Interreg
Baltic Sea Region
Baltic Slurry Acidification

EUROPEAN UNION
EUROPEAN REGIONAL DEVELOPMENT FUND

Possibilities and bottlenecks for implementing slurry acidification techniques in the Baltic Sea Region

Editors: Lena Rodhe, Justin Casimir
and Erik Sindhöj

EU STRATEGY FOR THE BALTIC SEA REGION
FLAGSHIP

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(revised)

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Contents

1. Preface

Baltic Slurry Acidification is a flagship project in the action plan for EU strategy for the Baltic Sea Region (BSR). The project is being carried out between 2016-2019 with a budget of 5.2 million euros, of which 4 million euros is funded by the EU Regional Development Fund through the Interreg Baltic Sea Region Program.

The general aims of the project are to reduce ammonia emissions from animal production and create a more competitive and sustainable farming sector by promoting the implementation of slurry acidification techniques (SATs) throughout the Baltic Sea Region. This report falls under Work Package 2 - Technical feasibility studies which aims to identify technical issues, bottlenecks and other barriers that may hinder the implementation of slurry acidification techniques (SATs), originally developed in Denmark, to other countries in the BSR.

This report presents a general description of the different SATs that are commercially available from Denmark. Then, an overview of the potential in each BSR country for implementing SATs based on the types of animal production and common manure handling used. The final part of the report is an analysis, made by local experts, of how these SATs could be implemented in each country with focus on any potential technical bottlenecks or other barriers that would hinder using the SATs.

Producing this report has been an extensive collaboration between many partners in many countries, also supported by their individual networks. The Danish SATs producers have also contributed greatly to helping us to understand technical details important for implementation and we are very grateful for their help and cooperation.

This is a revised version of the report that was first released in October 2017. The main changes include the removal of sections describing implementation of SATs in Denmark and a clarification of the regulations in Sweden that could potentially limit the implementation of in-house SATs.

May 2018

Erik Sindhöj
Project Coordinator for Baltic Slurry Acidification

2. Summary

This report: 1) describes slurry acidification techniques (SATs) that are commercially available today in Denmark including in-house, in-storage and in-field SATs, and 2) summarizes expert judgements on how these SATs could be implemented in each country in the Baltic Sea Region (BSR). Special focus on technical bottlenecks for implementing SATs with existing manure management systems were considered.

Data from Eurostat and national statistics show that a large portion of manure in each country is handled as slurry and all the national experts considered implementing SATs as relevant for their respective countries.

The in-field SATs were considered the most applicable SAT for implementation in the BSR. They are flexible and mobile and in general have the lowest acid consumption. If investments in in-field SATs are done by agricultural contractors or farmer cooperation’s, then acidification techniques will also be available to smaller farms. Bottlenecks for implementation are related to the need for large slurry tankers and powerful tractors to operate the SATs.

The in-storage SATs that acidify slurry just before spreading were ranked second of interest in most countries. Mobile equipment is ideal for contractors and co-operations and therefore each unit could potentially treat a lot of slurry. Another advantage is that once the slurry is acidified, any available spreading equipment can be used. The major bottleneck is that extra storage capacity is needed during acidification, so the foaming will not overflow. Most farmers do not have this extra storage capacity, so if storages are full, some slurry would have to be spread untreated before the rest of the tank could be acidified.

The stationary in-house SAT offers the greatest potential to reduce ammonia emissions, which would likely be of interest in environmentally sensitive areas and for large farms required to reduce emissions. It is also the easiest for the farmer to manage since everything is automatic and the farmer never has to handle the acid. However, it was considered the most difficult to implement into existing manure handling systems. There is a general uncertainty about reconstruction needs to install in-house SATs in existing animal houses and therefore it was considered best suited for new animal houses. In some countries, like Sweden, certain regulations would need to be addressed and additional tests needed before permits for the use of this SAT would likely be granted.

Compared to in-house, there was greater interest in the in-storage long-term SAT that acidifies all slurry sent to the storage (a modified version of the in-house SAT), since this would likely be easier to implement into existing manure handling systems. It is still a stationary system for a specific farm but installation would be simpler and emissions decreased from both storage and spreading.

In general, there is a good potential to implement currently available SATs into existing manure handling systems in BSR countries and most identified technical bottlenecks could be dealt with.

3. Introduction

Livestock manure is the main source of ammonia-nitrogen emissions in the Baltic Sea Region, which through atmospheric deposition results in a significant amount of nitrogen entering to the Baltic Sea. Together with small particles from society, the ammonia emissions could also threaten human health through the formation of smog, which as a pollutant is estimated to have a high negative impact on human health.

By adding acid to manure slurry, the pH is lowered, and ammonium nitrogen is prevented from being converted to gaseous ammonia nitrogen and lost. This leads to increased nitrogen utilization from livestock manure and reduces the need for purchasing mineral nitrogen fertilizers which contributes positively to the farm's economy. It will also enhance the sustainability of livestock production and lower the negative impacts of manure on the environment.

Farm scale slurry acidification techniques have been developed and widely tested and implemented in Denmark. There are different technologies for acidifying slurry in the animal house (in-house), in the slurry storage (in-storage) and in the field during spreading (in-field).

To promote the use of new technologies in countries other than Denmark, it is important to highlight how the different technologies are intended to be used and what to expect from them. Farms and farming systems can vary considerably between countries and even regions. Technologies that were developed and proven to work for one set of circumstances may not be immediately suited to circumstances in another area. Therefore, it is essential to guide potential users on which factors should be considered when choosing which technology is best applicable and how these technologies can be applied to their specific conditions.

This report starts with a general description of the various SATs that are commercially available today. Then, an overview of the potential in each BSR country for implementing SATs is presented followed by an analysis of how these SATs could be implemented in each country with focus on any potential technical bottlenecks or other barriers that would hinder using the SATs.

4. Descriptions of slurry acidification techