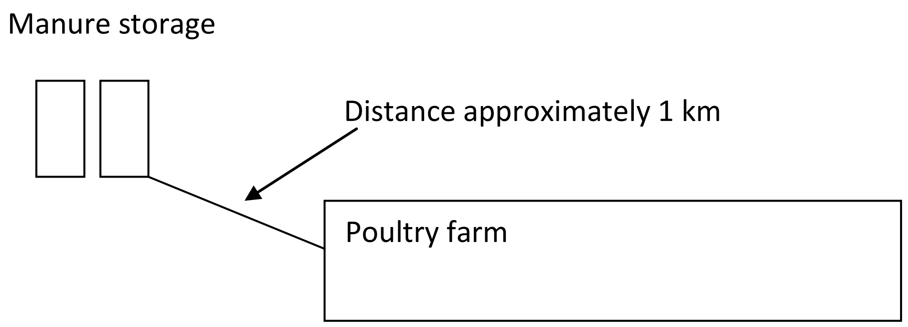


Figure 6.4.6. Schematic plan of poultry farm and manure storage.

Manure storage

The manure is stored in two areas, volume of the storage is 24 000 m^3 (Figure 6.4.6). The storage capacity is 6 month.

Manure end-use

All manure is used for fertilisation. Farm has possibility to fertilize 1000 ha, at a distance 10 – 18 km.

6.5 Poland

Ksawery Kuligowski, Dorota Skura and Andrzej Tonderski, POMCERT

Polish animal production amounts for about 5.6 M cattle, 14.8 M pigs and 130.9 M poultry. There are 752 industrial (IPPC) animal farms in Poland, including 146 pig farms and 606 poultry farms. Most farms are located in north western, western and central provinces of Poland. Polish animal farming produces almost 70 M tonnes of manure per year, of which majority constitutes pig solid manure (50%) and cattle solid manure (30%) with fewer amounts of poultry manure (10%) and slurry, both pig and cattle (10%) (General Statistics Office, 2010-2011). The most typical way of utilizing the manure in Poland is spreading on the agricultural land, however there are already 15 biogas plants, of which 12 are processing manure together with other substrates (March 2012). The total electrical power of these manure-based biogas plants is 11.5 MW. The rapid growth of investments in a manure-based biogas plants is noticeable since the Polish government has set an ambitious goal to build 2000 biogas plants before 2020.

The national law which determines manure handling is described by the following documents: Fertilizers and Fertilisation Act, Ministry of Agriculture Decree on application of fertilizers and education in fertilisation, Water Law Act and Environmental Protection Act and Ministry of Environment Decrees regarding Nitrate Vulnerable Zones. However it is noticeable that above mentioned legal acts are not commonly obeyed, as it is said in a document of the Polish Supreme Chamber of Control's, published after last control of industrial animal farms in Poland[1]. According to the fertilizer and fertilisation act, the manure can be spread on agricultural land with the dose not exceeding 170 kg N/ha/yr. only between 1st of March and 30th of November. The liquid manure has to be stored in the sealed tanks which have the capacity of at least 4 months. All other manure should be stored on hard surfaced pads or heaps in an environmentally friendly way and all the leakage should be collected. According to waste act, manure (waste code 02 01 06) is classified in the group together with waste from agriculture, arboriculture, hydroponic cultivation, forestry, hunting and fisheries. The law further describes the details for safe disposal of the manure, i.e. obeying fertilizer and fertilisation act, meeting sanitation requirements (not spreading on the fields, where crops are grown directly for human consumption), homogeneous spreading, injection not deeper than 30 cm below the ground and groundwater table located deeper than 1.5 m below the soil surface.

Normally in Poland, coefficients used for calculating farm-level livestock units (LU) on pig farms are from the Ministerial Decree from 9.11.2010 on projects likely to have significant environmental effects (Dz.U. Z 2010 Nr 213, poz. 1397), and these are 0.14 for fattening pigs and 0.35 for sows. These values are similar to the coefficients presented in the Reference Document on Best Available Techniques for The Intensive Rearing of Poultry and Pigs (BREF polish version) from July 2003, page 311, which are 0.16 for fattening pigs and 0.4 for and sow with piglets < 10kg. However, for the sake of comparative analysis between BSR farms in this report, the coefficients used to calculate LU on polish farms presented here were taken from COMMISSION REGULATION (EC) No 1200/2009, of 30 November 2009, implementing Regulation (EC) No 1166/2008 of the European Parliament and of the Council on farm structure surveys and the survey on agricultural

[1] Skorupski J., Kozłowska A., Green Federation GAJA (2011): Industrial animal farming in Poland. Green Federation GAJA, Baltic Green Belt Project.

production methods, as regards livestock unit coefficients and definitions of the characteristics, available currently at:
http://epp.eurostat.ec.europa.eu/statistics_explained/index.php/Glossary:Livestock_unit_(LSU)
and discussed in more detail in chapters 5 and 8.

We would like to express our gratitude for the hospitality and engagement during farm surveys as well as assistance during sampling, namely to: Ms. Diana Vennik and Mr. Gerrit van Ommeren (Farm 1), Mr. Maciej Baurycza (Farm 2) and Mr. Robert Adkonis (Farm 5). Special thanks to the employees of Poldanor (Farm 3 and 4); Ms. Danuta Leśniak, Ms. Mariola Piernicka and Mr. Marcin Budek for significant help during data collection and sampling.

6.5.1 Dairy farms

6.5.1.1 Farm 1

Farm 1 is a dairy cows farm owed by the company *Ompol Sp. z o.o.* and it is located in Northern Poland in Leśnice in the Municipality of Lębork. Farm data details are presented in Tables 1 – 7 in Appendix 2. Farm 3 has 320 cows (290 dairy and 30 dry cows) with an average production of 11 738 kg ECM/cow/year. Farm 1 has three types of housing systems such as: (1) loose housing with bedding, (2) loose housing with cubicles with bedding and (3) loose housing with cubicles with slatted floor, therefore there are two kinds of manure handling systems: solid manure and slurry based with manure production of about 4500 (solid manure) and 6065 (liquid manure) tonnes per year.

Feeding

The feeding is based on grass-silage, corn-silage, hay (produced on farm), soybean meal, wheat and corn meal (imported). Most of the feed is produced on farm.

Livestock housing

There are three animal housing systems located in two barns (plus additional buildings for administration, feed storage etc.):

- 1 barn with loose housing with straw bedding (system 1),
- 1 double barn with two parts: a) loose housing with cubicles and bedding (system 2) and b) loose housing with cubicles with slatted floors and sawdust bedding (system 3),

System 1 (Figure 6.5.1) is a loose housing with a large, open, deep-litter pen with a concrete base. Straw is used for bedding and animals have access to outdoor loafing areas. Manure is removed manually on a daily basis to a container just outside the building, from where it is transported to an outdoor concrete pad once a week.

System 2 (Figures 6.5.2) has cubicles with straw as bedding and is openly ventilated since the sides of the building are open. The manure is scrapped mechanically once a day to an outdoor, concrete solid manure pit, from where it is moved to the outdoor concrete pad once a month by mobile unit. Liquid fraction is collected by drainage system, pumped by the slurry tank and discharged into liquid manure pit in barn 2b (System 3).

System 3 (Figure 6.5.2) has 168 cubicles with sawdust bedding and slatted floor. The sides of the building are open for full ventilation and liquid manure is stored in 700 m^3 manure pit under the slatted floor. The mobile slurry tank also collects liquid fraction from the barn 2a (System 2), households wastewater and rainwater from the residential building of the farm owners, and after discharges them into liquid manure pit every 6 weeks.

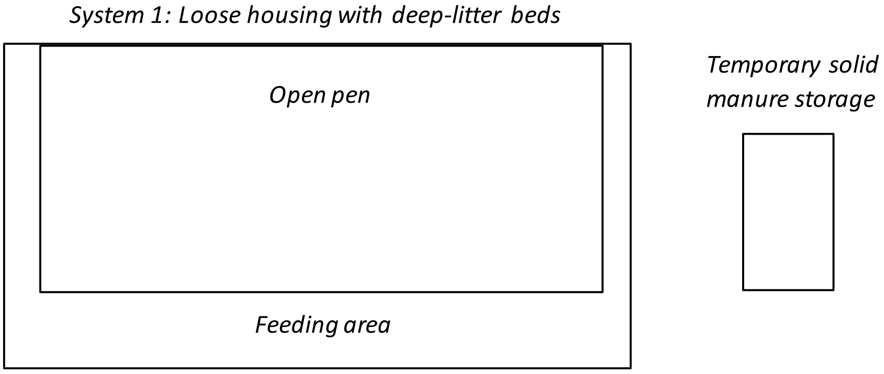


Figure 6.5.1. Barn 1 with loose housing (system 1) with the view of (A) the loafing area outside the barn and (B) the deep-litter pens inside. (Photos by Ksawery Kuligowski).

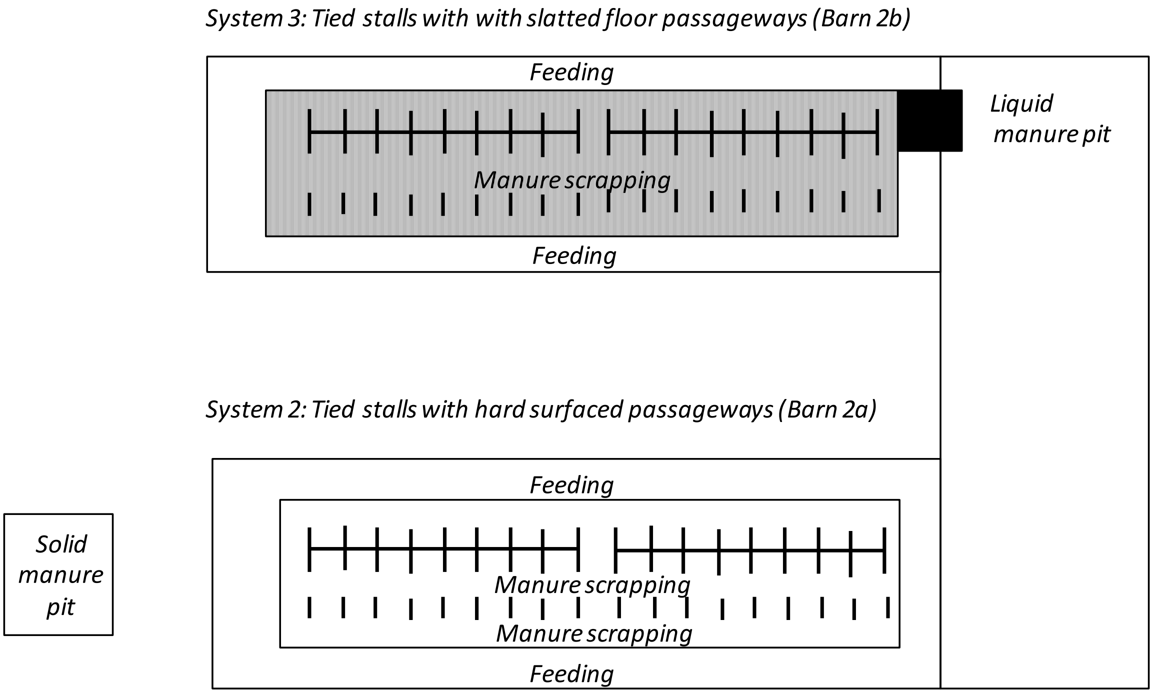


Figure 6.5.2. Barn 2 with tied stalls with solid passageways (system 2) and tied stalls with slatted floors (system 3).

Manure storage

The solid manure is stored outside the barns, whereas slurry is kept in the liquid manure pit inside the building (Barn 2b) before spreading on the land.

Figure 6.5.3. Solid manure storage outside barn 1 (system 1), barn 2a (system 2) and the deep pit for slurry inside barn 2b (system 3).

The solid manure from the System 1 and 2 is further transported to the outdoor concrete pad (Figure 6.5.4) with 2500 m^2 of the area with 3m high walls. From here it is taken to be spread on the fields. Additionally the liquid manure from System 3 is discharged to the same pad during winter time (when spreading is forbidden) by the mobile slurry tank (Figure 6.5.6). The leachate is directed into sewer.

Figure 6.5.4. Outdoor concrete pad for solid manures from System 1 and 2.

Manure end-use

On Farm 1, both solid manure and slurry is used for fertilizing purposes. Farm 1 has 100 and 200 ha of land for spreading of solid manure and slurry, respectively. The solid manure with the application of 45 t/ha and yr. is spread on maize fields 25 km away from the farm, whereas slurry is spread on grasslands for producing feed in the close by fields (< 1 km away from the farm). Solid manure is spread with a broadcaster (TEBBE) and slurry with a slurry tank (ROELAMA, capacity 12 000 l), presented on Figure 6.5.6.

Figure 6.5 6. Slurry tank for pumping of the urine, household wastewater, rainwater and liquid manure from System 3 and as well for spreading.

6.5.1.2 Farm 2

Farm 2 is a dairy cows farm owed by the company *Fortune Sp. z o.o.* and it is located in Northeast Poland in Cieszymowo Wlk. in the Municipality of Sztum. Farm data details are presented in Tables 1 – 7 for Poland in Appendix 2. Farm 4 has 380 cows (340 dairy and 40 dry cows) and total production of 10 148 kg ECM/ cow/ year. Dairy cows are mostly in-door with access to the outdoor areas while manure is removed from the buildings. Dry cows are on the pasture for 4 months within a year. Farm 2 has two housing systems: (1) loose housing with bedding and (2) loose housing with cubicles with bedding. Total solid manure production amounts for about 7500 tonnes per year and slurry for about 10 000 tonnes per year. All the manure is spread on an agricultural land.

System 1: Loose housing with deep-litter beds (Barn 1 and 2)

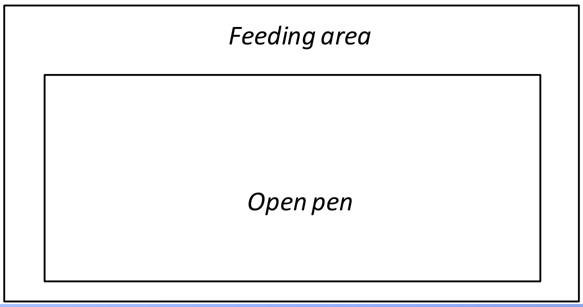


Figure 6.5.7. Barn 1 and 2 with loose housing in open pens (System 1), only one barn shown.

Feeding

The feeding is based on corn-silage, beet pulp, grass-silage and barley (produced on farm) and soybean meal, rapeseed meal and mineral feed (imported). The distribution of feed across animals at different growth stages presents as follows: dry cows are mostly fed with grass and corn silage and straw, dairy cows at lactation stage with grass and corn silage, corn, corn seeds silage, rapeseed meal, soybean meal, alfalfa and mineral feed. Heifers and calves are mostly fed with grass and corn silage, alfalfa and rapeseed meal.

Livestock housing

There are two animal housing systems located in three barns (plus additional buildings for administration, feed storage etc..):

- 2 barns with loose housing in open pens with straw bedding (system 1)
- 1 barn with loose housing with cubicles with straw bedding (system 2)

The housing system in Farm 2 is divided into two systems as shown on figures above. Barns 1 and 2 have system 1 (Figure 6.5.7), which is loose housing with open concrete pen. Straw is used for bedding and animal have access to the outdoor loafing areas. Solid manure is removed manually twice a week directly to the outdoor concrete pad. The liquid fraction of the manure is collected and removed with a tanker and deposited into the temporary slurry pit in Barn 3 (System 2 described below).

System 2 (Barn 3, Figure 6.5.8) has loose housing and cubicles with straw as bedding and animals have access to outdoor areas, whenever manure is removed (twice a day) by means of a tractor to the 192 m^3 outdoor concrete manure pit with slatted floors. Additionally the liquid fraction collected from Barns 1 and 2 (System 1) is discharged to the manure pit and diluted with the manure from Barn 3. The slurry is moved from the pit to the storage tank once a week by a mobile slurry tanker.

System 2: Tied pens with bedding

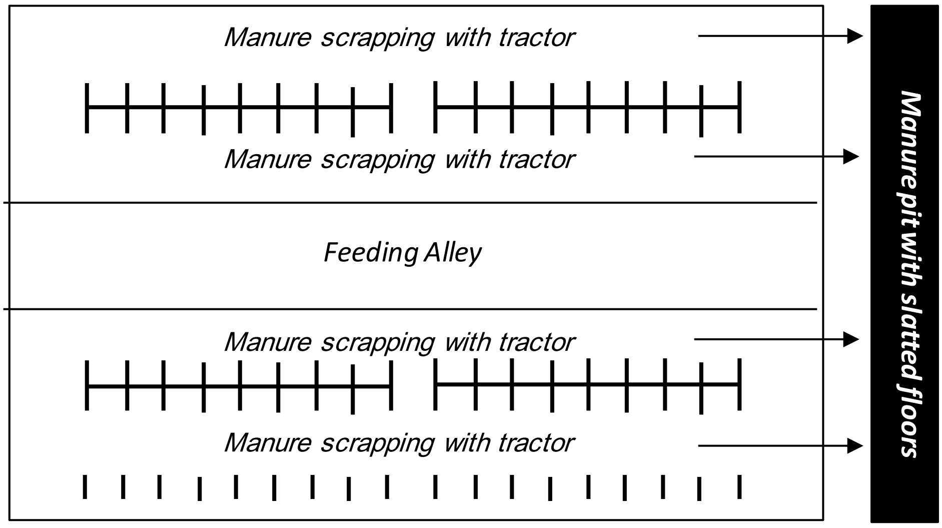


Figure 6.5.8. Barn 3 with loose housing with cubicles (system 2) and (A) a center drive-through feeding alley. (B) passageway just before scrapping with a tractor when cows are outside.

Manure storage

The manure from Barn 3 (System 2) is temporarily stored outside in a nearby manure pit, from where it is transported to the concrete tank once a week.

The actual storing takes place in three places: slurry in the concrete, uncovered tank located 20-100 m from all farm buildings (volume: 3000 m^3) and solid manure in both outdoor concrete pad (area: 2500 m^2, height: 4 m) shown on Figure 6.5.9 below and in the field heap (50m x 20m x 4m) 2 km away from the farm.

Manure end-use

On Farm 2, both solid manure and slurry is used for fertilizing purposes. Farm 2 has 200 and 300 ha of rape (200-300 m away) and maize (7 km away) fields, respectively. The slurry is spread on all fields using two band spreaders with trailing hose (ANNABURGER, capacity 18 000 l) with the application rate of 20 t/ha/yr., whereas solid manure is spread by broadcaster (FLIEGL, capacity 20 tonnes) only on maize fields with the application rate of 25 t/ha/yr. Corn fields are fertilised in early spring (April/ May), whereas rape fields during the summer (August). In autumn (October), some manure is used for spreading on pastures.

Figure 6.5.9. Outdoor concrete pad for solid manure (left) and concrete uncovered slurry tank (right).

Investments at Farm 2 after initial survey and farm description write-up (Feb-Dec, 2012)

Polish farmer from Dairy Farm 2 in the Cieszymowo Wlk. has expanded during 2012 by building a new stable with some innovative housing solutions as well as manure storage tank and solid-liquid separator. A brief description of these new components are given below however they are not included in the in the analysis or Appendix Tables for Poland.

New stable (Fig. 6.5.10) is able for housing of 520 cows (at the moment 400) and it is equipped with scratchers (b) for increasing cows welfare and cleaning them of dirt, dust, manure and bedding material. There are also two manure scrapers installed (e), special lock and guiding fence (d) leading to milking room (c). The new stable also has so called 'air curtain' (f) – a long plastic bag along the outer wall continuously filled with flowing air generated by low-power fan Fig 6.5.10).

Fig. 6.5.10 New housing solutions at Farm 2. Explanations in the text above.

Besides (not shown on the pictures) the milk from cows is cooled down from 32°C to ca. 16°C by heat exchanger and thereafter warm water is used for drinking cows.

Manure processing and storing

New stable has under-floor manure pit (1200 m^3), and the manure is thereafter separated into solid and liquid fractions by outside press separator (Fig 6.5.11 below). Depending on the separation efficiency it is planned to recycle part of the solid fraction into bedding as well as to export (another part) off-farm as a good-quality P fertilizer, whereas liquid fraction will be pumped directly to the 6100 m^3 roofed liquid storage tank.

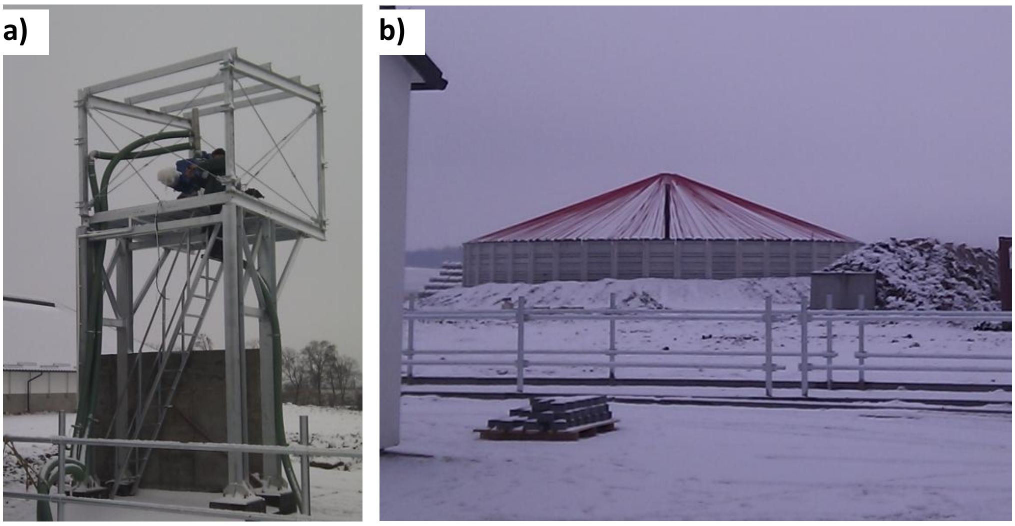


Fig.6.5.11. Outside manure separator and liquid manure storage tank at Farm 2.

6.5.2 Pig farms

6.5.2.1 Farm 3

Farm 3 is an IPPC fattening pigs farm owned by the company *Poldanor SA* and it is located in Northern Poland in Pawłówko in the Municipality of Człuchów. Farm data details are presented in Tables 1 – 7 for Poland in Appendix 2. Farm 3 has 9200 places for fattening pigs and yearly produces 31 585 pigs at 102 kg. The starting weight is 26 kg, there are 1090 starters per batch, time from start to delivery is 89 days, whereas down time between batches is 48h. Farm 3 has housing system with pens with slatted floors and manure handling is slurry based with a manure production of about 34 000 tonnes per year. Solid manure is not produced. All the manure is processed in a nearby biogas plant.

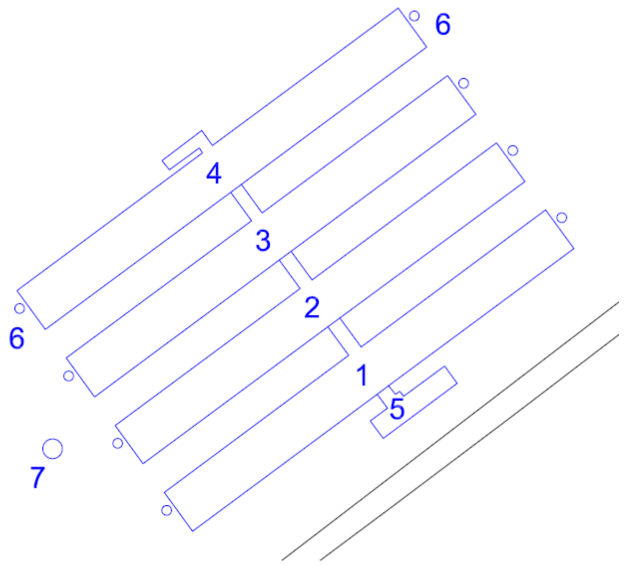


Figure 6.5.11. Layout of Farm 3 for fattening pigs (source: POLDANOR). (1-4) are animal housing units, (5) is the administration building, (6) feed silos (2 per housing unit), (7) manure pumping pit.

Feeding

The feeding is dry (86.3% dm) and it is based on triticale (28%), wheat (27.3%) and barley (20%) and smaller contents of lupin, wheat bran, soybean meal, sunflower meal and beef fat. Most of the feed is produced on farm and amounts for 2.94 kg/ animal/ day. The feed rate is constant during fattening period. Feed additives constitute calcium carbonate (1.05%), MCP Tesenderlo (0.55%), Salt (0.65%), Phyzyme xp5000 (0.01%) and Premiks FINISH (1%).

Livestock housing

There are 4 animal housing units on the farm (see Figure 6.5.10) plus additional buildings for storage and administration.

- Building 1: 72 pens (2 219 places)
- Building 2: 104 pens (2 237 places)
- Building 3: 104 pens (2 240 places)
- Building 4: 74 pens (2 230 places)

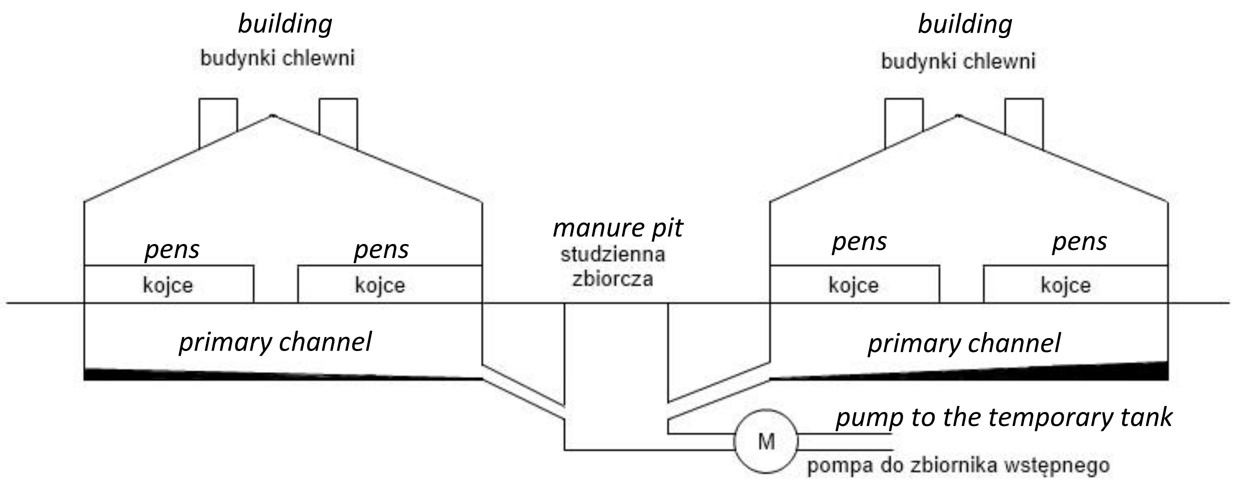


Figure 6.5.12. The cross section of the building on Farm 1 (source: POLDANOR).

The cross section of the building with indicated pens and primary channel is shown on Figure 6.5.11. The manure is gravitationally flowing from the primary channel, which is just under the pens, to the below-ground, concrete manure pit outside the building. There are no secondary (cross) channels within the buildings. Around 30 m^3 water is used for washing purposes (1 wash/building). Manure is pumped from the manure pits to a covered storage pond once a week where it is temporarily stored before processing. The storage pond is located about 300 m from the animal housing building.

Manure processing

100% of the manure is processed with anaerobic digestion in the biogas plant opened on 9th of June 2005. The biogas plant consists of:

- Substrates collection station
- Preliminary tank with pumping station (180 m^3)
- 2 fermentation tanks (750 m^3 each)
- Technical building with hygenisation
- Digestate storage lagoons (5 lagoons total volume 37 000 m^3)
- Combined heat and power plant of 0.95 MW_{el}

The yearly inputs to the biogas plants are: 29 000 tonnes of manure, 5500 tonnes of corn silage, 3000 tonnes of slaughter waste and 1000 tonnes of glycerine. The yearly production of biogas is around 3.4 M m^3, and electrical energy amounts for 8000 MWh.

Figure 6.5.13 Biogas plant on Farm 1 (source: POLDANOR).

Manure (digestate) storage

There are 5 covered storage ponds with a total volume of 37 000 m^3 used for storing digestate.

Manure end-use

On Farm 3, manure digestate is used for fertilizing purposes with the application rate of 40 tonnes/ ha/ year. Farm 3 has 645 ha of arable land available for spreading manure for cultivation of corn and triticale. An umbilical system (fixed underground pipelines, ∅ 110) supplied from a nurse tank is used for distributing all manure on the fields which is either applied with trailing hose applicators or closed slot injection (Agrometer Pioneer, and Samson, respectively), shown on the Figure 6.5.13. The arable fields are within 5 km from the farm.

Figure 6.5.14. Manure spreading on Farm 3 and 4 with the usage of umbilical trailing hose applicator (Agrometer Pioneer) to the left and closed slot injection (Samson) to the right (source: POLDANOR).

6.5.2.2 Farm 4

Farm 4 is an IPPC sows farm owned by the company *Poldanor SA* and it is located in Northern Poland in Płaszczyca in the Municipality of Człuchów. Farm data details are presented in Tables 1 – 7 for Poland in Appendix 2. Farm 4 has 3680 places for sows, 12.5 piglets at 6 kg are weaned per litter, average time between weaning and delivery is 28 days, average farrowing period amounts for 150 days and the total nr of piglets delivered per year is 91 608. Farm 4 has housing system with pens with slatted floors and manure handling is slurry based with a manure production of about 29 353 tonnes per year. Solid manure is not produced. All the manure is processed in a biogas plant.

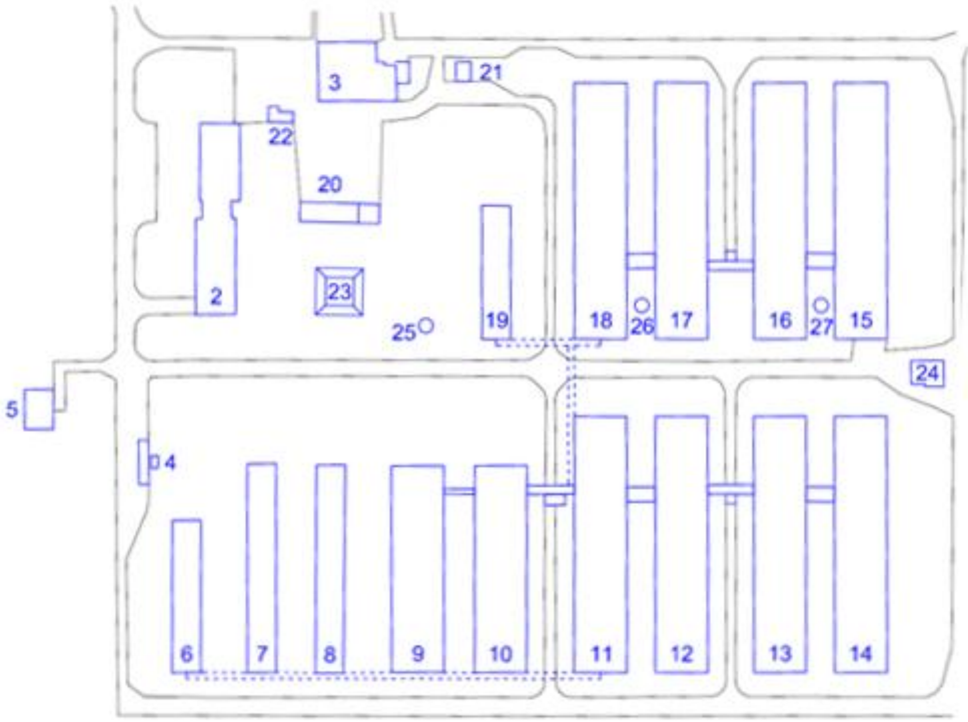


Figure 6.5.15. Layout of the Farm 4 for sows (source: POLDANOR).(2, 21-22) administration building, (3) residential building, (4) scales, (6-19) animal housing, (20) garage, (23) fire prevention building, (24) power transformer station, (25-27) manure collector pits.

Feeding

The feeding is dry (86% dm) and it is based on barley (30%), wheat (29%), triticale (15%) and wheat bran (10%) as well as small amounts of beet pulp, sunflower meal, rapeseed meal and poultry fat. The additives constitute calcium carbonate (0.98%), MCP Tesenderlo (0.68%), Salt (0.48) and Premiks GESTA (1%). Most of the feed is produced on farm and amounts for 77.58 kg/(sow+piglets)/ day. This amount is an average for a sow associated with its piglets.

Livestock housing

Farm 4 has 14 separate barns for animal housing (see Figure 6.5.15). All together they are equipped with 48 group pens occupied totally by 2016 sows. The pens are with slatted floor with area of 14-24 m^2 each. Remaining pigs are in individual pens. Farrowing pens use sawdust for bedding material. The manure is gravitationally flowing from the primary channel which is just under the pens, to the below-ground, concrete manure pit outside the building. There is no secondary (cross) channel within the building. From the pit, manure is pumped to the steel temporary tank once a week before anaerobic digestion.

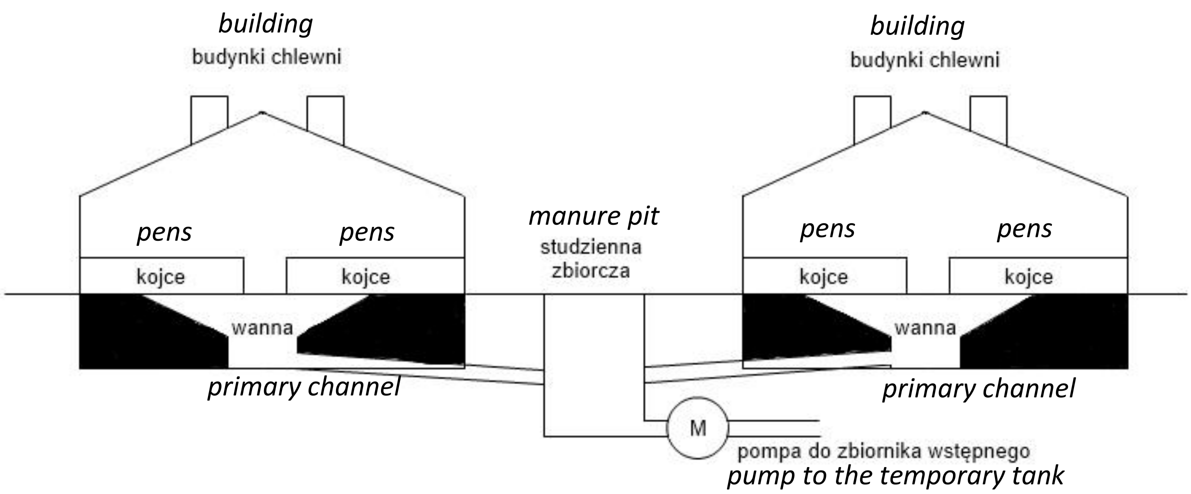


Figure 6.5.16. The cross section of the animal housing units on Farm 2 (source: POLDANOR).

Manure processing

Manure is pumped weekly from the manure pits outside the animal housing units to a LDPE covered steel tank once a week. This tank located about 300 m from the manure pits and is temporary storage before manure processing (see Figure 6.5.17). 100% of the manure is processed with anaerobic digestion in a biogas plant that opened on 21st of April 2008. The biogas plant consists of:

- 2 covered preliminary tanks (315 m^3)
- Covered substrates tank (300 m^3)
- Fermentation tank (1500 m^3)
- Covered digestate tank (2000 m^3)
- Covered storage pond for digestate (20 000 m^3)
- A combined heat and power plant of 0.625 MW_{el}

The yearly inputs to the biogas plants are: 18 500 tonnes of manure, 3700 tonnes of corn silage, 1000 tonnes of green waste (plant waste) and 500 tonnes of waste from processing of plant products. The yearly production of biogas is around 2.3 M m3, electrical energy amounts for 5300 MWh and heat amounts for 5900 MWh.

Manure (digestate) storage

The covered storage pond for digestate (seen in Figure 6.5.17) has a volume of 20 000 m^3.

Manure end-use

On Farm 4, manure digestate is used for fertilizing purposes with the application rate of 50 tonnes/ ha/ year. Farm 4 has 777 ha of arable land available for spreading manure for cultivation of corn, barley and triticale. An umbilical system (fixed underground pipelines, ∅ 110) supplied from a nurse tank is used for distributing all manure on the fields which is either applied with trailing hoses or closed slot injection (Agrometer Pioneer and Samson, respectively). The arable fields are within 5 km from the farm.

Figure 6.5.17. Biogas plant on Farm 4 (source: POLDANOR).

6.5.3 Poultry farm

6.5.3.1 Farm 5

Farm 5 is an IPPC poultry farm owed by the company *Adkonis* and it is located in Northern Poland in Kwakowo in the Municipality of Słupsk. Farm data details are presented in Tables 1 – 7 for Poland in Appendix 2. Farm 4 has total number of 180 000 laying hens with egg production of 54 million per year. Starters amount for 90 000 and they are purchased from outside. Farm 5 has housing system based on cages including 3 buildings for laying hens and 1 building for starters. Total manure production amounts for about 10 000 t per year. All the manure is spread on agricultural land.

Feeding

The feeding is based on maize (20%), wheat (15%), triticale (20%), produced on farm, grain mix (10%) and calcium carbonate (10.25%) as well as soybean meal (18%), rapeseed meal (5%), and mineral feed (imported). Additionally phosphate (0.75%), soybean oil (1%) and vitamins (1%) are added. The annual consumption of feeds are 7200 t.

Livestock housing

There is one housing system located in 4 buildings:

- 1 building with cages (2 m^2 each, 25 chickens/ cage) for purchased starters (area: 1500 m^2),
- 3 buildings with cages (2 m^2 each, 25 chickens/ cage) for laying hens (area: 2000 m^2 each),

No bedding is used and manure is mechanically removed twice a week by a conveyor belt located directly under the cages to a mobile container just outside for temporary storage (Figure 6.5.18).

Manure storage

The manure from the buildings is moved to the field heaps twice a week. There are 20 field heaps with capacity of 500 t of manure each, located 2 to 5 km away from the farm buildings. The bottom of the heaps is covered with straw. From each heap, manure is spread on 50 ha of neighbouring fields.

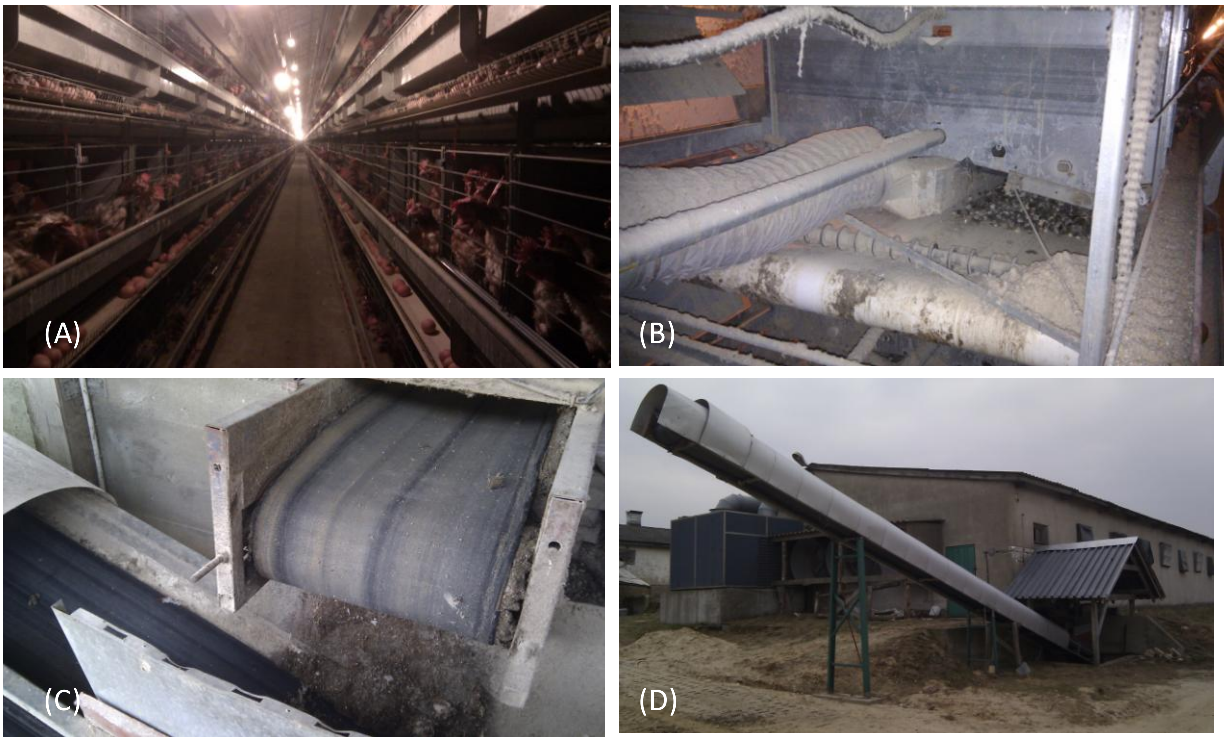


Figure 6.5.18. (A) Inside of one of the animal housing units, and (B-D) the manure removal system: B) view of the conveyor belt for mechanical manure removal from under the cages in use, C) manure transport from the indoor conveyor belt to outdoor conveyor belt, D) manure transport from outdoor conveyor belt to the mobile container.

Manure end-use

On Farm 5, all the manure is used for fertilizing purposes. Farm 5 has 1000 ha of agricultural land (2-5 km away) for spreading of the manure with the application rate of 10 t/ha/yr., where the following crops are cultivated: maize (500 ha), triticale (200 ha), mixed crops (200 ha) and legumes (100 ha). The spreading technique is broadcasting (FLIEGL, JEANTIL, with capacities of 20 and 16 t, respectively).

Figure 6.5.19. Broadcasters used for solid manure spreading: FLIEGL on the left and JEANTIL on the right.

6.6 Sweden

Erik Sindhöj and Lena Rodhe, JTI

Sweden currently (2012) has 148 IPPC poultry farms and 117 IPPC pig farms, most of which are located in the southern and south central part of Sweden (see the online database from the Swedish EPA for an updated list http://utslappisiffror.naturvardsverket.se/en/). There is no central database for permitting large dairy farms but this is done at the county level on an individual basis.

Livestock farming in Sweden has been shaped in part by animal welfare and environmental regulations. Animal welfare regulations that affect manure handling systems are generally related to housing systems and are detailed according to livestock types below. Environmental regulations are, on the other hand, more directed towards manure storage and land application. Details concerning these regulations can be found at the Swedish Board of Agriculture's website www.jordbruksverket.se. County-level regulations may be more stringent that national-level.

Manure storage regulations for large-scale livestock farms:

- Storage capacity of 8 months for cows and 10 months for pigs and poultry
- Slurry storage must be covered with a stabile natural crust or some other method for reducing ammonia losses
- Filling must occur below the cover

Regulations that affect manure spreading on agricultural fields include:

- Land application from December through February must be incorporated to at least 10 cm within 12 hours of application
- Maximum 22 kg phosphorus (P) per ha and year or 110 kg P per ha over a 5-year period.

In addition to these rules, land application in nitrate vulnerable zones (i.e., coastal regions in Southern Sweden and other agricultural land near waterways classified as sensitive to nitrogen pollution) include:

- Land application on bare soils must be incorporated within 4 hours.
- Slurry application in growing crops must be applied with bandspreading or injection techniques
- Maximum 170 kg nitrogen (N) per ha and year. Maximum 60 kg N per ha on winter oilseed crops and maximum 40 kg N per ha on other winter cereals.
- Land application between August and October is only permitted in growing crops or just before sowing winter crops.
- In Southern Sweden coastal regions land application between August and October is only permitted in growing crops or just before sowing winter oilseed crops. On clay soils, land application is permitted during this time just before sowing winter cereal crops.
- No land application from November through February (solid manure can be spread until the end of November)
- No land application on water saturated areas or on frozen or snow covered soils.
- No land application on slopes > 10% if the slope is facing a waterway.

6.6.1 Dairy farms

In Sweden, year-round confinement is not allowed and cows must have access to pasture during summer months. Housing systems with indoor manure storage in deep pits under slatted floors is not allowed. For detailed farm data from the surveys see Table 1 to 7 for Sweden in Appendix 2.

6.6.1.1 Farm 1

Farm 1 is one of the larger dairy farms in Uppsala County, and is located in central Sweden (60° 01' N) close to the coast. Farm data details are presented in Tables 1 – 7 for Sweden in Appendix 2. Milk and agricultural production on the farm has been certified organic since 2003. Farm 1 has 330 milking cows and a total herd size of about 550 animals. The herd is approximately 60% Swedish Holstein and 40% Swedish Red Cattle and production is 8800 ECM per cow per year. Farm 1 has loose housing systems and manure handling is slurry based with a manure production of about 18 000 m^3 per year. There is a small amount of solid manure produced from the calving pens with deep-litter beds in the service barn, and also from the calf and heifer barns which also have deep litter beds. All solid manure is mixed into the slurry storage before spreading.

Feeding

The feeding is based on total mixed rations with 3 feeding groups: high and low production cows and cows just before calving. All roughage cereal grains are produced on the farm. Grass silage is made in bunkers silos. A compound feed concentrate is purchased off-farm and a small amount of minerals are added to the feed.

Livestock housing

There are 4 animal housing units (see Figure 6.6.1) on the farm:

- Main barn for milking cows with 285 places and milking parlour – H1
- Service barn for calving, dry cows and cows with high cell counts, 56 places – H2
- Heifer barn 120 places – H3
- Dry cow and heifer barn, 100 places – H4

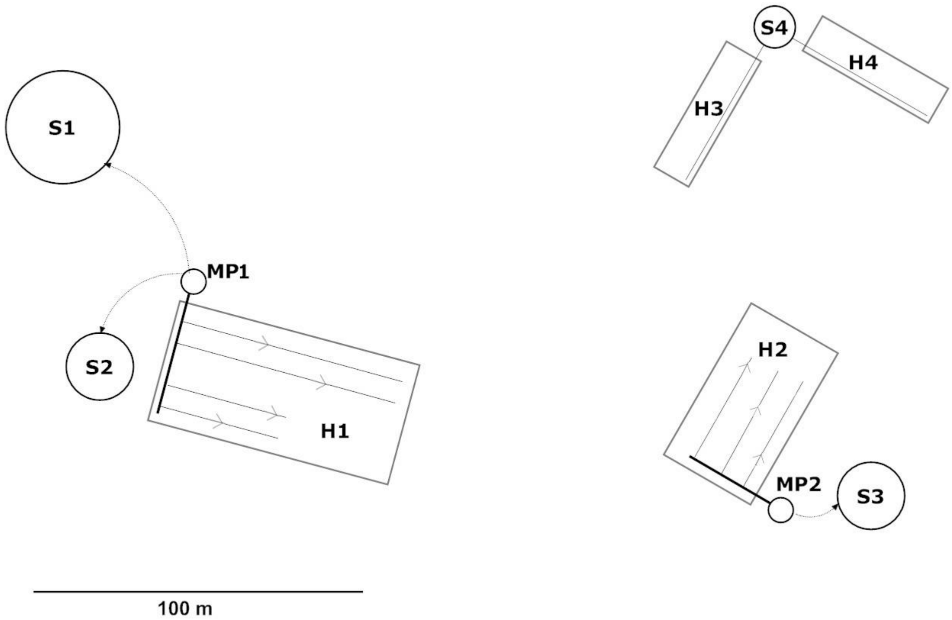


Figure 6.6.1. Layout of animal housing units (H1, H2, H3, H4), manure pits (MP1, MP2) and manure storage tanks (S1, S2, S3, S4) on Farm 1. There are 4 additional satellite storage tanks located between 2 and 20 km away.

The main housing (H1) was built in 2006 in loose cubicle (freestall) design with 285 places for milking cows and a centre drive-through alley with feeding bunks on either side (Figure 6.6.2). The building is naturally ventilated by adjusting the roof ridge opening. The building has a 24 cow carousel milking parlour, as well as the farm office and personnel room with toilets and showers. On each side of the drive-through there are 2 concrete alleys, one passageway with cubicles on both sides and a feeding alley with cubicles on one side and access to the feed bunk on the other. The alleys are cleaned with DeLaval hydraulic scrapers. The hydraulic cylinder is connected to a drawbar in a recess in the centre of the alley. The drawbar moves back and forth which moves the scraper in slow steps. The scrapers operate once per hour in the summer and continually in the winter to minimize freezing risk. Manure scraped from the passageways is deposited into a covered cross channel at the end of the barn. Approximately 2.5 m^3 of wood shavings are used as bedding material per day (760 m^3 per year). The cross-channel empties via gravity flow into a 125 m^3 below-ground, concrete, manure pit (MP1) just outside of the barn (Figure 6.6.1). The storage capacity of MP1 is about 4-5 days (10 days during summer). The cross-channel is flushed daily with wastewater collected from the milking parlour, the kitchen in the personnel room, 2 toilets and shower facilities. Water is also added to the slurry from daily rinsing the areas of the drive-through alley that cows cross to the milking parlour. The total volume of water added to the slurry is currently unknown.

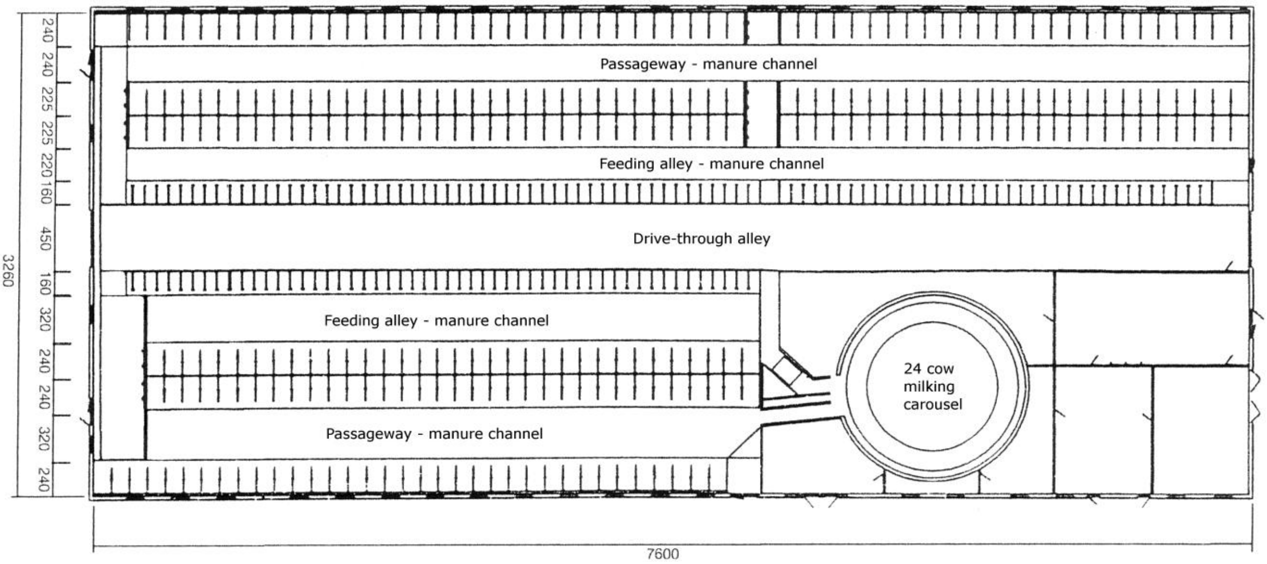


Figure 6.6.2. Main milking barn H1.

The service barn (H2) was renovated in 2010 and is an open sided barn divided into 2 sections and has a simple 5 cow milking parlour. One section has 6 deep-litter calving pens and the other section has loose cubical design. A portion of the pens are cleaned monthly with a tractor mounted front loader so that all deep-litter beds are changed twice annually. Straw bedding is used in the winter and dried peat is used in the summer. The solid manure is deposited directly into the nearby slurry storage tank (S3) described below. The loose housing section has 1 concrete passage with cubicles on both sides and a concrete feeding alley with cubicles on one side and access to the feed bunk on the other. Both alley ways are cleaned with DeLaval hydraulic scrapers (similar to those described above) once per hour in the summer and continually during the winter or alternatively with a tractor mounted scraper when freezing is a problem. Scraped manure from the main passageways is emptied into a covered cross-channel at the end of the barn, which empties via gravity flow to a 150 m^3 manure pit (MP2). Wastewater from the milking parlour is emptied into the cross-channel as well.

The remaining two barns, H3 and H4, are for calves, heifers and dry cows respectively and are simple structures that are completely open along the long side. They both have loose housing with deep-litter pens with a feeding alley passageway running along the barn that is scraped daily using a tractor mounted scraper. The tractor scrapes the manure and deposits it directly into storage (S4) which has a capacity of 350 m^3. Straw is used for bedding and the litter is changed once a year.

Manure storage

There are 4 primary storage facilities on Farm 1. The main storage (S1) is a round concrete tank with a capacity of 4000 m^3. S1 is partially below-ground and made with pre-fabricated 4.3 m high concrete panels. Slurry is pumped from MP1 about 50 meters to S1, but MP1 can also optionally pump slurry to an additional storage tank (S2) close by, which is a round below-ground tank made with pre-fabricated concrete panels and has a capacity of 1000 m^3. Both S1 and S2 are uncovered but have well-formed natural crusts and are filled below the surface. Slurry from TS2 is pumped to a third storage facility (S3) every 7-14 days. S3 is a round, uncovered, belowground tank made of pre-fabricated concrete panels and has a capacity of capacity of 1000 m^3. It is also filled below the surface and has a well-formed natural crust year round due to additions of solid manure from the deep-litter pens. Aside from the primary storage, there are 5 concrete satellite slurry storage tanks located between 2-20 km from the main storage facilities to buffer storage capacity and simplify logistics during spreading. Slurry mixing in storage tanks immediately prior to spreading is done with a tractor mounted propeller mixer.

Figure 6.6.3. Pictures of A) temporary storage tank (MP2) that is immediately adjacent to the housing unit (H2), and B) storage structure S1 including filling pipe for slurry pumped from MP1.

Manure end-use

Farm 1 has 500 ha of arable land available for spreading manure plus an additional 200 ha of permanent pasture. All manure is used on farm as fertilizer and spread with band spreading techniques. Soils range from heavy clay to loam and the arable fields spread out 20 km to the south and 15 km to the north of the animal production centre. The crop rotation in general is a 3-year ley followed by 1 or 2 years of cereals. About 350 ha of the arable land is under 3-year ley and receives 20-25 t/ha slurry during a summer application, except the first year leys do not receive manure application to enhance the establishment of clover. The remaining 150 ha is planted with spring and winter cereals. Spring cereals receive an initial application of 40 t/ha and winter cereals receive 35 t/ha.

The farm owns a 14 m^3 vacuum Joskin slurry tank which is used to transport slurry from the primary storages to the satellite storages. All manure spreading is hired in from a local contracting company with its own equipment. The contractor uses Samson slurry tankers with 12, 20 or 25 m^3 tanks, depending on field conditions, equipped with a 24 m boom and trailing hoses. Initial manure applications for cereals are done on bare soils and are incorporated within 24 hours after application. The rest of the applications are in growing crops and are therefore not followed by incorporation.

6.6.1.2 Farm 2

Farm 2 is one of the largest dairy farms in Northern Sweden (61° 48' N), and is about 70 km from the coast. Farm 2 has 430 milking cows and a total herd size of 880 animals. The herd is almost entirely Swedish Holstein and production is 10 500 ECM per cow per year. Farm 2 has loose housing systems and generates 25 000 m^3 slurry and 2000 tonnes solid manure per year.

Feeding

Feed is based on total mixed rations. Cows are divided into 4 feeding phases and grouped accordingly based on 3 levels of milk production and then dry cows and heifers just before calving. Most fodder is produced on farm. Silage from grass is made in bunkers and bales while silage from wheat and barley is made in long covered stacks. Aside from that a compound feed is purchased off-farm and a small amount of minerals are added to the feed. Diets consist of approximately 55% roughage, 35% grains and 10% concentrates and minerals.

Livestock housing

There are 4 main animal housing units (see Figure 6.6.4) on the farm, and 2 of the houses are divided into several different sections:

- Main barn with total 175 places for milking cows, milking parlour, calving section, dry cow section and milking cow section – H1
- New resting barn for milking cows, 305 places – H2
- Mixed barn for heifers, dry cows and sick cows 269 places – H3
- Calf barn < 5 months, 200 places – H4

The main housing unit (H1) has had several additions and modification made over the years and is divided into several sections, including an office and personnel room. There are 2 20-cow parallel milking parlours; a calving section with 7 deep-litter boxes; a section for 48 dry cows with deep-litter loose pens and a section for 120 milking cows with deep-litter loose pens. Both sections are naturally ventilated and there is one long concrete passageway through both sections with large deep-litter beds on one side and access to the feed bunk on the other side (Figure 6.6.5). The milking-cow section is the newest section with a deep litter bed loose housing and is open on both sides. There are 6 heated water troughs for drinking (approx. 60 liters) which are tipped and cleaned twice a week. There is a single passageway going through both the milking and dry cow sections which is cleaned with an automated chain pulled scrapper once an hour. Scrapped manure is deposited into a covered cross-channel. The cross-channel empties via gravity flow into a 250 m^3 below-ground, concrete, manure pit (MP1) just outside of the barn (see Figure 6.6.4).

Water additions to the slurry from cleaning water troughs (including 12 troughs from H2) are about 86 $m^3\ yr^{-1}$. Wastewater from dishwashing the milking equipment is also added to the slurry and is guessed to be 73 $m^3\ yr^{-1}$. The amount of rinsing water used during milking is not known but is also added to the slurry together with water used for rinsing some of the passageways.

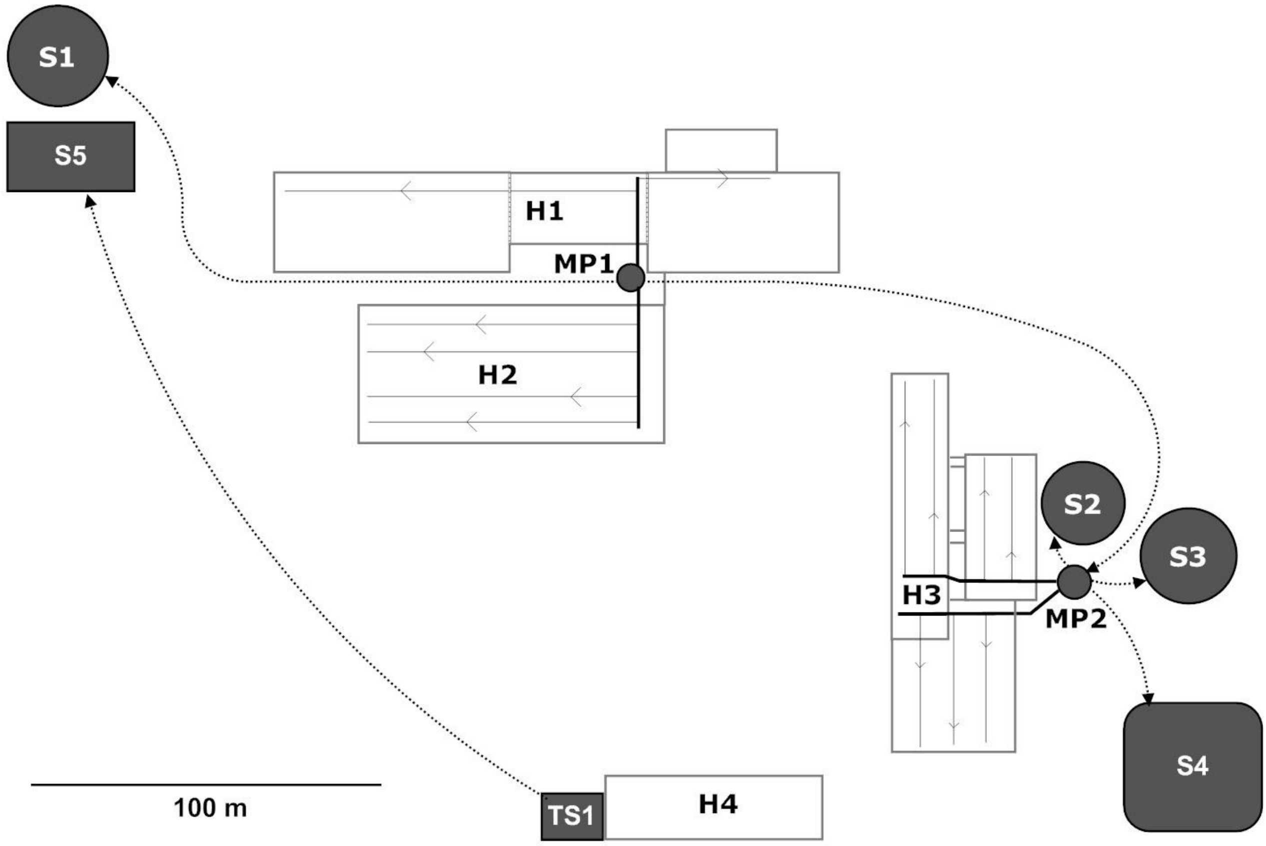


Figure 6.6.4. Layout of animal housing units (H1, H2, H3, H4), manure pits (MP1, MP2) and manure storage facilities (S1, S2, S3, S4, S5, S6) on Farm 2. There are 4 additional satellite storage tanks and 4 concrete manure pads located between 25 and 45 km away.

The new resting barn (H2) for milking cows was built in 2009 with a loose cubical or free stall design for 305 cows. The building is naturally ventilated and open on both long sides with cloth walls that can be closed in cold or windy conditions. The barn has 2 parallel concrete passageways on both sides of a central drive-through with feeding bunks on either side. The passageway surface is etched with a pattern to improve traction for the cows. Sawdust is used for bedding material and approximately 20 m^3 per week during winter months and less during the summer when they have access to pasture. At the ends and middle of the passageways there are loafing areas with large, heated water troughs (12) for drinking. Water troughs are approx. 60 litres and are tipped and cleaned twice a week. The passageways are scrapped with DeLaval reciprocating chain drive mechanical scrapers once an hour into a covered cross-channel at one end of the barn. The cross-channel empties with gravity flow into MP1 (described above).

Figure 6.6.5. A) Loose deep-litter pens and passageway in the milking cow section of H1. B) One of the passageways in H2 with stalls on left and feeding access on the right towards centre drive-through and water trough in loafing areas in the front. The passageway is concrete with a textured pattern cut into surface to improve traction for cows.

The mixed barn (H3) for heifers, dry and specialty needs cows has also had several additions and modification made over the years. There are 2 sections for heifers with 50 and 56 places with loose stall design and 2 parallel concrete passageways. The passageways have automated mechanical scrapers that operate once per 2 hours and empty into covered cross-channels at the end of the sections. One section uses drinking cups and the other section uses the large water troughs. The section for dry cows has 150 places and loose stall design and 4 parallel hard passageways with automated mechanical scrapers that operate every hour and empty into a covered cross-channel at the end of the section. In the end of this section there is a loafing area with water troughs for drinking. The specialty needs section has 13 pens with one passageway scraped into the cross-channel of one of the heifer sections. All 3 cross-channels have automated mechanical scrapers that operate once per day and empty into a manure pit (MP2) just outside the barn. MP2 is a belowground concrete tank with a volume of 250 m^3 and is emptied every 6-10 days.

The calf barn (H4) has 200 places with a deep litter individual and group pens. The building is closed with natural ventilation. There is a 200 m^2 temporary manure pad (TS1) just outside the end of the building. The solid manure pad is concrete with 1.2 m high walls on 2 sides.

Manure storage

There are 4 primary slurry storage facilities on Farm 2. Slurry from H1 and H2 is pumped from MP1 about 180 m to storage 1 (S1), which is a 4000 m^3 round tank, partially below ground and made of pre-fabricated 4.3 m high concrete panels. It is uncovered but there is generally a well-formed natural crust, due to the straw inputs from the deep litter pens in H1. It is also possible for MP1 to pump slurry to MP2, which is about 170 m away, when S1 becomes filled. MP2 can pump slurry to storage structures 2, 3 and 4 (see Figure 6.6.4). Storage 2 (S2) and 3 (S3) are both partially below-ground tanks made of pre-fabricated concrete panels with volumes 2000 and 2600 m^3 respectively. Both are bottom filled but often top filled during winter due to freezing problems. They are uncovered and have natural crusts however S3 has a thin and poorly formed crust. The fourth storage structure (S4) is a 6000 m^3 storage pond with an impermeable plastic liner. The pond is bottom filled and has a natural crust. There is also a primary storage for solid manure which consists of an 800 m^2 concrete pad. There are no walls around the pad and leachate is not collected. Aside from the primary storage, there are several satellite storage facilities located between 25 and 45 km away to buffer storage capacity and simplify logistics during spreading. There are 3 satellite slurry tanks which are round, partially below ground concrete tanks with capacities of 3000, 1200, and 1000 m^3. There are also 3 satellite solid manure pads which are about 250 m^2 each. None of the manure pads on Farm 2 are covered.

Manure end-use

Farm 2 has a total of 875 ha available for spreading manure, plus an additional 100 ha permanent pasture. All manure is used on farm and spread as fertilizer. Soils are generally loam and fields are spread out up to 50 km south of the animal production centre. Approximately 400 ha are leys which receive 25 t / ha in the late summer after the third cutting. Spring wheat is grown on 300 ha and barley is grown on 175 ha, both of which receive 20-40 t / ha before sowing, depending on the distance of the field from the animal production centre. Solid manure is spread at a rate of 20 t /ha on about 100 ha of cereals that receive lower amounts of slurry application.

Farm 2 owns and operates its own slurry and solid manure application equipment. They have a 20 m^3 Hill tank trailer from LK Verkstad AB with a 16 m trailing hose boom which is used for spreading on the leys. They also have a Hill 8 m wide cultivator slurry injector (“Svartjordsmyllare”, Figure 6.6.6) that is used for all spring slurry applications for cereals, so incorporation is immediate to a depth of about 15 cm.

Figure 6.6.6. Picture of slurry spreading equipment used on farm 2: (A) the 16m boom with trailing hose applicators and HTC 20 m^3 tanker by Hill (www.lkverkstad.se) and (B) the 8 m wide arable soil slurry injector also by Hill (“Svartjordsmyllare”).

6.6.2 Pig farms

In Sweden it is not allowed to house pigs on fully slatted floors, nor is it allowed to store manure in pits under the floors. The maximum allowed area for slatted floors in a pen is 25% of total pen area. Pens must have areas for resting, eating and defecating. Resting areas must be on hard solid surfaces and there should be enough bedding material for the pigs rooting needs and resting comfort. Tail docking is not allowed. Resting areas must also be large enough for all pigs to lie down at the same time. Gestation crates are not allowed. (Swedish Board of Agriculture www.jordbruksverket.se).

6.6.2.1 Farm 3

Farm 3 is the largest pig producer remaining in Uppsala County and is located in central Sweden (59° 49’ N) within designated vulnerable zone due to its proximity to Lake Mälaren. The farm has 3150 places for finishers, or fatteners, and a yearly production of over 9000 pigs. The manure handling system is slurry based with a yearly manure production of 5500 m^3. Farm 3 is owned by a cooperative of 5 surrounding farms which have a total of just over 700 ha available for spreading manure. Recruited pigs are 32 kg when they arrive and 124 kg when they are finished.

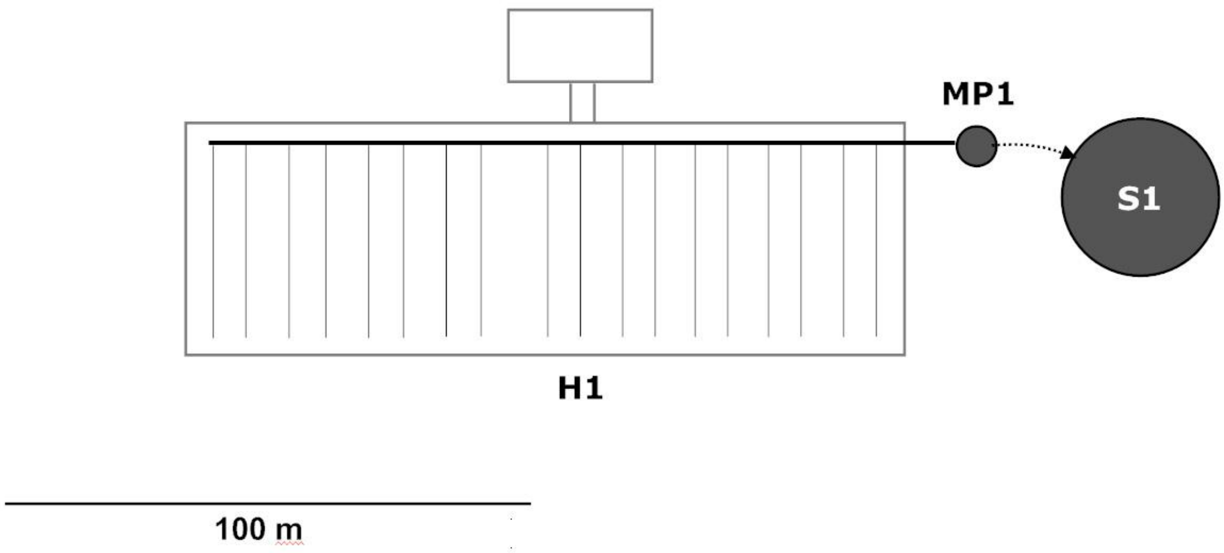


Figure 6.6.7. Layout of animal housing units (H1), manure pit (MP1) and primary manure storage tank (S1) on Farm 3. There is an additional satellite storage tank located 1.5 km away.

Feeding

All of the cereal grains are produced and milled on farm. A special blend of soybean and mineral concentrates are purchased off-farm. Phase feeding with 3 specific diet blends based on days and weight. Liquid feeding technology is used.

Livestock housing

This farm uses an indoor batch pen housing system with partially slatted floors. The building was built in 1997 and is closed with forced ventilation and heating. There is only one housing unit (see Figure 6.6.7) which is divided into 9 identical sections. Each section has 35 boxes and 10 pigs per box. The boxes are 9.9 m^2, which includes 2.3 m^2 slatted floors. Bedding material is a mixture of wood shavings and straw and approximately 1.6 m^3 wood shavings and 57 kg straw are used per day (600 m^3 wood shavings and 20.8 tonnes of straw per year). The boxes are scrapped manually once a day. Aquaglobe watering nipples (www.aquaglobe.se) are used in all boxes for reduced water spillage. Each section has two parallel manure channel covered by the slatted floors. Automated mechanical scrappers operate once a day to empty the manure into a perpendicular covered cross-channel that runs the entire length of the building. The manure transports by gravity flow in the cross-channel to the manure pit (MP1) just outside the building (Figure 6.6.7). MP1 is 40 m^3 which has a storage capacity of 2-3 days. Since nine years, cleaning of the sections after each batch is done by a fully automated washing robot made by Ramsta Robotics (www.ramstarobotics.com). Water meters were installed to measure water consumption during cleaning processes after batches which indicated that about 600 m^3 of water per year was added to the slurry from cleaning, which amounted to 11% of the total slurry volume.

Manure storage

There is 1 primary storage facility (S1) in close proximity to H1. The storage tank is round, partially below-ground and made of pre-fabricated concrete panels with a capacity of 2600 m^3. Slurry is pumped from TS1 about 15 meters to S1. When S1 is full, slurry is pumped to a satellite storage tank 1.5 km away that has a capacity of 1500 m^3. Before transport pumping, slurry in S1 is mixed using a tractor mounted mixer, and then pumped using the slurry pump in MP1. Flexible hose is rolled out to the satellite storage tank which is sloping just slightly downhill from the primary storage tank. Both S1 and the satellite tank are filled from the bottom and the straw used for bedding material helps keep a well-formed natural crust.

Manure end-use

The cooperative that owns Farm 3 has over 700 ha of arable land available for spreading manure. All manure is used on these farms as fertilizer and all fields for spreading are within 3 km of the storage facilities. About 150 ha of the arable land under cultivation with spring cereals receive 20-25 t/ha slurry during the spring and 100 ha of the winter cereals receive between 10-15 t/ha during the autumn. A small amount of maize is grown (20 ha) which receives 25 t/ha in the spring.

All manure spreading is hired in from a local contracting company with its own equipment. The contractor uses 20 or 25 m^3 Samson slurry tankers (www.samson-agro.com) depending on field conditions. The tankers are equipped with either an 18 m boom with trailing hoses, or an 8 m wide disc cutter injector. All applications on cereal crops are done with trailing hoses and applications for the maize are with the shallow injector. Manure is spread on bare soils and is incorporated within 12 hours after application just before sowing.

6.6.2.2 Farm 4

Farm 4 is a sow breeding farm located in Halland county in Southern Sweden (56° 27’ N) and is within designated vulnerable zones due to its proximity to coastal waters in the south. The farm has about 1 000 sows and produces over 25 000 feeder pigs per year. Piglet mortality rate is 16.8% and weaner mortality rate is 2.9%. The manure handling system is slurry based with a yearly slurry production of 18 000 m^3 and 400 tonnes of solid manure as well. In 2011 they built an anaerobic digester for treating all of their manure.

Feeding

All fodder is purchased off-farm in the form of a single complex feed type. Specific diets are given to mating sows, gestating sows, farrowing sows and dry sows and the grower pigs are divided into 2 phases with specific diets: weaned piglets up to 20 kg and 20-35 kg. Liquid feeding technology is used in all housing systems.

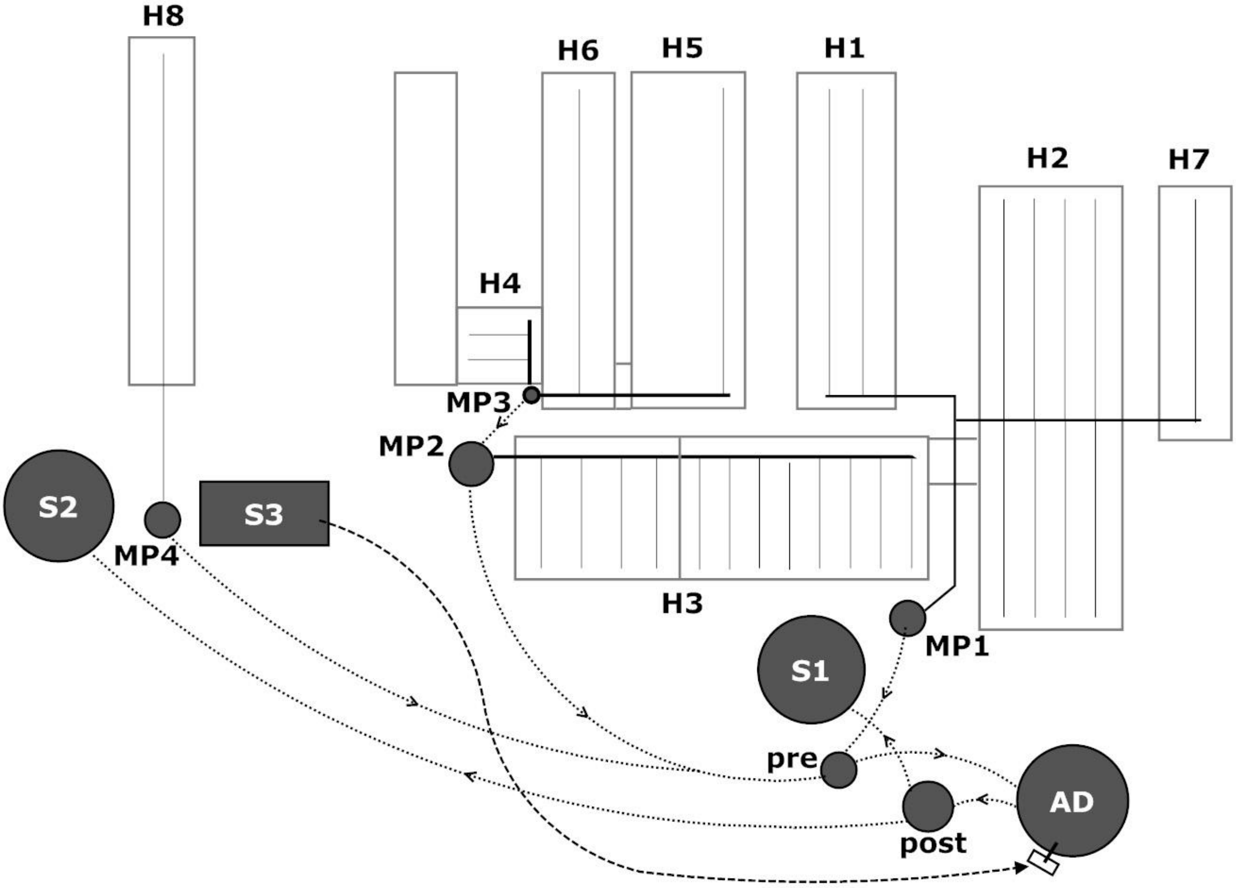


Figure 6.6.8. Layout of animal housing units (H1, H2, H3, H4, H5, H6, H7, H8), manure pumping pits (MP1, MP2, MP3, MP4) anaerobic treatment tanks (pre, AD, post), primary slurry storage facilities (S1, S2) and solid manure storage (S3) on Farm 4. Manure flow pathways within house and between pumping pits and storage systems are indicated with dotted and dashed arrows.

Livestock housing

This farm has 7 buildings for animal housing and some of the houses have several different sections (see Figure 6.6.8). All houses are closed with forced ventilation and heating. Straw is used for bedding material in the deep-litter pens and a combination of straw and wood shavings are used for bedding in the other boxes. In total 2400 tonnes of straw and 720 m3 of wood shavings are used annually.

- Gilt barn, 684 places – H1
- Farrowing / weaner barn, 176 / 3600 places – H2
- Farrowing / weaner barn, 80 / 3200 places – H3
- Farrowing barn, 28 places – H4
- Breeding barn, 210 places – H5
- Dry sow barn, 180 places – H6
- Dry sow barn, 160 places – H7
- Dry sow barn, 180 places – H8

The newest housing system (H1) was built in 2009 and is for gilts. There are two separate sections, one for younger gilts with 48 boxes and 9 per box, and another section for older gilts, which has 42 boxes with 6 per box. The boxes have partly slatted floors covering the primary manure channel that runs the length of the building. There are two parallel primary manure channels that are emptied with a vacuum system directly into a manure pit (MP1).

The main farrowing barn (H2) was built in 2002 and has a farrowing section and a growing section for weaners. The farrowing section is divided into 4 parallel areas with 44 boxes in each area. There are 4 parallel primary manure channels runs along each area. Farrowing boxes are 6 m^2 with access to 2 m^2 slatted floors covering the primary manure channel. The weaner section is also divided into 4 parallel areas, each with a manure channel and 46 partially slatted boxes. Primary manure channels in both sections are emptied with a vacuum system directly into MP1.

The second farrowing barn (H3) was built in 1995 and is also divided into a farrowing section and a growing section for weaners. The farrowing section has 2 separate areas with 40 partially slatted boxes in each area. There are 2 parallel primary manure channels that run the length of the building. The weaner section is divided into 4 separate areas, with 40 partially slatted boxes in each area. Primary manure channels in scraped with automated mechanical scrapers directly into a manure pit (MP2).

The extra farrowing barn (H4) has 28 places. The farrowing section has 2 separate areas with 40 partially slatted boxes in each area. There are 2 parallel primary manure channels that are scraped with automated mechanical scrapers directly into cross channel that is emptied into a manure pit (MP3).

The breeding barn (H5) was built in 2002 and has 6 separate deep-litter bed pens with partially slatted floors covering the primary manure channel running the length of the building. The manure channel is scraped with mechanical scrapers into a closed perpendicular cross-channel at the end of the building, which is emptied with mechanical scrapers into a manure pit (MP3). The deep-litter beds are changed with a mobile unit and the solid manure is transported directly to a concrete manure pad for storage (S3).

The mixed barn (H5) was built in 1995 and has 2 sections: a dry sow section (180 places), a farrowing section (28 places). All sections have boxes with partially slatted floors. Each section has one The manure channel in the farrowing section empties into a cross-channel that empties into MP2, with the help of mechanical scrapers.

The remaining 3 housing units are for dry sows. H6 was built in 1995 and has 180 places. There is one primary manure channel with automated mechanical scrapers that operate once per day. The primary channel empties into a cross-channel that empties into MP3. H7 was built in 2002 and has one primary manure channel that runs the length of the building with partially slatted boxes on either side. Manure is removed with a vacuum system that transfers it into MP1. The oldest barn on the farm was renovated in 2002 into a dry sow barn (H8) and has 160 places. There is one primary manure channel that runs the length of the building. Hydraulic scrapers transport the manure along the manure channel and push it directly into a manure pit (MP4) just outside the building.

Manure processing

In 2011, farm 4 built an anaerobic digester for treating all of the manure produced on the farm. The digester (AD) is 1400 m^3 and has a 28 day retention time. Fresh slurry is collected from MP1, MP2 and MP4 in a belowground feeding tank (pre) that is 150 m^3. The feeding tank is mixed by re-circulating the slurry with a pump to ensure a homogeneous mixture. About 50 m3 of slurry is fed into the digester daily using a centrifugal pump, and 2 tonnes of solid manure are added every second day via a screw conveyor leading directly into the digester. The digester is an aboveground enamelled steel tank and is continually mixed with a submersible mixer. Digestate is lead from the digester by gravity flow to an above-ground, covered, post-digestion tank (post) with a volume of 330 m^3 and with heat pumps for cooling the digestate to 20°C before it is lead to storage. The heat recovered is then used to heat the incoming substrate into the digester. The digester is currently generating 300 m^3 of biogas per day, which is utilised in a combined heat and power (CHP) production, however they hope to increasing production. Heat and electricity production are used on farm.

Manure storage

There are 2 primary storage facilities for digestate (S1 and S2). Both below ground and made of pre-fabricated concrete panels. The post-digestion tank can divert digestate by gravity flow to the nearby storage tank (S1), which has a volume of 1500 m^3. Alternatively digestate can be pumped approximately 175 m to another storage tank (S2) with a 2000 m^3 capacity. The storage facilities, S1 or S2, have very thin and poorly developed crusts and no other cover so they add extra straw to help build a crust. The solid manure pad (S3) is now only used for temporary storage of the solid manure until it is incorporated into the AD tank.

Manure end-use

Farm 4 has 315 ha of arable land available for spreading manure. However, depending on the crop rotation, less land is actually available any given year since some crops (potatoes and peas) do not receive slurry. In 2011 only 230 ha of arable land were used for spreading manure. Beets, oats, oilseed and wheat received spring applications with 20-25 t/ha and winter barley received autumn applications with 20 t/ha. Only 30% of the digestate is utilised on farm which amounts to about 5500 m^3. The rest of the digest, 12 500 m^3, is exported to nearby farms. This transport of manure is hired in by a local contractor.

Manure spreading is hired in from a local contracting company with its own equipment. The contractor uses 20 or 25 m^3 slurry tankers, depending on field conditions, that are fitted with an 18m boom and trailing hoses. All spreading is done on bare soils just before sowing and is incorporated within 4 hours after application.

Contracts are made with surrounding farmers to accept the excess digestate that is not used on farm. Commercial tanker-trucks are used to transport digestate to off-farm storage facilities provided by the contracting farmers.

6.6.3 Poultry farm

Broilers in Sweden must be raised free range on litter covered floors with maximum stocking density of 36 kg live weight or 25 chickens per m^2.

6.6.3.1 Farm 5

Farm 5 is a poultry broiler farm located in Södermanland county in Central Sweden (58° 51’ N). The farm is within designated vulnerable zones due to its proximity to the coast. The farm has approx. 8 400 m^2 available for raising broilers, split among 3 identical building with 2 similar sections in each building. Currently they deliver approximately 180 000 chickens per batch at 1680g after 32 days, with 9 batches per year. Chick mortality rate is 3%.

Feeding

Most of the feed is purchased as a complete feed for broilers. Daily rations are split and given twice a day. Farm-grown wheat is mixed into rations in linearly increasing proportions from 4% on day 7 to 36% on day 32. The feeding strategy is divided into 4 phases each with a specific complete feed composition. Phase 1 is up to day 10, phase 2 is until day 17, phase 3 is until 27, and phase 4 feed is used from day 28 until slaughter.

Figure 6.6.9. Picture of one of the barn sections. A thin layer (2-3 cm) of sawdust is used for bedding and the manure accumulates on the floor and is mixed with the sawdust during the entire growth period. Manure is removed with a tractor after the batch is delivered.

Livestock housing

This farm has 3, essentially identical, buildings for raising broilers. All houses are closed with forced ventilation and heating. Each house is divided lengthwise into 2 separate sections (see Figure 6.6.9). Each section is approximately 1400 m^2 with an open floor-plan and hard concrete floors. About 1.5 tonnes of wood shavings and sawdust is used for bedding material in each section. Usually 300-350 kg of extra bedding is spread during the batch to cover water spills. Manure removal occurs after the chickens leave the barn for slaughter. Then the feeding trays and drinkers are raised up and the manure is scraped and removed with a small tractor. The manure is loaded onto a 22 m^3 trailer which is then weighed using a permanently installed platform scale outside of the barns. After weighing the manure is transported to storage. The manure typically has moisture contents of about 35%. When the barns are washed and cleaned, the water is collected in an underground tank outside the barns which is then, depending on the time of year, either spread directly on nearby fields or transported to a slurry storage tank on a nearby farm.

Manure storage

Approximately two thirds of the manure produced on the farm is stored. Manure is stored on a concrete manure pad with support walls and drainage collection, or alternatively in field heaps (Figure 6.6.10). Farm 5 has received permission from the authorities to store manure in field heaps based on the dry matter content of the manure and that specific placement of the heaps is far from either waterways or drainage ditches. Approximately 5 or 6 field heaps are made each year and the fields are between 1 and 12 km from the barn. The heaps are made directly after each batch according to the weight of the load, the size of the field and an application rate of about 2.5 tonnes per hectare. After placement of the heaps, they are covered with a 5-10 cm layer of chopped straw.

Figure 6.6.10. Picture of one of the field heaps. A thin layer (10 cm) of chopped straw is used to cover the heap. Manure is weighed prior to transport to the fields and the size of the heap is made according to spreading capacity of adjacent fields at a rate of approximately 2.5 tonnes per hectare. Heaps must be placed far from drainage ditches, slopes or waterways.

Manure end-use

Approximately one third of the manure produced on the farm is sold to a nearby farm based biogas plant that digests primarily pig manure. In addition, last year they sold 140 tonnes to a neighbouring farmer to be used as fertilizer. The rest of the manure, approximately 885 tonnes, is used on the farm as fertilizer.

Farm 5 has 490 ha of arable land available for spreading manure. In 2011, 370 ha of arable land were used for spreading manure. Most of the manure is applied in the spring on growing crops of winter wheat. The rest of the manure (about 40%) is applied in the spring and immediately incorporated prior to sowing for barley, oats, rape and peas. The targeted application rate is 2.5 tonnes per hectare based on the P fertilisation limits; however it is very hard to spread this small quantity with currently available solid manure spreaders.

Manure spreading is hired in from a local contractor with their own equipment. The contractor uses a Samson SP12 for solid manure and a front loader to fill the spreader.

7 Characteristics of manure handling chains in BSR

In total, we looked at manure handling chains on 31 large-scale animal production systems in the Baltic Sea Region (Figure 7.1); 13 dairy farms, 12 pig farms and six poultry farms. All farms in this study were based on indoor confinement systems with the exception of the dairy farms in some countries, where cows had access to pasture during summer months.

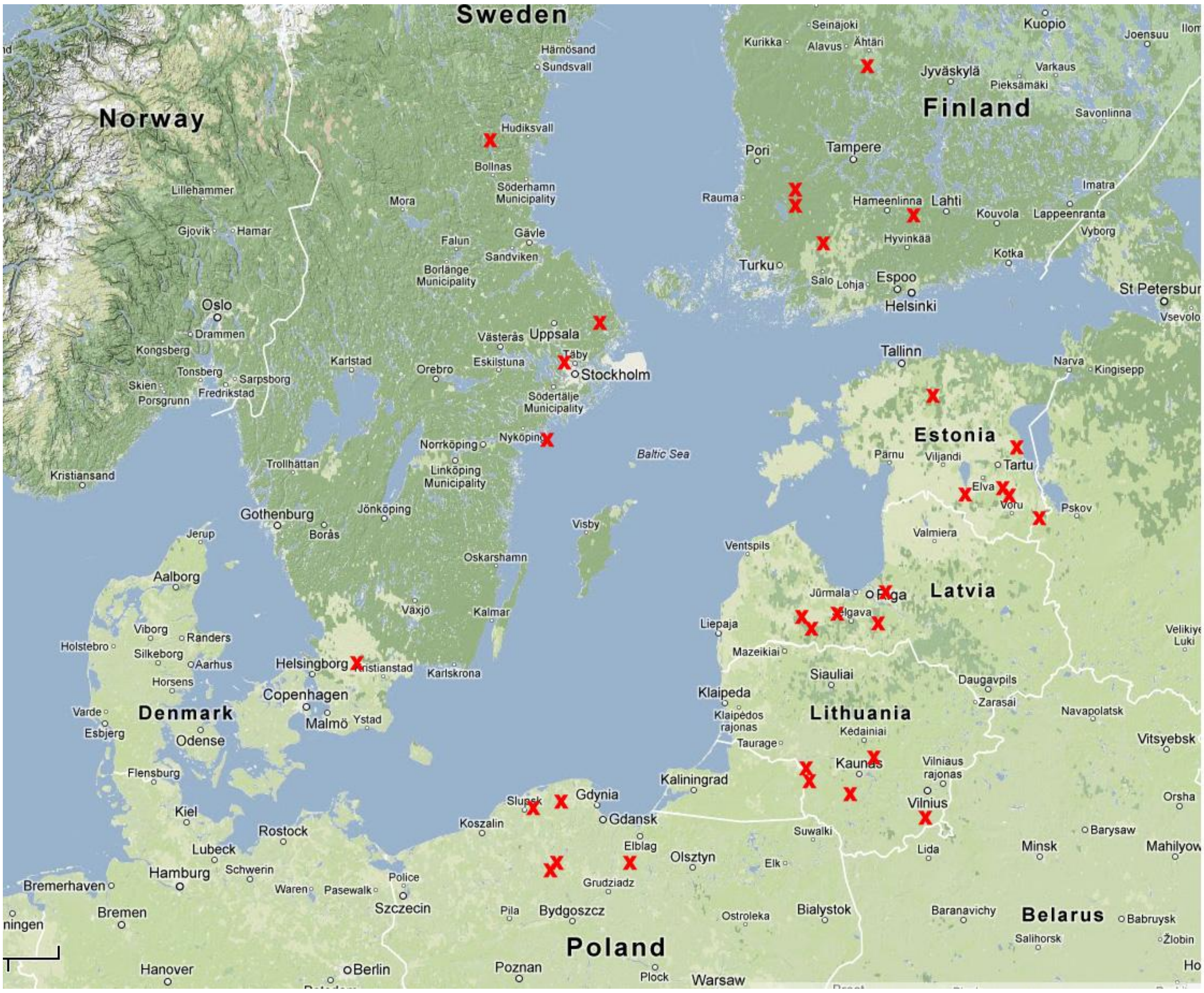


Figure 7.1. General location of the case study farms in the Baltic Sea Region.

The number of livestock units (LU) on the case study farms ranged from about 400 to over 30 000 (see Tables in Appendix 2). The median size of farms in this study was 509 LU (n=13) for dairy, 2938 LU (n=12) for pits and 5216 LU (n=6) for poultry. Care should be taken, however, when comparing these values with those reported in other studies, since LU may be based on different conversion coefficients. In order to standardise comparisons between countries and livestock types in this report, LU conversion coefficients from the European Commission Eurostat Glossary were used. However, these were originally determined to relate the feed requirements for various animals using a standard reference unit (1 LU) of a dairy cow weighing approx. 600 kg and producing 3000 kg of milk annually without concentrate feedstuff, which is unrealistically low for modern farms. More complex conversion equations can be used to account for weight and production level differences between dairy cows, and also the relationship between cows and other livestock. However, we decided that a simple standard conversion would be sufficient for the purposes of this study.

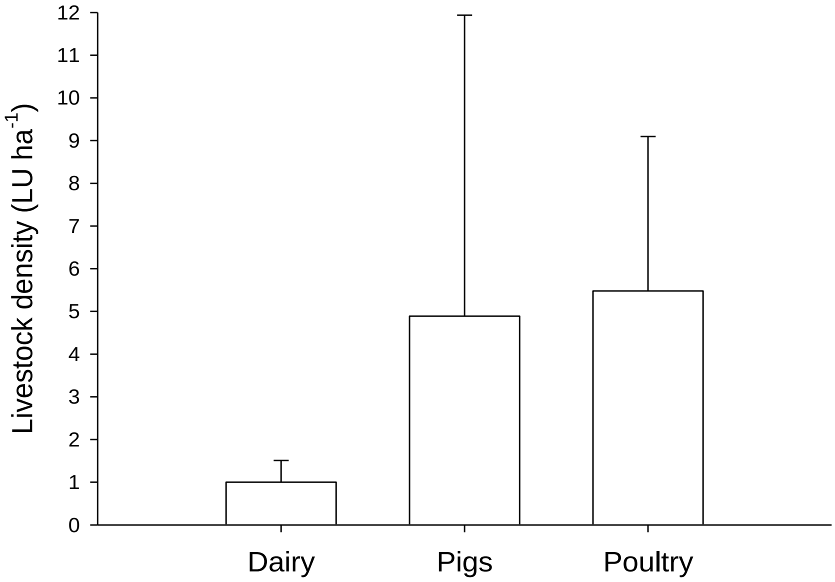


Figure 7.2. Average livestock density on case study farms in the Baltic Sea Region. Error bars = 1 SD. Dairy n=11, pigs n=10, poultry n=3 (two poultry farms did not have land and are not included).

Dairy farms had the lowest livestock densities and poultry farms had the highest (Figures 7.2 and 7.3). The lower livestock densities on dairy farms, even at these intensive production levels, are due to the requirement for grassland to provide roughage, which makes up a large proportion of the diet for dairy cattle. There was also much greater variation in livestock density among pig and poultry farms than for dairy farms. The median livestock density followed similar trends although with less differences (1.2, 3.3 and 4.8 for dairy, pig and poultry respectively).

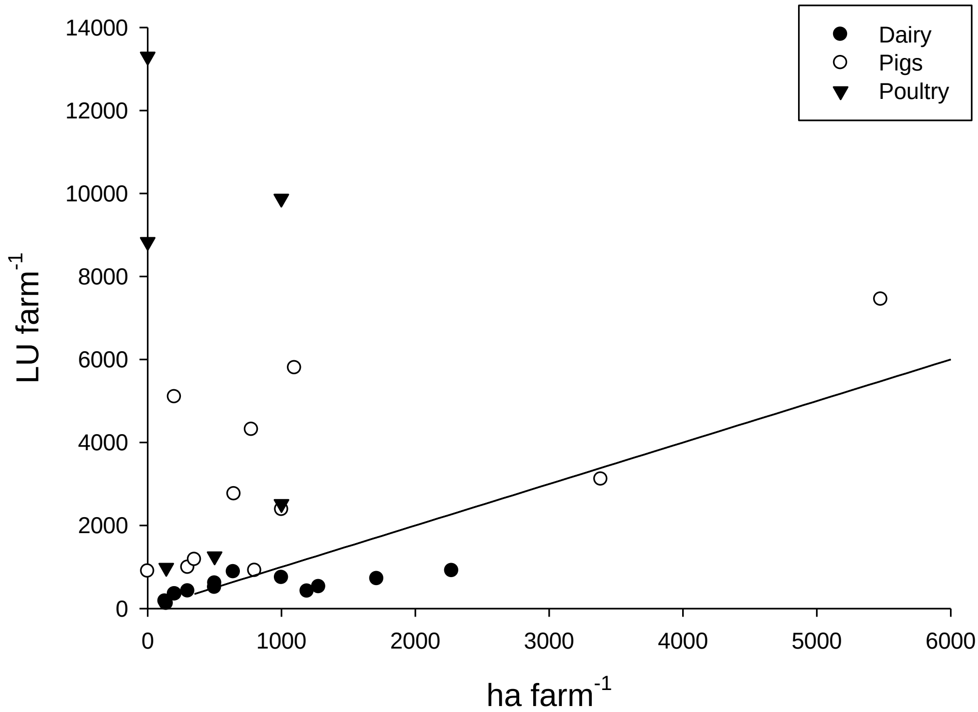


Figure 7.3. Livestock density on case study farms in the Baltic Sea Region as a function of farm size. The solid line is equivalent to 1 LU ha^{-1}, and with <1 LU ha^{-1} below the line LU and >1 LU ha^{-1} above. One farm (Farm 4 from EE, a cooperative pig farm with 16 050 LU and access to 46 000 ha for spreading), is not included in the diagram. Note that two poultry farms and one pig farm (points on y-axis) operated solely as a livestock production units and did not have any land.

7.1 Manure handling

Manure handling on dairy and pig farms was predominantly slurry based, although deep-litter beds for calves and calving pens, and even in some cases for heifers and milking cows, were still common on dairy farms (Table 7.1). Manure handling on pig farms was almost exclusively as slurry on the farms in this study and only one sow production system used deep-litter beds in its breeding stalls. In contrast, poultry farms were almost exclusively solid manure handling systems, with the exception of one farm that had a slurry system in some buildings.

Table 7.1. Type of manure system used for animals (percentage of total LU) on all the case study farms (n=31)

Animal type	LU	Solid manure (%)	Slurry (%)
Dairy*	6 796	37.6	62.4
Pigs	66 169	0.2	99.8
Poultry	36 769	86.7	13.3

** Total herd including heifers and calves*

In most cattle and pig houses, the slurry was removed at least once a day except in houses with deep-litter beds, where it was removed at 1-3 week intervals (Table 7.2). For poultry, the frequency was determined by the type of production, with manure removed 1-2 times a week for laying hens and after each production batch for broilers.

Table 7.2. Number of production units falling into different manure/slurry removal frequency categories, sorted according to animal type

	Frequency			
Animal type	Continuously-Daily	1-2 times a week	Every 2-3 weeks	Once per batch
Dairy	11	5	0	0
Pigs	10	1	2	0
Poultry	0	3	0	3
Total	21	9	2	3

The technique used for removing slurry was mainly automatic mechanical scrapers in primary channels and gravity flow in cross-channels, but some farms also had mechanical scrapers (Table 7.3). The slurry was transported directly from the cross-channel to the pumping pit. For solid manure, mobile units were common, but in two cases the deep-litter beds for cows were manually removed from the buildings.

Table 7.3. Number of production units using different techniques for removing animal manure from houses, sorted according to animal type

	Slurry						Solid			
	Primary channels				Cross-channel		Primary channels			
Animal type	Scra-pers	Gravity flow	Mobile Scrapers	Vacuum	Gravity	Scrapers	Manu-ally	Mobile unit	Scra-pers	Conveyor belts
Dairy	9	0	1	0	6	1	2	2	0	0
Pigs	5	6	0	2	7	2	0	1	0	0
Poultry	0	0	0	0	0	0	0	3	2	2
Total	13	6	1	2	13	3	2	7	2	2

7.2 Manure production and additives

Manure production per LU was similar for pig farms and poultry farms but it was much greater for dairy farms (Figure 7.4). Manure production here refers to ex-storage, since the farmers were most familiar with how much manure they spread or exported off-farm every year. Solid manure was in some cases reported in cubic metres and in others it was reported in tonnes, depending on how the farmer kept track of it. Solid manure volumes were converted to tonnes based on results from comprehensive density studies of various types of manure with various levels of dry matter (Malgeryd et al., 1993). However, applying these general conversion coefficients may have underestimated or overestimated the actual manure quantity, since dry matter content probably differed between farms.

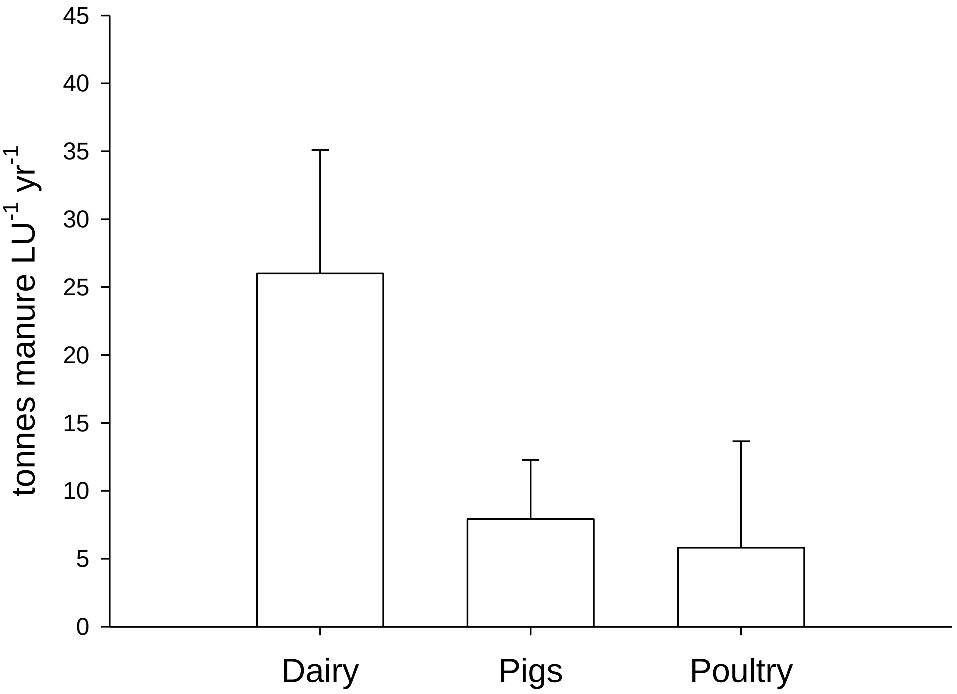


Figure 7.4. Annual manure production (ex-storage) per livestock unit on all case study farms. Error bars = 1 SD. Dairy n=11, pig n=10, poultry n=5.

There was a trend for manure production to increase with increasing milk production per cow and year, although there was no clear statistical relationship (Figure 7.5). Addition of water could be a major factor behind differences in manure production between farms. In most cases, the farmers were not aware of exactly how much water was added during various cleaning processes or by spillages and leaks. Furthermore, the manure amounts presented here are ex-storage, in other words they include rainwater for storage units without a roof. A solid roof keeps the rainwater out, but covering materials such as Leca pebbles do not.

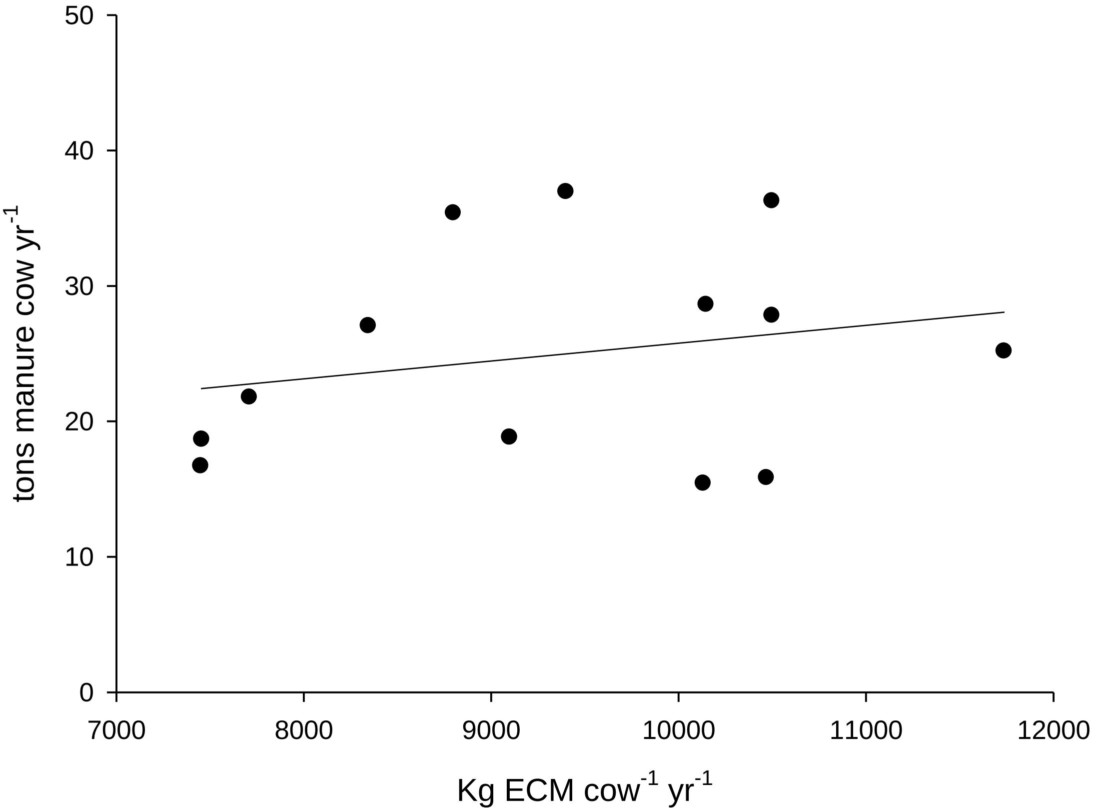


*Figure 7.5. Total manure production from the entire herd on dairy farms in relation to mean milk production per cow and year. For the regression line (y=12.59+0.0013*x), r^2=0.05.*

Numerous sources of water addition to slurry are possible in housing systems, many of which could possibly be avoided in order to reduce unnecessary dilution. Sources of water addition to slurry were only reported for five dairy farms and five pig farms, although most farms only estimated some of the potential sources for water added to slurry (Table 7.4). It is difficult to analyse these data, since the specific sources of water additions were not consistently included in the totals presented for each farm. However, water additions reported on these dairy farms represented between 0.6 and 7.9 % of the total volume of slurry produced, which is probably an underestimate since not all sources are included in the figures. One farm, in an effort to reduce water entering the slurry, installed a mechanical scraper to clean the waiting area instead of rinsing with water. One farm also reported the water added from emptying and cleaning drinking troughs twice a week, which when added up amounted to around 100 m^3 yr^{-1}. Actual measurements of water additions (including wastewater from cleaning milking equipment and milk tanks, rinsing water from the milking parlour and passageways, and wastewater from staff rooms and showers) were made on one cattle farm after the survey was completed. This happened to be the farm with the greatest reported water addition in terms of volume per year (1447 m^3 yr^{-1}), volume per animal (4.39 m^3 LU^{-1} yr^{-1}) and per cent of total slurry volume (8.0%). Water additions from rinsing passageways were included however this amounted to only a small fraction (1,5%) of the total water additions.

Table 7.4. Wastewater additions to slurry on the 10 case study farms that reported these data, presented as absolute amount, as a percentage of slurry produced on the farm and relative to number of livestock units (LU) on the farm. Sources listed are not inclusive of all sources on a particular farm. Quantities were either estimated or measured. A proportion of the LUs on some dairy farms were housed on deep-litter beds and did not actually contribute to slurry production

Livestock type	Farm	Sources	Measured or estimated	Water addition (m^3 yr^{-1})	% of slurry volume	m^3 LU^{-1}
Dairy	EE Farm 1*	Cleaning of milking equipment & milk tank, flushing milking & waiting areas	Estimated	117	1.8	0.66
	EE Farm 2	Cleaning of milking equipment & milk tank, flushing milking & waiting areas, staff showers	Estimated	613	4.4	0.69
	LT Farm 2	Cleaning of milking equipment	Estimated	37	0.6	0.10
	SE Farm 1	Cleaning of milking equipment & milk tank, flushing milking areas, staff showers, rinsing passageways	Measured	1447	8.0	4.39$^+$
	SE Farm 2	Cleaning of milking equipment & milk tank, tipping/cleaning drinking troughs	Estimated	257	1.0	0.35
Pigs	EE Farm 4	Cleaning of sections after batches	Estimated	5000	8.3	0.16
	EE Farm 5	Cleaning of sections after batches, drinking spillage	Estimated	600	3.3	0.08
	FI Farm 3	Cleaning of sections after batches	Estimated	810	12.7	0.25
	FI Farm 4	Cleaning of sections after batches	Estimated	648	8.1	0.18
	SE Farm 3	Cleaning (robot) of sections after batches	Measured	604	11.0	0.66

**Experimental farm with one robot for milking half the cows and a parallel milking parlour with eight places for the other half.*
$^+$ Calculation only includes livestock that are on slurry manure handling.

Water additions on pig farms mainly come from cleaning the stalls after each production batch and drinking water spillages. It is important to clean the stalls after each batch to control the spread of disease. Due to the nature of this cleaning process, it would be difficult to keep the wastewater separate from the slurry handling system, although this would be desirable. On the five pig farms that reported estimated water additions to slurry from cleaning after batches, the amount varied from 0.08 up to 0.66 m^3 LU^{-1} yr^{-1}. The cleaning water represented between 3 and 13 % of the total slurry volume produced on each of the five farms. It is unclear why there should be such a large difference in water usage for cleaning. Actual measurements of water usage were made on one pig farm during the cleaning of seven identical sections and it was this farm that had the highest reported amount of water added per LU. One explanation could be that this cleaning was done by a robot, which according to farmers used more water than manual cleaning.

Water spilled by livestock when drinking is difficult to estimate and there is little helpful data in the literature for estimating the quantity involved. One study comparing spillages from two types of water dispensers for pigs showed average spills of 2.7 litres per animal and day for conventional valves and 1.6 litres per animal and day for bite ball valves (Larsson, 1997). Even with this reduction, there is still ample room for design improvements to further reduce spills leading to slurry dilution.

Straw, sawdust or wood shavings and peat were all commonly used bedding materials on dairy farms (Table 7.5). The amounts used and eventually adding to the manure were of course much greater for deep-litter systems than for slurry systems. In many cases, specific data on the amount of bedding material used were not available. When amounts were reported, they ranged for example from 1.2 to 2 m^3 LU^{-1} yr^{-1} for sawdust and 0.9 to 1.5 m^3 LU^{-1} yr^{-1} for peat. Since the results of actual analyses of dry matter concentrations in manure were not available for this report, and since the bedding amounts used were most often reported in m^3, we were unable to estimate how much the bedding material contributed to the dry matter content of the slurry. Straw was predominantly used for deep-litter beds, but two dairy farms used peat for this purpose.

Table 7.5. Number of production units using different types of organic bedding materials on the case study farms. Farms listed under None did not use bedding materials for their livestock. The farms that did use bedding often used different types of bedding for different groups of livestock. Dairy n=13, pigs n=12, poultry n=6

Animal type	Straw	Peat	Wood shavings/sawdust	None
Dairy	10	3	6^	2*
Pigs	4	1	4	8
Poultry	0	2	1	3
Sum	14	6	11	13

^One farm used lime together with sawdust
**One farm used a disinfectant material on rubber mats*

Bedding material for pigs was essentially only used on farms in two countries, although a farm in a third country used some sawdust for its farrowing sows. Three of the pig farms that used bedding material used both sawdust and straw and the fourth farm used sawdust and peat. The use of bedding material on poultry farms depended on whether it had broiler production or laying hens, since the three egg farms included in the study housed the laying hens in cages and did not use bedding material.

7.3 Manure storage

Average storage capacity for slurry in terms of months was greater for pig farms than for dairy farms (Figure 7.6). Total farm-level slurry production per year (mean ± s.d.) was greater on pig farms (27 715 ± 23 510 m^3) than on dairy farms (11 035 ± 6 000 m^3).

It is not entirely clear why pig farms have invested in higher storage capacity than dairy farms. Outdoor grazing of cattle was only practised on four of the 13 dairy farms studied, and mainly dry cows or young cattle. This may be because cattle farms tend to have more grassland in the crop rotation and thus have more spreading opportunities during the year than farms on which cereal production dominates. Another factor may be that dairy farms are not regulated under the EU IE Directive.

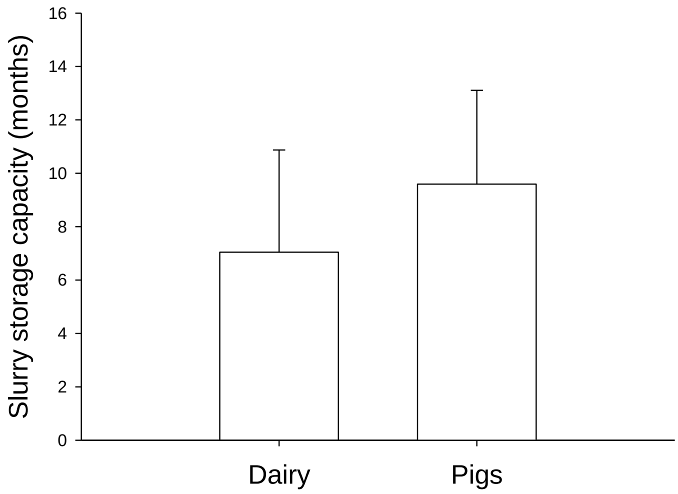


Figure 7.6. Mean slurry storage capacity on dairy and pig farms, with bars showing standard deviation. n=12 for dairy, n=10 for pig farms. Two pig farms with over dimensioned lagoon storage systems were excluded.

Slurry storage capacity (m^3) in relation to the volume produced per animal species and year on the farms is plotted in Figure 7.7. Two pig farms had extremely high storage capacity, a surplus capacity related to larger production in earlier days. One of these farms had the largest herd (5800 LU) and the second largest manure production rate per LU (14.7) of all the pig farms included. It also stored digestate from a neighbouring biogas plant. The other farm separated the slurry into a liquid fraction and a solid fraction. The liquid fraction was stored in large-scale lagoon systems with a capacity four times greater than annual on-farm manure production, which could be explained by earlier larger number of animals on the farm. This processing storage system for slurry closely resembles the anaerobic lagoon systems for treating manure described by Harper et al. (2000) and Aneja et al. (2001).

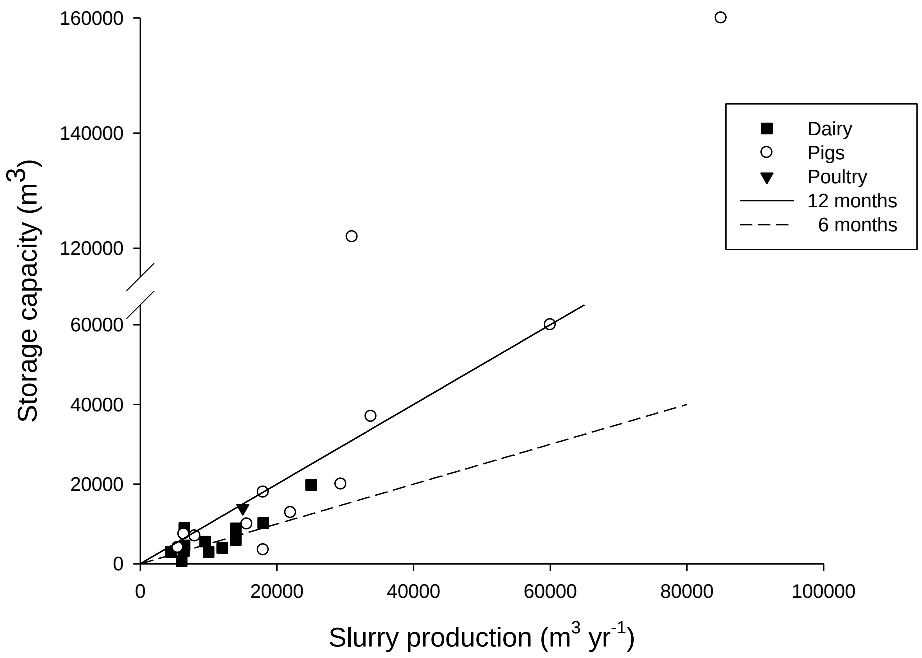


Figure 7.7. Farm-level manure (slurry) storage capacity in relation to annual slurry production on the case study farms. The solid line represents 12 months of storage capacity and the dashed line 6 months. Note y-axis is broken.

It was quite common for farms to have satellite storage facilities (here defined as 0.5 km or more from animal houses), which were found on 9 of the 31 farms studied. The storage tanks on the farms were usually constructed of pre-fabricated concrete panels (Figure 7.8), whereas the satellite storage units were also in the form of lagoons. For solid manure, there were concrete pads, often with concrete walls, on the farm, and some manure was also stored in field heaps.

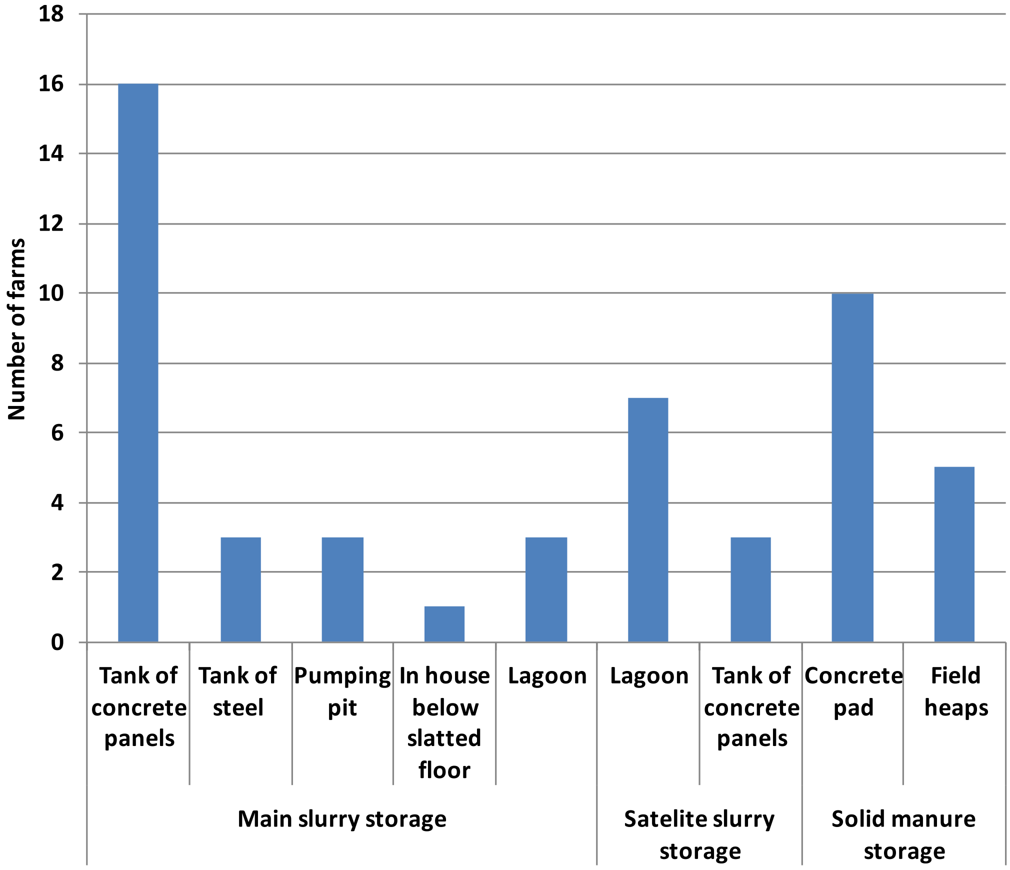


Figure 7.8. Type of storage for slurry and solid manure on the case study farms.

The slurry was mostly transported to the satellite storage site or the field by tanker, in one case a slurry truck with a 30 m^3 tank designed for road transport. Hydraulic transportation by pumping slurry in pipes was also used on five farms, four of which were pig farms. Both mobile and permanently installed pipes were used for this purpose. On a Finnish farm, the slurry was pumped 500 m to a nearby biogas plant, and in return the farm received co-digested slurry via the same pipeline. In Estonia, the slurry was pumped 1.5 km in pipes from the farm centre to satellite lagoons (40 000 m^3). In Sweden, the slurry was pumped 1.5 km through flexible hoses to a satellite tank (1500 m^3). On a Lithuanian pig farm, the slurry was pumped through a flexible hose to an umbilical trailing hose spreader (Agrometer Pioneer). Two other pig farms in Poland also spread slurry with similar umbilical trailing hose spreaders, but on these farms the slurry was pumped from the main storage tank to nurse tanks via pipes permanently installed underground.

More than half the farms studied had some kind of cover on their slurry storage units, with an undisturbed crust dominating, particularly on dairy farms (Figure 7.9). Floating covers of Leca pebbles or a geomembrane were found on some pig farms. On two poultry farms, the manure heaps were covered, with peat and 10 cm straw, respectively. Unfortunately, nearly half the slurry storage units studied lacked a cover. Most of the solid manure was stored on concrete pads, but several poultry farms and at least one dairy farm also stored solid manure in field heaps.

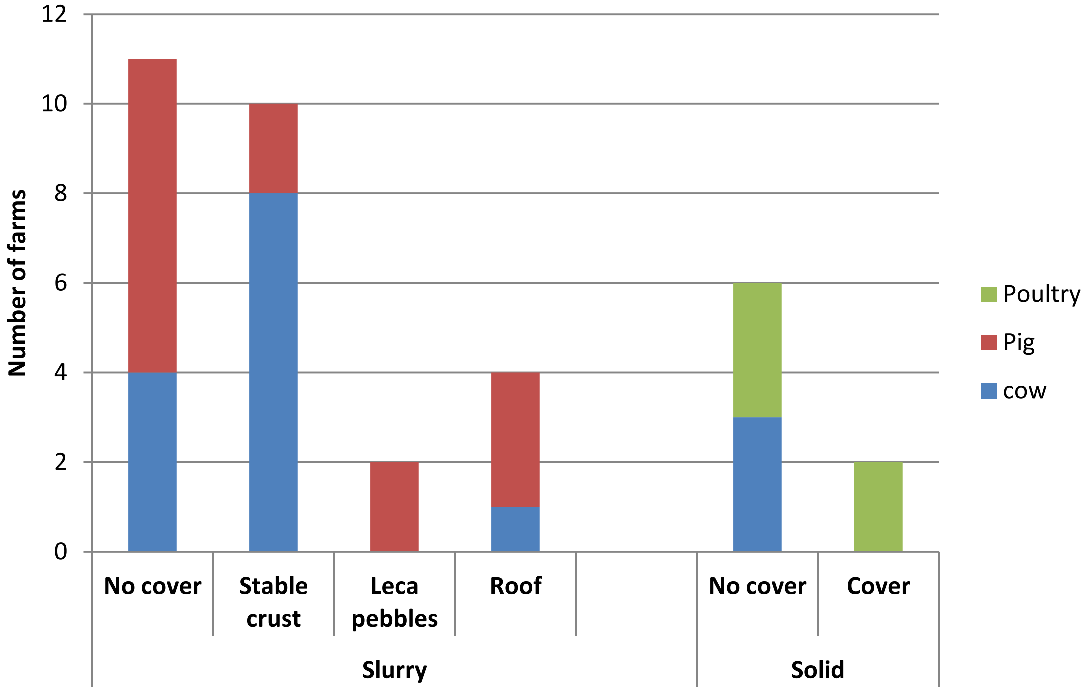


Fig. 7.9. Frequency of farms using different forms of storage for manure as slurry and solid manure, sorted according to animal species.

7.4 Manure processing

Anaerobic digestion and mechanical separation were the only types of manure processing encountered on the case study farms in this report. Of the 31 farms studied, three pig farms and two dairy farms had biogas plants for anaerobic digestion of the slurry. Two of these were in Poland, one in Latvia, one in Finland and one in Sweden. In addition to this, one pig farm in Finland exported all of its manure to a nearby biogas plant and a poultry farm in Sweden exported 30% of its manure to a nearby biogas plant. Aside from anaerobic digestion for biogas production, only one farm in Lithuania processed manure using mechanical separation for producing a solid and liquid phase of the pig slurry. One other farm in Poland had just recently invested in mechanical separation equipment and was planning to use the separated dairy solids for bedding material in its cow barns.

7.5 Manure utilisation after storage

The transport distance between farm storage and field was only stated in a few cases, but distances of up to 8, 15, 18, 20 and 50 km were reported.

For slurry spreading, band spreading techniques, primarily with booms with trailing hoses, were much more common than either broadcast or injection techniques (Figure 7.10). In all, 84.4% of the slurry spread on the farms in this study was applied with band spreading techniques using trailing hoses, 8.3% with broadcast techniques, and 7.2% with injection techniques. However, on some farms the relative amounts spread with trailing hoses and injection techniques were not clearly reported, so the amount spread by injection may actually have been greater. In general, the slurry was spread by tankers but, as mentioned earlier, three farms used umbilical hose systems for serving the spreader with slurry, which accounted for 42% of the total amount of slurry applied with band spreading techniques.

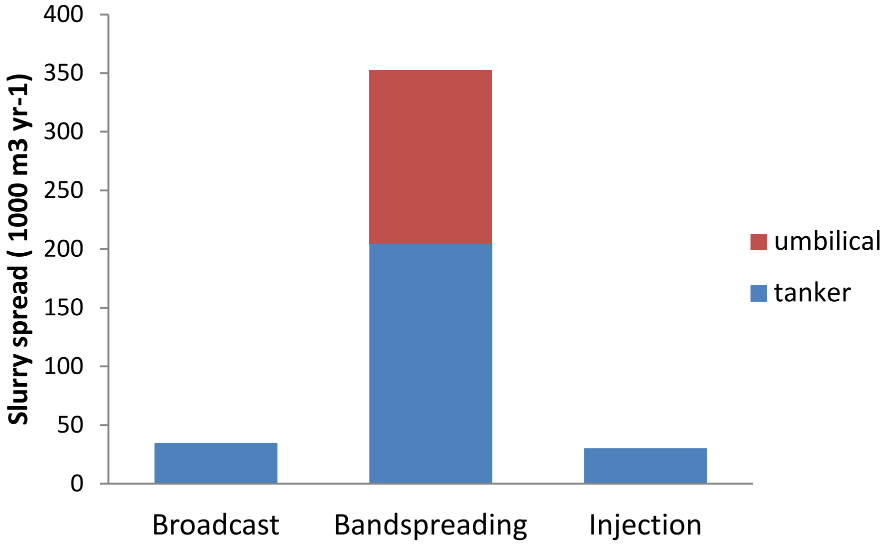


Figure 7.10. Total amount of slurry spread with broadcast, band and injection techniques on all case study farms. The total volume of slurry spread on the 25 farms with slurry manure handling was approximately 418 000 m^3 per year. This did not include solid manure.

Injectors were usually of two types; shallow disc tines (about 0.05 m working depth) mostly used in grasslands, or deep injection (0.15 m working depth) cultivator tines often used in open soil before sowing maize. In the latter case the slurry was placed in closed slots, minimising the ammonia emissions, while the discs created open slots, with possibility of some ammonia emissions (Rodhe & Etana, 2004). One farm used a sod injector on grassland, which involved drawing a 0.01 m deep slit by a knife tine in order to make it easier for the slurry to infiltrate into the soil.

On open soil, the manure was incorporated directly after spreading on some farms, while on other farms incorporation occurred some hours after spreading or within a day, but in many cases no information was provided. On many farms the spreading was done by contractors, and therefore the farmers were perhaps more focused and interested in animal production and less in crop production.

In general, most of the case study farms used the manure as a fertiliser on the farm, spreading it on arable land and/or grassland. Grassland was the dominant crop fertilised with slurry on dairy farms, while cereal (both winter and spring) was the dominant crop fertilised with slurry on pig and poultry farms. Aside from leys and cereals, manure was also used to fertilise rapeseed, maize, triticale and peas (Table 7.6). Four farms supplied no information about how the manure was used concerning crops, application rates or spreading techniques, as the manure was exported from those farms. As can be seen in Table 7.6, application rates of 20-30 tonnes per ha dominated, but rates as high as 80 tonnes per ha were reported for grassland, spring and winter cereals and rapeseed on two Lithuanian farms. Higher application rates of 40 and 50 tonnes per ha were also reported.

Table 7.6. Application rates reported by farmers on the case study farms for different crops. X=one farm response. NI = No Information given.

	Rate, tonnes/ha													
Crop	2.5*	5*	10*	15	20	25	30	40	50	60	70	80	90	NI
Grassland					xx	xxxx	xxxx	xxx	x			x		xx
Spring cereal	x	x	xx	x	xx	xxxx	xxx	x				xx		xx
Winter cereal	x	x	xx		x		x		xxx			x		
Rapeseed	x				xxx	x						x		
Maize			x		x	x		x	xxx					
Sugar beet						xx								
Green manure					x									
Before ploughing					x									
Peas	x		x											
Crop unknown			x				xxx	xx						
Total	4	2	7	1	11	12	11	7	7			5		4

*Poultry manure

The times of manure spreading reported for different crops are presented in Table 7.7. Spreading during the spring dominated, but autumn spreading was also frequent on grassland and before sowing of a winter cereal. There are more opportunities for spreading with grassland, although spreading outside the growing season increases the risk of nutrient leakage to water.

On the whole, manure handling after storage was the least well-described part of the manure handling chain. Again, this could be attributable to the individual farmer's preference for animal production as opposed to crop production and to many farmers contract out these services. However, in order to minimise harmful leakage of nutrients to water and ammonia volatilisation, it could be important to increase farmer awareness of the importance of appropriate manure application rates and timing for achieving high nutrient uptake by plants and low leakage to water. It is also important to use measures to minimise ammonia emissions during storage and after spreading, for example immediate incorporation of manure into the soil. For this, planning tools and knowledgeable advisors are essential.

Table 7.7. Application times reported by farmers on the case study farms for different crops. X=one farm response

	Application time								
Crop	**April**	**May**	**June**	**July**	**August**	**Sept.**	**Oct.**	**Nov.**	**Dec.**
Grassland	xxxx	x	xxxx	x	x	xxxxxx			xx
Spring cereal	xxxxxxxx	xxxxxxxx							
Winter cereal	xxxx				xxxx	xxxxxx			
Rapeseed	xxx	x			x	x			
Maize	x	xxx							
Sugar beet		x							
Green manure		x							
Before ploughing							x		
Peas	**x**	x							
Crops unknown		xxxx	x	x	x	x	xxxx		
Total	21	20	5	2	7	14	5		2

7.6 Exporting manure off-farm

When livestock density increased above 2 LU per hectare, the portion of manure exported off-farm also increased (Figure 7.11). In total for all farms studied, 13% of the slurry produced and 86% of the solid manure was reported to be exported off-farm. Several farms spread a portion of their manure on neighbouring farms which should have been considered exporting, however, it was not always possible to gather exact data concerning how much manure was spread where, so the amount of slurry exported off-farm was probably greater than 13%.

Most of the solid manure exported was from poultry farms that did not have any land for spreading manure and therefore exported 100% off-farm. In these cases, the manure was exported in direct conjunction with manure removal from the housing system, so storage facilities were not needed. One pig farm did not have any land and exported all of its slurry to a centralised biogas plant which then took over responsibility for transport, storage and spreading of the digestate.

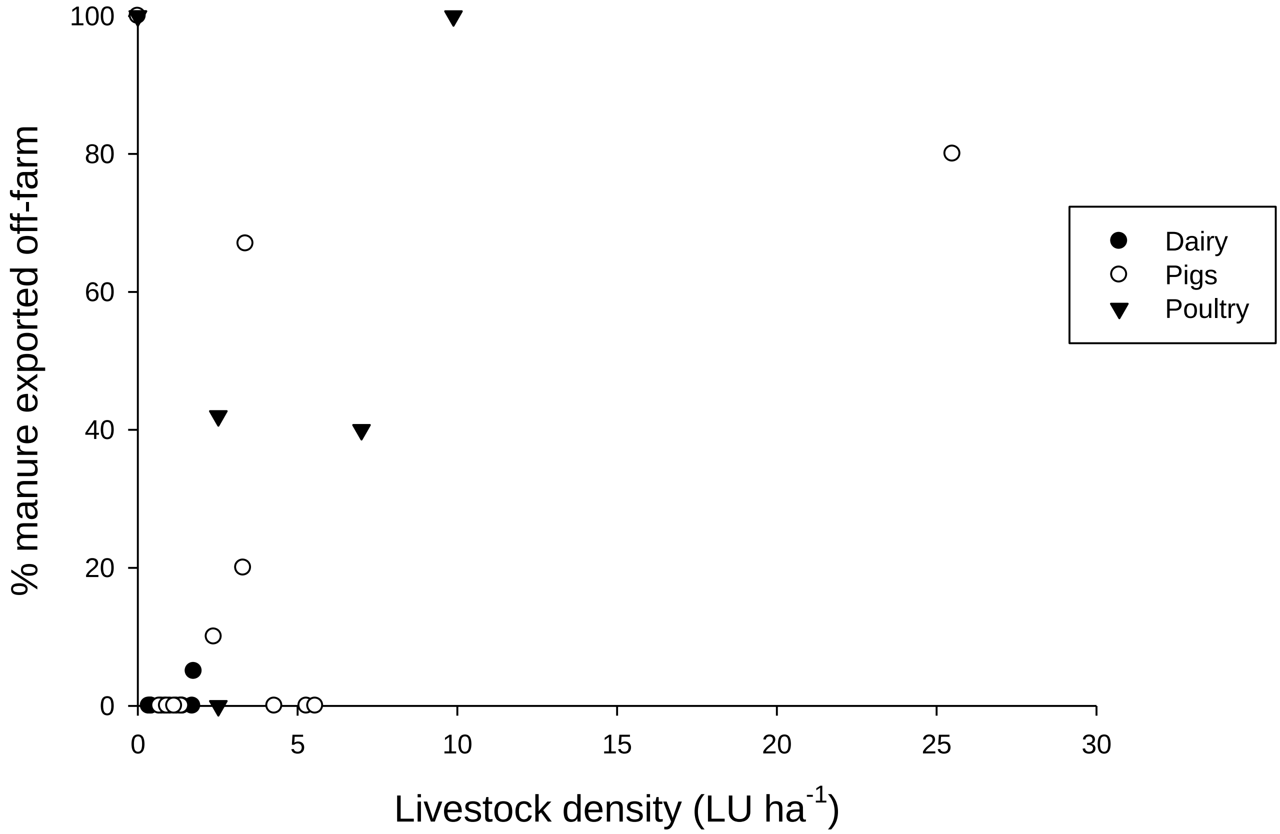


Figure 7.11. Percentage of manure exported off farm as a function of farm-level livestock density. The three farms (2 poultry and 1 pig) that did not own any land and exported 100% of their manure are shown having a livestock density of 0, when actually they had a value of infinity.

8 Bottlenecks and barriers to sustainable manure handling

Baltic Manure aims to contribute to the overall strategic goal of the BSR Programme to manage the Baltic Sea as a common resource. Manure is a resource to be utilised and new knowledge and technologies can improve the economic and environmental viability of manure handling. Under practical circumstances, however, farmers can experience a range of problems, or bottlenecks, in their manure handling systems that limit the utilisation of the resource potential in manure. In most cases if the problem is perceived as a bottleneck, there is some type of barrier to implementing a solution to that bottleneck. During the surveys described in this report, we asked farmers open questions about the types of bottlenecks and barriers they encountered to being able to fully utilise the nutrient resources in manure. We then grouped these bottlenecks into categories based on the segment of the manure handling chain to which they belonged, and in order of relevance in terms of obstructing a solution to that bottleneck (Table 8.1).

Table 8.1. Bottlenecks for utilisation of nutrient resources in manure identified by farmers on the case study farms. Potential barriers to overcoming these bottlenecks are divided into four different classes: 1) Costs/economic factors, 2) technological limitations, 3) lack of knowledge of solutions, 4) regulation or lack of incentives and support mechanisms for adopting BAT. The barrier categories are listed in order of importance according to farmers.

Handling chain	Bottlenecks - description	Barriers
Manure storage	Inadequate storage capacity for synchronising spreading times with crop requirements	1
	No closed cover to prevent dilution and nutrient losses	1, 4
	Difficulty in mixing sediments in lagoon storage	2
Spreading	Nuisance (odours) limiting spreading near populated areas	3, 2, 1
	Transport logistics	
	Fields far from animal houses/storage	1, 2
	Fragmentation of fields	1
	Poor road conditions for transport	1
	Soil compaction (heavy loads)	2, 3
	Soil status (certain fields saturated with P)	3, 2
	Difficult to match soil and plant requirements with manure production in terms of time and amount	2
	Difficult to find someone to take excess manure	3, 1
Spreader technology	Injection expensive compared with surface spreading	1, 4
	Inadequate technology for spreading small amounts of solid poultry manure evenly	2
	Difficult to use umbilical hose systems	3, 2
	Do not own best available spreading technology	1, 4
Manure processing	Not used	3, 1, 2, 4
General	Regulations, e.g. different status for raw manure and digestate	4

Cost constraints and lack of profitability are the main barriers to adopting best available techniques and technologies, according to the farmers surveyed in this study. It could be argued that lack of credit availability and adequate incentives for investing in environmentally friendly handling and processing technologies are also barriers, but this was only specifically pointed out by farmers interested in biogas technology. However, their interest in this technology was focused totally on biogas production instead of the value added to manure by anaerobic processing. In some cases, an assumption on lack of profitability was perhaps made by the farmer due to the uncertainty regarding potential benefits of various manure handling and processing systems, which might actually be better categorised as lack of knowledge.

The costs involved in implementing environmentally friendly technology on farms were in most cases seen as a burden, since the increased costs generally do not lead to increased sales prices for the products, even when the environmental impact is reduced. In some cases the implementation of environmentally friendly technology can lead to direct savings for the farmer, through decreased logistical handling costs or more effective utilisation of resources. In other cases the savings relative to the investment costs might not be worth the risk to farmers. However, investments in environmental technologies that reduce odour, ammonia and GHG emissions, recycling of nutrients or the generation of renewable energy benefit not only the farmer, but also society at large. Therefore it seems reasonable for society to support and encourage adoption of these technologies.

In many cases, there is no available technology to solve the bottleneck, e.g. there is no available spreading equipment that can evenly distribute solid poultry manure at relatively low rates of 2-3 tonnes per hectare. In addition, there is no viable technology currently on the market that can significantly reduce the volume of slurry and concentrate the nutrients in order to help redistribute nutrients to fields far from the animal house. This is where research and development needs to be focused. There are many areas across the manure handling chain that could benefit from technological development, of which Table 8.1 lists only a few.

Overcoming these barriers is essential to viewing manure as a valuable resource and acknowledging that the more optimal its utilisation, the lower its environmental impact. When the economic benefits of manure handling and processing technologies become apparent, there is a greater chance of them being adopted. This will automatically reduce the environmental impact of large-scale livestock production without additional regulation.

9 Discussion

One of the main aims of the Baltic Manure Project is to facilitate a shift in the principal drivers behind improving manure handling systems from regulation to innovation. Innovation can be facilitated by creating awareness of the resource potential in manure. Once the resource value of manure is understood, this will create for opportunities for economic benefit as livestock producers better utilise their manure. By focusing on the economic benefits of optimising manure management, producers will solve environmental problems for economic reasons, rather than for regulatory reasons.

Considerable variation exists in manure handling chains among large-scale livestock farms in the BSR. Manure handling, storage and distribution of large quantities of manure create economic and logistical challenges to using the nutrient resource in an efficient way at farm level. Animal slurry is a relatively low concentration fertiliser that contains less than 1% of the nitrogen in mineral nitrogen fertilisers (N28) and has a water content of 88-95%. This leads to higher handling costs per kg nitrogen, phosphorus or potassium than for mineral fertilisers (Brundin & Rodhe, 1990). The distance over which it is economically feasible to transport slurry to appropriate fields is therefore often limited and there is a high risk of soil compaction during application with heavy slurry tankers. This is where technology and processing options for manure could play an important role in creating more rational and economic handling chains for utilising the resource potential in manure.

This study revealed large variations in manure production per livestock unit for similar livestock types, which could be attributable to differences in water addition to slurry between farms. Such water additions can originate from many different sources along the manure handling chain, e.g. spillages from drinking cups or troughs and water from various cleaning activities including washing and showering, leaks and rainwater can all end up in the slurry tank, causing costly dilution. Avoiding this unnecessary dilution of slurry by limiting water additions should be a key element in farm-level manure management planning, and will directly affect the cost of manure handling. Source separation of dirty water and diversion of this to either a cheap treatment plant or an irrigation system could also prevent dilution of manure. The use of roofs on slurry storage facilities together with other management decisions to reduce water inputs could have a positive impact on the quantity and quality of slurry generated. Thus there is a need for technology and innovation to reduce water inputs.

Data on crop requirements and soil status should be an integral part of plans to increase the utilisation of nutrients in manure at farm level. However, when conducting this survey we noted that manure handling after storage was the least well-described part of the manure handling chain, indicating that this was a relatively low priority or interest for the livestock farmers studied. This is an important issue, since to minimise the environmental impacts of slurry spreading, it must be applied in the right place, at the right time and in the right dose. However, slurry generally has a greater P:N ratio than needed by most crops, which can lead to over-dosing with phosphorus if application rates are based on nitrogen requirements. Processing techniques or feeding regimes that lead to an N:P ratio better suited to crop requirements could be developed. In addition, more emphasis should be placed on the responsibility of livestock farmers for the end-use of manure. For this purpose, well-informed advisory services and planning tools are essential.

In many cases, implementation of relatively simple technologies or management practices could lead to improved overall use of the nutrient resources in manure, instead of focusing on new innovative technologies for processing manure. Extra storage capacity that allows manure to be stored until it is needed by the crop and having a roof on storage facilities to reduce dilution and conserve nitrogen by limiting ammonia emissions are both examples of technologies readily available across the BSR, but also represent large investment costs. The use of a roof to cover slurry storage units can lead to savings for the farmer in terms of avoided water additions and nitrogen saved, but in many circumstances the savings do not entirely offset the cost of constructing the roof.

Overall, cost was the greatest perceived barrier to the adoption of beneficial technologies or management practices for manure handling in all case study countries in the BSR. It is imperative that researchers, advisors, businesses and regulators work to find effective ways to reduce this barrier and ensure cost-effectiveness.

It is important to bear in mind that for each livestock type, the data presented for these case study farms represent only one or two farms of many with similar production levels in each country. Therefore we do not claim that these descriptions represent the general situation for all similarly sized farms in the BSR. Farm selection for this study was in some cases partly influenced by proximity, since it is easier to sample and collect data from farms that are close to each other. It was also influenced of course by the willingness of the farmers to participate. However, regardless of its shortcomings, this compilation of data gives a valuable overview of manure handling techniques actually used on farms around the BSR.

10 Conclusions

- Manure was predominantly handled in the form of slurry on large-scale case study livestock farms in the BSR. In most cases slurry was removed from the animal house at least once a day, while solid manure was removed less frequently, from twice a week to once per production batch (broilers).
- Large variations existed in the amount of slurry produced per LU for similar livestock types. Water additions in the house and during storage may be one of the contributing factors, as well as production levels, feeding and slurry removal technique.
- Examples of environmentally friendly technology such as slurry store covers or injector techniques were found in most countries, showing both a demand from farmers/authorities and the capacity of the market to supply these technologies.
- In general, increased storage capacity for slurry is needed on farms in the BSR to allow manure to be stored until it is needed by the crops. This is particularly important for dairy farms, which had an average storage capacity of 7 months in this study.
- There is a need to cover stored slurry in order to minimise ammonia emissions. Half of slurry storage units on case study farms lacked a cover and those that were covered relied on natural crust formation.
- In addition to reducing ammonia emissions, plastic roofs or covers would exclude rainwater that would otherwise dilute the slurry. Good examples existed on case study farms, for example storage tanks covered with a plastic covering, lagoons with floating sheets or Leca pebbles and poultry manure heaps with a peat cover.
- On-farm processing of manure was uncommon, even on the large-scale intensive farms studied. Four farms had anaerobic digesters for energy production and two other farms used separators for producing solid and liquid fractions from the slurry.
- In general, manure handling after storage was the least well-described part of the manure handling chain.
- It is therefore very important to draw farmers' attention to measures to minimise harmful leakage of nutrients to water and ammonia volatilisation during and after spreading. Best management practices include appropriate application rates and timing to achieve high nutrient uptake by plants, immediate incorporation of the manure into soil after spreading and increased use of injectors for slurry. Planning tools and well-trained advisors are essential in this regard.
- Overall, cost was the greatest barrier perceived by farmers to adoption of beneficial technologies or management practices for manure handling. It is very important that researchers, advisors, businesses and regulators work to find effective ways to reduce this barrier and ensure cost-effectiveness.

11 Recommendations

- **Minimize water addition to manure in stable and storage** for example by reduced spillage, choice of drinking and feeding technology, re-use of cleaning water *e.g*. from milking equipment, and cover storage. Source separation of dirty water and diversion of this to either a cheap treatment plant or an irrigation system could also prevent dilution of manure.
- In general, **increase storage capacity for slurry to allow manure to be stored until it is most needed by the crops.**
- Increase use of **environmentally friendly technology** such as slurry store covers or injector techniques.
- **Spreading technology must have high precision** in dosage and spreading evenness, based on actual nutrient contents of the manure and site specific conditions in field (GPS-GIS)
- Farmers, advisers, researchers, policymakers and industry must all together take responsibility and **co-operate for a more environmentally friendly end-use of manure for example:**
  - free or low cost skilled advisory service for manure management,
  - controls that legislations are followed,
  - planning tools for crop fertilisation,
  - reliable verified technology on the market,
  - carrots and whips are necessary (good balance in-between),
  - increased awareness that the manure handling has a great impact on water and air quality.

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Appendix 1. Manure handling surveys forms

We are including an example of the survey form for dairy farms. We also had specific forms for pig and poultry farms. The livestock herd and production description was of course different for different livestock as well as the description of the livestock housing units. Otherwise they were similar.

Survey form for dairy farms

Manure handling questionnaire for Dairy farms (v2.2)

Farm name: ______________________________

Manager: ______________________________

Location: ______________________________

Date: ______________________________

1. Livestock

1.1. Livestock numbers and specifics *(fill in all that apply)*

Livestock	Average no. per year		
Milking cows		Average lactation period	
Dry cows (sinkor)		Average dry period	
Nursing cows (diakor)		Average lactations per cow	
Heifers (recruitment %)			
Pregnant heifers			
Calves			
Young bulls			
Bulls			

Breeds	% of total

1.2. Production

Cows		Define units
Milk[1]		
Milk protein		
Milk fat		
Feed efficiency[2]		
Average body weight	kg	
Number of calvings	/yr	

Heifers, calves etc…

Average birth weight of calves	kg
Market weight	kg
Days from birth to market	
Recruited heifers (no.)	/yr
Recruited heifers weight	kg

[1] preferably as ECM[1] = 0.25*(kg milk) + 12.2*(kg fat) + 7.7*(kg protein)
[2] example: MJ/kg ECM

2. Diet composition for milking cows

2.1. Feed type and quality

	kg/day per animal	DM %	N %	P %	Energy (MJ)	Ash %	OM %	OM digestibility %
Produced on-farm								
Grass-Silage								
Corn-Silage								
Hay								
Barley								
Corn								
Wheat								
Other?								
Purchased								
Rapeseed cake								
Mineral feed								
Other?								

DM – dry matter, OM – organic matter

2.2. Feed additives

Define	Amount (g/animal)	Annual consumption (kg)

3. Housing systems. Complete one for each barn if necessary.

3.1. Livestock types (*from 1.1.)* ____

3.2. Confinement

Permanent, 100%	Yes / No	______ months per year
Access to outdoor areas	Yes / No	
Concrete	Yes / No	
Drainage collected	Yes / No	
Pasture	Yes / No	______ months per year

3.3. Pen type

Tied	Yes / No
Loose housing	Yes / No
Other	

3.3. Bedding material *(check all that apply)*

		Annual consumption (t)
Straw (*type*)		
Sawdust / wood shavings		
Peat		
Sand		
Other -		
Rubber mat		

3.4. Describe/sketch housing system layout and details

**include make and model of equipment if available*

3.5a. In-barn manure transport *(check all that apply).*

Slurry system				Solid manure based system			
Primary manure channel		Secondary (cross) channel		Primary manure channel		Secondary (cross) channel	
Under slatted floors		covered		Under slatted floors		covered	
Mechanical removal*		Mechanical removal*		Mechanical removal*		Mechanical removal*	
Hydraulic removal*		Hydraulic removal*					
Mobile unit		Mobile unit		Mobile unit		Mobile unit	

**Describe details in 3.4.*
Mechanical removal: scrapers, conveyer belt, pressers, screws / augers, pistonnes
Hydraulic removal: flushing, gravity, pumping

Urine/liquid gutter		Urine pipe/gutter	
Gravity		Gravity	
Pump		Pump	

3.5b. In-barn transport/removal frequency.

	Slurry system		Solid system	
	Manure channel	Cross channel	Manure channel	Cross channel
Times/day				

3.6a. Removal/transport of manure from barn to storage *(check all that apply).*

Slurry system		Solid manure based system	
Mechanical removal		Mechanical removal	
Hydraulic removal		Hydraulic removal	
Mobile unit		Mobile unit	

**Describe details of each mechanical/hydraulic systems in 3.7.*

3.6b. Removal frequency to from barn to storage

	Slurry system	Solid system
Times/day		

3.7. Additives to Manure / Slurry / Liquid waste

	Yes/no	Approx. volume / quantity	Frequency
Water (washing, rinsing)*			
Wastewater from cleaning milk lines			
Other -			
Would it be possible to measure by installing flow meters on specific water lines?			

*from rinsing milking areas, passageways etc…

4. Manure storage

4.1. General questions

Is all manure stored — Yes / No

If no, how is it disposed ________________________________

% not stored __________%

4.2. Liquid manure / Slurry

		Barn 1	Barn 2	Barn 3
Pumping pit	yes/no	Pump pit 1	Pump pit 2	Pump pit 3
	volume =	(m^3)	(m^3)	(m^3)
	frequency emptied =			

Storage		**Storage 1**	**Storage 2**	**Storage 3**
	Tank / lagoon / other			
	Slurry / urine / dirty water			
	Volume =	(m^3)	(m^3)	(m^3)
	no. animals served =			
	Storage capacity =	(months)	(months)	(months)
	Covered	Yes / No	Yes / No	Yes / No
	Roof or crust (*describe*)			
	Filled	Top / Bottom	Top / Bottom	Top / Bottom
	Distance from barn =	(km)	(km)	(km)
Mixing	Pump / propeller / other			

4.3. Solid manure storage

Concrete pad — Yes / No

- % of solid manure stored ____________________%
- Transport to storage ____________________
- Frequency of loading ____________________
- Seepage collected — Yes / No
- Storage capacity ____________ (months)
- Covered — Yes / No

Field heap — Yes / No

- Size of heap ____________________
- Distance from barn ____________________
- Transport to heap ____________________
- Frequency of loading ____________________

Measures to decrease NH4 loss — Yes / No

5. Manure treatment / processing

5.1. Portion or quantity of manure processed / treated

Solid ___________

Slurry ___________

Liquid ___________

5.2. Does processing occur before or after storage?

Some treatment or processing technology examples

Tech type	*Tech specifics*	*Noteworthy aspects or options*
Aerobic	*Heap, reactor*	*Mixing (front loader, screws, other), Volume, Aeration (forced, passive), Retention time*
Anaerobic	*Digester*	*Volume, Biogas production, Retention times*
Additives		*Enzymes, Nitrification inhibitors, Acidification, Quantity used*
Separation	*Sedimentation*	*Flocculation (polymers, Fe, Al), sedimentation*
	Mechanical	*Centrifuge, press, screws, other…*
Drying		
Incineration		
Pyrolysis		

5.3. Describe/sketch process system in detail, including: continuous or batch processing, eventual storage and end-use of all fractions.

6. Manure quantity and quality *(if available)*

Ex- barn, Ex-storage or Ex-processing *(circle one)*

Analysis performed laboratory analysis / Farm analysis
Dates of analysis ______________________________
Analysis frequency ______________________________
Has quality changed over time? ______________________________

	Total quantity produced t/yr or m^3/yr	DM %	TN kg/t	NH4-N kg/t	TP kg/t	$P_{inorganic}$ kg/t	Ash %
Solid							
Semi-solid							
Slurry							

7. Manure Application

7.1. General question

Total field area available for manure spreading	___________ ha
Portion of manure spread on fields	___________ %
Amount of manure exported off-farm	___________ tonne
Use or fate of exported manure?	___________
Soil nutrient analysis before spreading	Yes / No

7.2. Application to fields

Crop type	Field area (ha)	Manure type[1]	Distance from barn	Application rates (t/ha) and dates	Grow -ing crop[2]	Spreading technique[3]	Incorp-oration[4]	Depth[5]

1) Slurry, solid, semi-solid
2) Application in growing crop (check if yes)
3) Broadcasting, band spreading, injection
4) Time between application and incorporation. **0** (immediately), **1** (within 4hrs), **2** (between 4-24hrs), **3** (after 1 day), **No** (no incorporation)
5) Depth of injection or incorporation

7.3. Spreading equipment used

Transport Liquid/ slurry	**Make / model / description**
Slurry tank	*Volume*
Umbilical system	
Irrigation	
Spreading Liquid/slurry	
Band spreaders	*1 (hanging hoses or trailing shoe)*
Injector	*(open or closed slot)*
Broadcaster	*1*
Other	
Solid manure	
Broadcaster	*1, Loading capacity*

Incorporation method	

[1]Distribution uniformity – Evenly distributed, satisfactory, patchy

8. Additional questions

Main source of information for farm management decisions *(Advisory agencies, feed dealers, trade organizations)*
How do you assess the quality of your manure?
What difficulties do you encounter in managing your manure?
Are there plans to change your manure management strategy?
What would you like to improve about your manure management system?
What barriers are there to implementing available technologies? *(not aware of latest techniques and how they might benefit? Or financial barriers?)*

Appendix 2. Case-study farm data by country

Estonia

Table 1. General description and location of case-study farms in Estonia. Livestock units (LU) are calculated according to the coefficients given in Table 2. LU for dairy farms is calculated based on the total herd. LU for the pig farms with sows is calculated including piglets and growing weaned pigs. Livestock density is the LU divided by total area on farm available for spreading manure.

Country Farm	Animal type	Nr of animal places	Region	Baltic drainage area	LU	Livestock density (LU/ha)
EE Farm 1	Dairy	125/250*	Tartu	Gulf of Finland	176	1.35**
EE Farm 2	Dairy	520/1120*	Tartu	Gulf of Finland	885	1.38@
EE Farm 3	Dairy	600/1200*	Jõgeva	Gulf of Finland	909	0.40^
EE Farm 4	Pigs - finishers/sows	36 000/10 500+	Viljandi	Gulf of Riga	31 260	0.68**
EE Farm 5	Pigs - finishers	12 212	Põlva	Gulf of Finland	7450	1.36**
EE Farm 6	Poultry – broilers/layers	1 200 000/ 350 000#	Harju	Gulf of Finland	13 300	-

*Number of milking cows / total herd including heifers and calves
** Part of the manure spread in fields of contractor farmer
+Finishers/sows
#Broilers/layers
@Company have 3200 ha arable land for manure spreading. Also have company three animal units, two dairy and one pig farm with total number of ca 4400 LU. One dairy farm is involved to our project as test farm.
^Company have 2300 ha arable land for manure spreading and only one animal unit what is involved to our project as test farm.

Table 2. Production levels at the Estonian case-study farms. ECM is calculated as 0.25(kg milk) +12.2*(kg fat)+7.7*(kg protein)*

Country - Farm	Animal type	Nr of animal places	Production	Units
EE Farm 1	Dairy	125*	9400 ECM	per cow per year
EE Farm 2	Dairy	520*	10 470 ECM	per cow per year
EE Farm 3	Dairy	585*	10 133 ECM	per cow per year
EE Farm 4	Pigs - finishers/sows	36 000/10 500	65 000 finishers @ 113-115kg 280 000 piglets @ 7.1-8 kg	per year per year
EE Farm 5	Pigs - finishers	12 212	24 846 finishers @ 113-115kg	per year
EE Farm 6	Poultry – broilers/layers	1 200 000/ 350 000	74 000 000 eggs 126 000 broilers @ 2.34 kg	per year per year

*only milking cows

Table 3. General description of the feeding systems at case-study farms in Estonia. TMR = total mixed ration, MR = partially mixed ration, FA = feeding automat (concentrates)

Country - Farm	Livestock type	Feed system	Production phases with specific feed mixtures	Feed composition	Mineral feed/Feed additives	Portion of feed grown on-farm
EE Farm 1	Dairy	MR, FA	Milking cows Dry cows	53.5% roughage 46.5% concentrates 94.9% roughage 5.4 % concentrates	Limestonnee Min. feed Ca:P = 2.5:1 Anion feed	Roughage 100%
EE Farm 2	Dairy	TMR	Milking cows (3 groups milking + dry)	47.8% roughage 52.2%concentrates	Min. feed Ca:P = 2.5:1 Feed add. Optigen (Alltech)	Roughage 100% Cereals 100%
EE Farm 3	Dairy	TMR	Milking cows (3 groups milking + dry)			Roughage 100% Cereals 100%
EE Farm 4	Pigs - finishers/ sows	Wet feed	Weaners ≤ 8 kg Fatteners ≤ 70kg Fatteners > 70kg Gestation sows Lactating sows 1 Lactating sows 2	100 % complete feed for all groups	Limestonnee, MCP*, NaCl, Lysine, Methionine, Threonine, L-Trypthophane, Biophospatine	0%
EE Farm 5	Pigs - finishers	Wet feed	Fatteners ≤ 70kg Fatteners > 70kg	100 % complete feed for all groups	Limestonnee MCP* NaCl Lysine Methionine Threonine L-Trypthophane Biophospatine	0%
EE Farm 6	Poultry – broilers/ layers		Broilers Layers Young birds Breeding birds	85% concentrate 15% wheat for broilers	MCP Lysine Methionine Threonine $NaHCO_3$ NaCl Colinechloride	0%

*Monocalciumphosphate

Table 4. General description of the housing systems at case-study farms in Estonia. Milking cows are in barn all the year. Number of barns for milking cows (total number of barns for herd).

Country - Farm	Animal type	Confinement	No. of barns	Housing type	Bedding material
EE Farm 1	Dairy	Without grazing, 100%	1 (2)	Loose cubicle housing, semi uninsulated building, natural ventilation	Rubber mats with peat
EE Farm 2	Dairy	Without grazing, 100%	1 (7)	For dairy cows loose cubicle housing, uninsulated building, natural ventilation	Rubber mats with sawdust
EE Farm 3	Dairy	Without grazing, 100%	1 (3)	Loose cubicle housing, uninsulated building, natural ventilation	Rubber mats without bedding, disinfection material Delta sec
EE Farm 4	Pigs - finishers/ sows	100%	4	Group housing / partially slatted floors	Without bedding
EE Farm 5	Pigs - finishers	100%	1	Group housing / partially slatted floors	Without bedding
EE Farm 6	Poultry – broilers/ layers	100%		Broilers – loose housing Layers – cages or enriched cages	Deep litter (cover 1-2 cm), peat Without bedding

Table 5. General description manure handling systems in-house at case-study farms in Estonia.

Country - Farm	Animal type	Manure handling	Primary manure channel	Cross channel	In-house manure transport	Removal frequency
EE Farm 1	Dairy	Slurry	Open concrete passageway covered with rubber mats	Covered	-Automatic scrapers from primary manure channel to cross channel -Mechanical removal from cross channel to pumping pit -Hydraulic removal from pumping pit to manure storage	Continuously Two times per week Two times per week
EE Farm 2	Dairy	Slurry	Open concrete passageway	Covered	-Automatic scrapers from primary manure channel to cross channel -Hydraulic removal from cross channel to pumping pit -Hydraulic removal from pumping pit to manure storage	Eight times per day Two times daily (summer). Eight times daily (winter) Once per day
EE Farm 3	Dairy	Slurry	Open concrete passageway	Covered	Automatic scrapers from primary manure channel to cross channel Mechanical removal from cross channel to pumping pit Hydraulic removal from pumping pit to manure storage	Multiple times per day Two times per day Two times per day
EE Farm 4	Pigs - finishers/ sows	Slurry	Under slatted floors,	Covered	Hydraulic (vacuum) removal from primary channel to cross channel Hydraulic (pumping) removal from cross channel to pumping pit Hydraulic (pumping) removal from pumping pit to manure storage	Once per day Once per day Once per day
EE Farm 5	Pigs - finishers	Slurry	Under slatted floors,	Covered	Hydraulic (vacuum) removal from primary channel to cross channel Hydraulic (pumping) removal from cross channel to pumping pit Hydraulic (pumping) removal from pumping pit to manure storage	Once per day Once per day Once per day
EE Farm 6	Poultry – broilers/ layers	Solid Slurry	- Under slatted floor	- Covered	Mobile removal from deep litter area to manure storage Mechanical (scrapers) removal from primary channel to cross channel Mechanical (conveyor belts) removal from cross channel to pumping pit. Hydraulic (pumping) removal from pumping pit to manure tanker	Once per period (38-42 days) Once per day Once per day Once per day

Table 6. Manure storage at case-study farms in Estonia. Primary storage is within close proximity to the barns. Storage capacity is calculated from total farm storage (primary + satellite).

Country – Farm	Animal type	Manure type	Manure production (per yr)	Primary storage	Covered	Satellite storage	Storage capacity (months)
EE Farm 1	Dairy	Slurry	6500 m^3	4630 m^3	Armed concrete roof	-	8.5
EE Farm 2	Dairy	Slurry	14 000m^3	6000m^3	Crust	-	5.1
EE Farm 3	Dairy	Slurry	14 000m^3	8900m^3	Crust	-	7.6
EE Farm 4	Pigs-finishers/ sows	Slurry	60 000m^3	60 000m^3	Floating cover (floating gravel)	40 000m^3	20
EE Farm 5	Pigs-finishers	Slurry	18 000m^3	18 000m^3	Floating cover (floating gravel		12
EE Farm 6	Poultry – broiler laying hens	Solid/ Slurry	25 000m^3/ 15 000m^3	Concrete pad / 14 000m^3	Manure heap is covered with peat	-	8 / 11

Table 7. Manure application to fields at case-study farms in Estonia.

Country – Farm	Crop type	Field area (ha)	Spreading time[1]	Application rate (tonne / ha)	Spreading technique	Incorpo-ration	Manure exported off-farm
EE Farm 1	Grassland Grassland	20 26	May September	40 40	Band spread. Band spread.	No No	100%
EE Farm 2	NI	3200	No information		Bandspread and contractor		
EE Farm 3	Cereals Grassland Rapeseed		April/May April/May April/May	20 20 20	Band spread. Band spread. Band spread.	No No No	0%
EE Farm 4	Cereals Grassland		April December		Band spread.	Yes	
EE Farm 5	Cereals Grassland		April December		Band spread.	Yes	
EE Farm 6	Oil seed rape, barley, wheat		Before seeding and to winter crops in spring	5 to 10	Two-step solid manure spreader (Fliegel and Samson)		100%

Finland

Table 1. General description and location of case-study farms in Finland. Livestock units (LU) are calculated according to the coefficients given in Table 1. LU for dairy farms is calculated based on the total herd. LU for the pig farms with sows is calculated including piglets and growing weaned pigs. Livestock density is the LU divided by total area on farm available for spreading manure.

	Animal type	Number of animal places	Region / County	Baltic drainage area	LU	Livestock density (LU/ha)
FI Farm 1	Dairy	215/430*	Lammi/Häme	Northern Baltic	300	1.5
FI Farm 2	Dairy	120/260	Pirkanmaa	Northern Baltic	220	1.6
FI Farm 3	Pigs / finishers	3000	Vampula/Varsinais-Suomi	Northern Baltic	3240	**
FI Farm 4	Pigs /finishers	3300	Koski TL/Varsinais-Suomi	Northern Baltic	3510	11.7
FI Farm 5	Poultry	140 000	Huittinen/Varsinais -Suomi	Northern Baltic	660	40.4

*number of milking cows / total herd including heifers and calves

**Farm 3 is owned and operated by a cooperative including 5 surrounding farms on which manure can be spread

Table 2. Production levels at the Finnish case-study farms. ECM is calculated as 0.25(kg milk)+12.2*(kg fat)+7.7*(kg protein)*

	Animal type	Number of animal places	Production	Units
FI Farm 1	Dairy	215*	9100 ECM	per cow per year
FI Farm 2	Dairy	120*	10 500 ECM	per cow per year
FI Farm 3	Pigs / finishers	3000	10 800 pigs @ 120 kg	per year
FI Farm 4	Pigs / finishers	3300	11 700 pigs @ 130 kg	per year
FI Farm 5	Poultry	140 000	808 500 broilers @ 1.80 kg	per year

*only milking cows

Table 3. General description of the feeding system at case-study farms in Finland. TMR = total mixed ration

Country - Farm	Livestock type	Feed system	Production phases with specific feed mixtures	Feed composition	Feed additives	Portion of feed grown on-farm
FI Farm 1	Dairy	TMR	Milking cows Dry cows	76 % roughage 24 % concentrates 98 % roughage 2 % concentrates	Vitamin A Vitamin D3 Vitamin E $Ca(IO_3)_2$ $CoCO_3$ $CuSO_4 \bullet 5H_2O$ MnO ZnO Na_2SeO_3	Roughage 100 %
FI Farm 2	Dairy	TMR	Milking cows	46% roughage 17 % barley 37 % concentrates	Min. feed, propylene glycol for high yield cows	Roughage 100%
FI Farm 3	Pigs - finishers	Wet feeding	First 5 days solid (dry) complete feed, then liquid feeding Phase 1 < 60 kg Phase 2 > 60 kg	100 % complete feed (dry) liquid feeding; WBP* barley whey concentrate wheat oats	Phytase and organic acid mixture in dry complete feed $C_6H_7KO_2$[¤] $CaCO_3$ MCP[+] NaCl $NaHCO_3$ MgO $CuSO_4$ $FeSO_4$ Na_2SeO_3 $Ca(IO_3)_2$ MnO ZnO Vitamin A, D3, B	0%
FI Farm 4	Pigs - finishers	Wet feeding	Phase 1 <50 kg Phase 2 50-80 kg Phase 3 <80 kg	WBP* MRL[#] barley concentrate	$C_6H_7KO_2$[¤] HCOOH[Ͻ] $CaCO_3$ MCP[+] NaCl MgO $CuSO_4 \bullet 5H_2O$ Na_2SeO_3 Vitamin A, D, E L-Lysine L-Threonine DL-Methionine	30% of the barley
FI Farm 5	Poultry		0-7 days 8-21 days 22-34 days 35 - days	75 % concentrate 25 % wheat	Vitamin A, D, E $CuSO_4$ Na_2SeO_3 Xylanase Phytase Coccidiostat	65 % of the wheat

*wet-barley-protein, [¤]potassium sorbate in WBP, [+]monocalcium phosphate, [#]milk rinsing leftover, [Ͻ]formic acid in milk rinsing leftover.

Table 4. General description of the housing systems at case-study farms in Finland. Milking cows are on pasture during summer months. Number of barns for milking cows (total number of barns for herd).

	Animal type	Confinement	No. of barns	Housing type	Bedding material
FI Farm 1	Dairy	100 % heifers and dry cows on pasture approx. 4 months	2	Loose cubicle housing, natural ventilation	Rubber mats with sawdust or wood shavings Deep litter bed straw
FI Farm 2	Dairy	100 %	2	Loose cubicle housing	Rubber mats with peat / Deep litter bed straw
FI Farm 3	Pigs / finishers	100%	1	15 separate sections all w/ partially slatted floors	hay, sawdust, wood shavings
FI Farm 4	Pigs / finishers	100 %	1	15 separate section w/ partially slatted floors	straw, peat
FI Farm 5	Poultry	100%	4	Loose housing, peat bedding	Peat

Table 5. General description manure handling systems in-house at case-study farms in Finland

	Animal type	Manure handling	Primary manure channel	Cross channel	In-house manure transport	Removal frequency
FI Farm 1	Dairy	Slurry/ solid	Open concrete passageway	Open	Small loader scraper / gravity flow	2 per day
FI Farm 2	Dairy	Slurry / solid	Open concrete passageway	Open	Scraper	48 times a day
FI Farm 3	Pigs / finishers	Slurry	Under slatted floors	None	drainage pipe system	1 per 3 weeks
FI Farm 4	Pigs / finishers	Slurry	Under slatted floors	None	drainage pipe system	1 per 2 weeks
FI Farm 5	Poultry	Solid			4-wheel loader	6 per/year

Table 6 Manure storage at case-study farms in Finland. Primary storage is within close proximity to the barns. Storage capacity is calculated from total farm storage (primary + satellite).

	Animal type	Manure type	Manure production (per yr)	Primary storage	Covered	Satellite storage	Storage capacity (months)
FI Farm 1	Dairy	Slurry Solid	5800 m^3 180 m^3	9000 m^3 200 m^3	Crust No		12 12
FI Farm 2	Dairy	Slurry Solid	4500 m^3 1500 m^3	3000 m^3 1400 m^2	No Roof	No Field heaps	8 11
FI Farm 3	Pigs / finishers	Slurry	6371 m^3	7500 m^3	No		14
FI Farm 4	Pigs / sows	Slurry	8000 m^3	2200 m^3	No	4	12
FI Farm 5	Poultry	Solid	2400 m^3	~2400 m^3	No	0-1000 m^3	12

Table 7. Manure application to fields at case-study farms in Finland

	Crop type	Field area (ha)	Spreading time[1]	Application rate (tonne / ha)	Spreading technique	Incor-poration	Manure exported off-farm
FI Farm 1	Ley Spring rye+ pea+ley	170 30	After 1st silage cut Spring	30 ?	Injection Broadcast	(1 cm) 8 hrs	5 %
FI Farm 2	Ley Oats, winter cereals	85 55	After 1st silage cut Spring	50 40	Injection Broadcast (solid)	(5 cm) 4 hrs	0%
FI Farm 3	-	-	-	-	-	-	100%*
FI Farm 4	W.wheat S.wheat Barley Peas Rapeseed	100 80 60 30 30	Spring Spring Spring Spring Spring	20 25-30 25-30 15 25-30	Trailing hoses Injection Injection Injection Injection	4-5 4-5 4-5 4-5 4-5	20 %
FI Farm 5	Wheat Rapeseed	120 20	Spring	10 ?	2-phase spreader	5 cm	40 %

*Farm 3 pumps all manure to a nearby biogas plant, which returns the processed manure via same pipeline into the storages, which are rented by the biogas company and a contractor transports and spreads the processed manure.
[1]Summer spreading is in growing crops

Latvia

Table 1. General description and location of case-study farms in Latvia. Livestock units (LU) are calculated according to the coefficients given in Table 1. LU for dairy farms is calculated based on the total herd. LU for the pig farms with sows is calculated including piglets and growing weaned pigs. Livestock density is the LU divided by total area on farm available for spreading manure.

Country – Farm	Animal type	Number of animal places	Region / County	Baltic drainage area	LU	Livestock density (LU/ha)
LV Farm 1	Dairy	436/850*	Auce	Gulf of Riga	719	0.42
LV Farm 2	Dairy	315/463*	Blīdene	Gulf of Riga	417	0.35
LV Farm 3	Pigs	14 560	Ulbroka	Gulf of Riga	2385	2.38
LV Farm 4	Pigs	17 076	Jaunbērze	Gulf of Riga	3116	0.92
LV Farm 5	Poultry	2 620 000	Iecava	Gulf of Riga	8832	)**

*number of milking cows / total herd including heifers and calves

** since 2010, all manure is sold to a company, which they are marketed on.

Table 2. Production levels at the Latvian case-study farms. ECM is calculated as 0.25(kg milk)+12.2*(kg fat)+7.7*(kg protein)*

Country – Farm	Animal type	Number of animal places	Production	Units
LV Farm 1	Dairy	436*	7452 ECM	per cow per year
LV Farm 2	Dairy	315*	8346 ECM	per cow per year
LV Farm 3	Pigs	14 560	27 000 finishers x 110 kg	per year
LV Farm 4	Pigs	17 076	56 100 piglets x 25 kg	per year
LV Farm 5	Poultry	2 620 000	510 million eggs	per year

*only milking cows

Table 3. General description of the feeding system at case-study farms in Latvia. (MISSING)

Table 4. General description of the housing systems at case-study farms in Latvia. Milking cows are on pasture during summer months. Number of barns for milking cows (total number of barns for herd).

Country – Farm	Animal type	Confinement	No. of barns	Housing type	Bedding material
LV Farm 1	Dairy	100 %	1 (3)	Loose cubicle housing, open, natural ventilation	Rubber mats with sawdust
LV Farm 2	Dairy	Milking cows – 100 % Dry cows - pasture, approx. 5 months	1 (2)	Loose cubicle housing, open, natural ventilation	Rubber mats with rape straw
LV Farm 3	Pigs	100 %	4 (10)	Pens with slatted floors: for fatteners and pregnant sows – 100 %, for suckling sows and weaned piglets – 74 %	-
LV Farm 4	Pigs	100%	4	Pens with slatted floors: for young swines – 20%, pregnant sows – 80%, suckling sows and weaned piglets – 50%	-
LV Farm 5	Poultry	100%	20	Cages with sieve floor, below it is located manure conveyor belt.	-

Table 5. General description manure handling systems in-house at case-study farms in Latvia.

Country – Farm	Animal type	Manure handling	Primary manure channel	Cross channel	In-house manure transport	Removal frequency
LV Farm 1	Dairy	Slurry	Open concrete passageway	Covered	Automatic scrapers / gravity flow	Continually
LV Farm 2	Dairy	Slurry	Open concrete passageway	Covered	Automatic scrapers / gravity flow	Continually
LV Farm 3	Pigs	Slurry	Under slatted floors	Covered	Gravity flow	Continually
LV Farm 4	Pigs	Slurry	Under slatted floors	Covered	Gravity flow	Continually
LV Farm 5	Poultry	Solid	conveyor belt below cages	conveyor belt	Conveyor belt	Twice a week

Table 6. Manure storage at case-study farms in Latvia. Primary storage is within close proximity to the barns. Storage capacity is calculated from total farm storage (primary + satellite).

Country – Farm	Animal type	Manure type	Manure production (per yr)	Primary storage	Covered	Satellite storage	Storage capacity (months)
LV Farm 1	Dairy	Slurry	12 000 m^3	4000 m^3	Crust	-	6
LV Farm 2	Dairy	Slurry	9500 m^3	5600 m^3	Crust	-	7.2
LV Farm 3	Pigs	Slurry	22 000 m^3	12 000 m^3	Roof	850 m^3	7.2
LV Farm 4	Pigs	Slurry	15 600 m^3	10 000 m^3	Floating film	6 540 m^3	7.7
LV Farm 5	Poultry		190 000 tonnes				All manure is sold

Table 7. Manure application to fields at case-study farms in Latvia.

Country – Farm	Crop type	Field area (ha)	Spreading time[1]	Applicatio n rate (tonnes / ha)	Spreading technique	Incor- poration	Manure exported off-farm
LV Farm 1	Rape Wheat Maslin for green mass Before autumn plowing	60 270 30 130	Spring Spring / Summer Spring Autumn	20 20 20 20	Broadcasting Broadcasting Broadcasting Broadcasting	No no / 24hrs No 24 hrs	0%
LV Farm 2	Maize Grassland Crops	90 60 280	Spring Spring Autumn	40 30 30	Broadcasting Broadcasting Broadcasting	24 hrs No 24 hrs	0%
LV Farm 3		~ 1000	Spring /autumn	30 - 40	Band spread.	24 hrs	10%
LV Farm 4		~ 3400	Spring /autumn	30 - 40	Band spread.	24 hrs	0%
LV Farm 5							100%

Lithuania

Table 1. General description and location of case-study farms in Lithuania. Livestock units (LU) are calculated according to the coefficients given in Table 1. LU for dairy farms is calculated based on the total herd. LU for the pig farms with sows is calculated including piglets and growing weaned pigs. Livestock density is the LU divided by total area on farm available for spreading manure.

Country – Farm	Animal type	Number of animal places	Region / County	Baltic drainage area	LU	Livestock density (LU/ha)
LT Farm 1	Dairy	230/500	Taurage region,	East Baltic	350	1.71
LT Farm 2	Dairy	300/560*	Kaunas region	East Baltic	524	0.41
LT Farm 3	Pigs	2400/13300*	Marijampole region	East Baltic	5800	5.28
LT Farm 4	Pigs	2250/11800*	Taurage region	East Baltic	5100	25.5
LT Farm 5	Poultry	705 513	Vilnius region	East Baltic	9877	9.88

*Dairy - number of milking cows / total herd including heifers and calves
*Pigs – number of sows/finishers

Table 2. Production levels at the Lithuania case-study farms. ECM is calculated as 0.25(kg milk)+12.2*(kg fat)+7.7*(kg protein)*

Country – Farm	Animal type	Number of animal places	Production	Units
LT Farm 1	Dairy	230*	Milk 7000 kg/year, 3.3% protein; 4,6% of fat	per cow per year
LT Farm 2	Dairy	300*	Milk 7844 kg/year, 3.5% protein; 3,8% of fat	per cow per year
LT Farm 3	Pigs - finishers	2400/13 300*	50 000 pigs @ 108 kg	per year
LT Farm 4	Pigs - finishers	2250/11 800*	39 000 pigs @ 107 kg	per year
LT Farm 5	Poultry	705 513	17 million eggs	per month

*Dairy – only milking cows
*Pigs – number of sows/finishers

Table 3. General description of the feeding system at case-study farms in LIthuania . TMR = total mixed ration, MR = partially mixed ration, FA = feeding automat (concentrates)

Country - Farm	Livestock type	Feed system	Production phases with specific feed mixtures	Feed composition	Mineral feed/Feed additives	Portion of feed grown on-farm
LT Farm 1	Dairy	TMR	Milking cows Dry cows Calves	86.2% roughage 13.8 % concentrates 87.5% roughage 12.5 % concentrates	Min. feed additives NaCl	Roughage 100% Cereals 100%
LT Farm 2	Dairy	TMR	Milking cows Dry cows Calves	83% roughage 17% concentrates	Min. feed additives NaCl	Roughage 100% Cereals 100%
LT Farm 3	Pigs - finishers/ sows		Weaners Fatteners Sows	100 % complete feed for all groups	Min. feed additives	0%
LT Farm 4	Pigs-finishers Sows		Weaners Fatteners Sows	100 % complete feed for all groups	Min. feed additives	0%
LT Farm 5	Poultry – layers		Layers Young birds	100 % complete feed for all groups	Min. feed additives	0%

Table 4. General description of the housing systems at case-study farms in Lithuania. Number of barns for milking cows (total number of barns for herd).

Country – Farm	Animal type	Confinement	No. of barns	Housing type	Bedding material
LT Farm 1	Dairy	Pasture, approx. 6 months*	1	Loose housing, natural ventilation	Straw – only for calves**
LT Farm 2	Dairy	Pasture, approx. 5 months*	1	Loose housing with deep-litter pens, natural ventilation	Deep-litter bed straw
LT Farm 3	Pigs - finishers	100%	44	Batch pen with partially slatted floors	No
LT Farm 4	Pigs - finishers	100%	n.d.	Batch pen with partially slatted floors	No
LT Farm 5	Poultry	100%	n.d.	Hens live in cages - 39 in one cage.	

* Pasture - only for dry cows and heifers

Table 5. General description manure handling systems in-house at case-study farms in Lithuania.

Country – Farm	Animal type	Manure handling	Primary manure channel	Cross channel	In-house manure transport	Removal frequency
LT Farm 1	Dairy Calves	Slurry Solid	Open concrete passageway Manually	Covered	Automatic scrapers / gravity flow	2 times per day Once a month
LT Farm 2	Dairy	Solid	Open concrete passageway	Covered	Mobile scraper unit	1 per week
LT Farm 3	Pigs - finishers	Slurry	Under slatted floors	Covered	Automatic scrapers /gravity flow	1 per day
LT Farm 4	Pigs - finishers	Slurry	Under slatted floors	Covered	Automatic scrapers /gravity flow	1 per day
LT Farm 5	Poultry	solid			Slurry and manure are removed mechanically	2 times per week

Table 6. Manure storage at case-study farms in Lithuania. Primary storage is within close proximity to the barns. Storage capacity is calculated from total farm storage.

Country – Farm	Animal type	Manure type	Manure production (per yr)	Primary storage	Covered	Satellite storage	Storage capacity (months)
LT Farm 1	Dairy	Slurry Solid	6400 m^3 125 m^3	3220 m^3 n.d.	Crust	no	6
LT Farm 2	Dairy	Solid	11 400 tonnes	3800 m^2	No	no	7
LT Farm 3	Pigs	Slurry	85 000* m^3	160 000 m^3	No	no	12+
LT Farm 4	Pigs	Slurry incl. separated solids	31 000** m^3 3100** m^3	122 000 m^3	No Yes	no	12+
LT Farm 5	Poultry	Solid	n.d.	24 000 m^3	no	no	6

*Estimated, not recorded or measured
**Data provided by company owner

Table 7. Manure application to fields at case-study farms in Lithuania.

Country – Farm	Crop type	Field area (ha)	Spreading time[1]	Application rate (tonne / ha)	Spreading technique	Incor-poration (depth)	Manure exported off-farm
LT Farm 1	Cereals/ grasses	400/200	Spring / early autumn	25-35	Band spreading	n.a.	n.a.*
LT Farm 2	Cereals, sugar beet, maize/grasses	1000/200	Spring / early autumn	25-30	Solid manure spreader	n.a.	0%
LT Farm 3	Cereals Rape Grasses	2300	Spring / early autumn	Max 80	Umbilical hose system with a band spreader	n.a.	n.a.*
LT Farm 4	Cereals		Spring /early autumn	37 (slurry)	Broad casting	n.a.	80%*
	Grasses Field crop? Total	240 1487	At dry seasons	84 (liquids) ? (solids)	Broadcasting		
LT Farm 5	Arable crops	1000	Spring / early autumn	n.a.	n.a.	n.a.	100%*

n.a. implies that information was not available

* transported and applied on fields of neighbouring farms

Poland

Table 1. General description and location of case-study farms. Livestock units (LU) are calculated according to the coefficients given in Table 1. LU for dairy farms is calculated based on the total herd. LU for the pig farms with sows is calculated including piglets and growing weaned pigs. Livestock density is the LU divided by total area on farm available for spreading manure.

Country - Farm	Animal type	Nr of animal places	Region/ County	Baltic drainage area	LU	Livestock density (LU/ ha)
PL Farm 1	Dairy	290/515*	Lębork	Baltic Proper	420	1.4
PL Farm 2	Dairy	340/780*	Sztum	Baltic Proper	612	1.22
PL Farm 3	Pigs- fattening	9200	Człuchów (Pawłówko)	Baltic Proper	2760	4.28
PL Farm 4	Pigs- sows	3680	Człuchów (Płaszczyca)	Baltic Proper	4313	5.56
PL Farm 5	Poultry	180 000	Słupsk	Baltic Proper	2520	2.52

*number of milking cows / total herd including dry cows, heifers and calves
** including piglets

Table 2. Production levels at the case-study farms. ECM is calculated as 0.25(kg milk)+12.2*(kg fat)+7.7*(kg protein)*

Country - Farm	Animal type	Nr of animal places	Production	Units
PL Farm 1	Dairy	290*	11 738 ECM	per cow per year
PL Farm 2	Dairy	340*	10 148 ECM	per cow per year
PL Farm 3	Pigs- fattening	9200	31 585 pigs @ 102 kg	per year
PL Farm 4	Pigs- sows	3680	91 608 pigs @ 6 kg	per year
PL Farm 5	Poultry	180 000	54 M eggs	per year

*only milking cows

Table 3. General description of the feeding system at case-study farms in Poland. TMR = total mixed rations.

Country - Farm	Livestock type	Feed system	Production phases with specific feed mixtures	Feed composition	Feed additives	Portion of feed grown on-farm
PL Farm 1	Dairy	TMR	Milking cows Dry cows Heifers, Calves	71% roughage 29% concentrates 99% roughage 0,4% concentrates 100% roughage 100% roughage	LNB Mineral feed	Roughage 100% Concentrates 50%
PL Farm 2	Dairy	TMR	Milking cows Dry cows Heifers, Calves	58% roughage 42% concentrates 90% roughage 10% concentrates 87% roughage 13% concentrates 65% roughage 35% concentrates	Own mineral feed	Roughage 100% Concentrates 63%
PL Farm 3	Pigs - finishers	FA, dry	35-55 kg 55-100 kg	100% complete feed for all groups	Limestone MCP Tesenderlo Salt Phyzyme xp 5000 Premiks rosta Primiks FINISH	100%
PL Farm 4	Pigs - sows	FA, dry	Sows + piglets Sows during lactation Sows (loszka remontowa) Fatteners 0-10kg	100% complete feed	Limestonnee MCP Tesenderlo Salt Premiks START Gesta, Premiks LAKTA, Premiks PLANT, Optimix SPC 60 Hemoglobine Brewing yeast Potato protein Softacid II	100%
PL Farm 5	Poultry	TMR, dry	Laying hens	100% concentrates	Limestone Phosphates	Concentrates 73%

Table 4. General description of the housing systems at case-study farms in Poland. Milking cows are on pasture during summer months. Number of barns for milking cows (total number of barns for herd).

Country - Farm	Animal type	Confinement	No. of barns	Housing type	Bedding material
PL Farm 1	Dairy	100%	3	1) Loose housing, 2) Tied pens, 3) Tied pens with slatted floors natural ventilation	1) Straw, 2) Straw, 3) Sawdust
PL Farm 2	Dairy	100%	3	1) Loose housing, 2) Loose housing, 3) Tied pens, natural ventilation	Straw
PL Farm 3	Pigs- fattening	100%	4	354 group pens with slatted floors	-
PL Farm 4	Pigs- sows	100%	15	48 group pens with slatted floors, farrowing pens with partial bedding	Sawdust (farrowing pens)
PL Farm 5	Poultry	100%	4	Cages: 1 building for starters, 3 buildings for laying hens	-

Table 5. General description of manure handling systems in-house at case-study farms

Country - Farm	Animal type	Manure handling	Primary manure channel	Cross channel	In-house manure transport	Removal frequency
PL Farm 1	Dairy	1) Solid 2) Solid 3) Slurry	1) None 2) None 3) Open concrete pit	None	1) Manually 2) Automatic scrappers, gravity flow, 3) Gravity flow	1) 1 per day 2) 1 per day, 3) Continuously
PL Farm 2	Dairy	1) Solid 2) Solid 3) Solid/ Slurry	None	None	1) Manually 2) Manually 3) Mobile unit (tractor)	1) 2 per week, 2) 2 per week, 3) 2 per day,
PL Farm 3	Pigs- fattening	Slurry	Under slatted floors	Covered	Gravity flow	Continuously
PL Farm 4	Pigs- sows	Slurry	Under slatted floors	Covered	Gravity flow	Continuously
PL Farm 5	Poultry	Solid	Conveyor belt under cages	-	Mechanical	2 per week

Table 6. Manure storage at case-study farms. Primary storage is within close proximity to the barns. Storage capacity is calculated from total farm storage (primary + satellite)

Country – Farm	Animal type	Manure type	Manure production (per yr)	Primary storage	Covered	Satellite storage	Storage capacity (months)
PL Farm 1	Dairy	Solid Slurry	4500 t 6065 m^3	250 t 700 m^3	No (open concrete pad) In the barn	4500 t None	12 1.2*
PL Farm 2	Dairy	Solid Slurry	7500 t 10 000 m^3	None 192 m^3	No (open concrete pad and field heap) No (lagoon)	3750 t 3000 m^3	6 4
PL Farm 3	Pigs- fattening	Slurry	33 757 m^3	2000 m^3	Geomembrane LDPE, Before the biogas plant: lagoon/ after the biogas plant: lagoon	37 000 m^3	13.2***
PL Farm 4	Pigs- sows	Slurry	29 353 m^3	80 m^3	Geomembrane LDPE Before the biogas plant: steel tank/ after the biogas plant: lagoon	300/ 20 000 m^3	8.2***
PL Farm 5	Poultry	Solid	10 000 t	None	No (20 field heaps, each for 500 t)	10 000 t	12

***** storage in the barn, during winter excess discharged on the solid manure concrete pad,
*** based on the volume of biogas digestate lagoons (37 000 m^3 at Farm 3; 20 000 m^3 at Farm 4)

Table 7. Manure application to fields at case-study farms

Country – Farm	Crop type	Field area (ha)	Spreading time[1]	Application rate (tonne/ha)	Spreading technique	Incorp-oration	Manure exported off-farm
PL Farm 1	Maize Grass (arable)	100 200	Apr/ Sep Jun/ Sep	45 (solid), 25 (slurry),	Broadcaster Slurry tank	No No	0%
PL Farm 2	Rape Maize	200 300	August April	20 (slurry), 20 (slurry), 25 (solid)	Band spreader Band spreader Broadcaster	(15 cm) (15 cm) No	0%
PL Farm 3	Maize Winter triticale	473 172	May August/ Sep	50 50	Umbilical hose system with band spreader (Agrometer), tanker with injector (closed slots)	(15 cm) (15 cm)	0%
PL Farm 4	Maize Winter triticale Winter barley	446 167.5 163.5	May August/ Sep August/ Sep	50 50 50	Umbilical hose system with band spreader (Agrometer), tanker with injector (closed slots)	(15 cm) (15 cm) (15 cm)	0%
PL Farm 5	Maize Triticale Mixed crops Legumes	500 200 200 100	May Aug/ Sep May-Sep May-Sep	10 10 10 10	Broadcaster	(5 cm) (5 cm) (5 cm) (5 cm)	0%

Sweden

Table 1. General description and location of case-study farms in Sweden. Livestock units (LU) are calculated according to the coefficients given in Table 1. LU for dairy farms is calculated based on the total herd. LU for the pig farms with sows is calculated including piglets and growing weaned pigs. Livestock density is the LU divided by total area on farm available for spreading manure.

Country - Farm	Livestock type	Number of animal places	Region / County	Baltic drainage area	LU	Livestock density (LU/ha)
SE Farm 1	Dairy	330/560*	Uppsala	Northern Baltic	509	1.02
SE Farm 2	Dairy	430/880*	Gävleborg	Gulf of Bothnia	745	0.76
SE Farm 3	Pigs - finishers	3050	Uppsala	Northern Baltic	915	1.14[¤]
SE Farm 4	Pigs - sows	1000	Halland	Kattegat	1183	3.38
SE Farm 5	Poultry	180 000[+]	Södermanland	Northern Baltic	1260	2.52

*Number of milking cows / total herd including heifers and calves

[¤] Farm 3 is owned and operated by a cooperative including 5 surrounding farms on which manure can be spread

[+] Number of places is based on max 36 kg live weight per m^2 and a current delivery weight of 1,6 kg.

Table 2. Production levels at the Swedish case-study farms. ECM is calculated as 0.25(kg milk)+12.2*(kg fat)+7.7*(kg protein)*

Country - Farm	Livestock type	Number of animal places	Production	Units
SE Farm 1	Dairy	330*	8800 ECM	per cow per year
SE Farm 2	Dairy	430*	10 500 ECM	per cow per year
SE Farm 3	Pigs - finishers	3050	9 000 pigs, 124 kg	per year
SE Farm 4	Pigs - sows	1000	25 200 pigs, 30 kg	per year
SE Farm 5	Poultry	180 000	1 620 000 chickens, 1.6kg	per year

*only milking cows

Table 3. General description of the feeding system at case-study farms in Sweden. TMR = total mixed rations.

Country - Farm	Livestock type	Feed system	Production phases with specific feed mixtures	Feed composition	Feed additives	Portion of feed grown on-farm
SE Farm 1	Dairy	TMR	Milking cows Dry cow	53% roughage 46% concentrates	Mineral feed Ca:P = 2:1	Roughage 100% Cereals 100% Protein 100%
SE Farm 2	Dairy	TMR	4 (3 groups milking plus dry)	58% roughage 23% cereals 18% concentrates	Mineral feed Ca:P = 14:1	Roughage 100% Cereals 100%
SE Farm 3	Pigs - finishers	Wet feeding	Phase 1 < 70 kg Phase 2 > 70 kg	22% cereals 3.5% peas 3.7% soybean 70% water	Mineral conc. L-Lysine DL-Methionine L-Threonine Phytase	Cereals 100% Peas 100%
SE Farm 4	Pigs - sows		Gilts Sows Gestating sows Farrowing sows Dry sows Weaned pigs	100% complete feed	Mineral conc. L-Lysine DL-Methionine L-Threonine Phytase	
SE Farm 5	Poultry		1-7 days 8-17 days 18-27 days 27-32 days	65% concentrate 35% wheat	Xylanase ß-glucanase Protease Phytase Coccidiostat	Wheat 100%

Table 4. General description of the housing systems at case-study farms in Sweden. Milking cows are on pasture during summer months. Number of barns for milking cows (total number of barns for herd).

Country - Farm	Livestock type	Confinement	No. of barns	Housing type	Bedding material
SE Farm 1	Dairy	Pasture, approx. 4 months	1 (4)	Loose cubicle housing, natural ventilation	Rubber mats with sawdust
SE Farm 2	Dairy	Pasture, approx. 4 months	2 (7)	1) Loose cubicle housing, open, natural ventilation 2) Loose housing with deep-litter pens, open, natural ventilation	1) Rubber mats with sawdust 2) Deep-litter bed straw
SE Farm 3	Pigs - finishers	100%	1	9 separate sections all w/ partially slatted floors	Sawdust / straw
SE Farm 4	Pigs - sows	100%	8	Group housing w/ partially slatted floors, farrowing pens w/ partially slatted floors	Sawdust / straw; deep-litter bed straw
SE Farm 5	Poultry	100%	3	Confined, loose housing, environmentally controlled	Sawdust

Table 5. General description manure handling systems in-house at case-study farms in Sweden.

Country - Farm	Livestock type	Manure handling	Primary manure channel	Cross channel	In-house manure transport	Removal frequency
SE Farm 1	Dairy	Slurry	Open concrete passageway	Covered	Automatic scrapers / gravity flow	Continually
SE Farm 2	Dairy	Slurry / solid	Open concrete passageway	Covered	Automatic scrapers / gravity flow	1 per hour
SE Farm 3	Pigs - finishers	Slurry	Under slatted floors	Covered	Automatic scrapers /gravity flow	1 per day
SE Farm 4	Pigs - sows	Slurry / solid	Under slatted floors	Covered	Automatic scrapers, hydraulic press, vacuum system/mobile unit	1 per day / 1 per week / 1 per week
SE Farm 5	Poultry	solid	n.a.	n.a.	Mobile unit	After each batch

n.a.; not applicable

Table 6. Manure storage at case-study farms in Sweden. Primary storage is within close proximity to the barns. Storage capacity is calculated from total farm storage (primary + satellite).

Country - Farm	Livesto ck type	Manure type	Manure production (per yr)	Primary storage	Covered	Satellite storage	Storage capacity (months)	Manure exported off-farm
SE Farm 1	Dairy	Slurry	18 000 m^3	6350 m^3	Crust	3900 m^3	6.8	0%
SE Farm 2	Dairy	Slurry	25 000 m^3	14 600 m^3	Crust	5200 m^3	9.5	0%
		Solid	2000 tonnes	1000 m^2	No	300 m^2	12	
SE Farm 3	Pigs - finishers	Slurry	5500 m^3	2600 m^3	Crust	1500 m^3	9	0%*
SE Farm 4	Pigs - sows	Slurry Solid	18 000 m^3 400 tonnes	3500 m^3 200 m^2	Crust No		2.3 12	67%
SE Farm 5	Poultry	Solid	1540 tonnes	250 m^2	10 cm straw	Field heaps		42%

*Farm 3 is owned and operated by a cooperative including 5 surrounding farms on which manure also is spread

Table 7. Manure application to fields at case-study farms in Sweden.

Country - Farm	Crop type	Field area (ha)	Spreading time	Application rate (tonnes/ ha)	Spreading technique	Incorpo-ration	Manure exported off-farm
SE Farm 1	Ley	350	Summer	20-25	Band spread.	No	0%
	Cereals	75	Spring/autumn	40 / 35	Band spread.	24hrs	
SE Farm 2	Ley	400	Late summer	25	Band spread.	No	0%
	Wheat	300	Spring (solid)	20	Broadcast		
			Spring (slurry)	20-40	Injection	(10 cm)	
	Barley	175	Spring (solid)	20	Broadcast		
			Spring (slurry)	20-40	Injection	(10 cm)	
SE Farm 3	Wheat	120	Spring / early autumn	20-25 / 10-15	Band spread.	12hrs	0%
	Maize	20	Early summer	25	Injection, disc tines	(5 cm)	
SE Farm 4	Sugar beets	25	Spring	25	Band spread.	4 hrs	67%
	Oats	25	Spring	25	Band spread.	4 hrs	
	Rapeseed	15	Spring	25	Band spread.	4 hrs	
	Barley	50	Spring	25	Band spread.	4 hrs	
	Wheat	120	Spring	25	Band spread.	4 hrs	
SE Farm 5	W. Wheat	220	Spring	2.5	Broadcast	No	42%
	Barley	30	Spring	2.5	Broadcast	Direct	
	Oats	30	Spring	2.5	Broadcast	Direct	
	Rapeseed	30	Spring	2.5	Broadcast	Direct	
	Peas	60	Spring	2.5	Broadcast	Direct	

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This report in brief

This report presents an overview of manure handling techniques currently in practice on large-scale animal production farms in the BSR. The entire manure handling chain was examined on study farms in Estonia, Finland, Latvia, Lithuania, Poland and Sweden, from feeding to crops.

Considerable variation exists in manure handling chains among large-scale livestock farms in the BSR. Large differences were found in amounts of manure produced per livestock unit for similar animals, possibly due to water management by the farmers.

In many cases, relatively simple technologies or management practices could improve the use of nutrient resources in manure. This could be extra storage capacity, covers for storage facilities, or immediate incorporation into soil at spreading. Appropriate application rates and timing is also important to achieve high nutrient uptake by plants. Cost was the greatest barrier to the adoption of optimal manure handling and it is imperative to reduce this barrier and ensure cost-effectiveness.

This report on Manure Handling Techniques was prepared as part of work package 3 on Innovative Technologies for Manure Handling in the project Baltic Manure.

About the project

The Baltic Sea Region is an area of intensive agricultural production. Animal manure is often considered to be a waste product and an environmental problem.

The long-term strategic objective of the project Baltic Manure is to change the general perception of manure from a waste product to a resource. This is done through research and by identifying inherent business opportunities with the proper manure handling technologies and policy framework.

To achieve this objective, three interconnected manure forums has been established with the focus areas of Knowledge, Policy and Business.

Read more at www.balticmanure.eu.

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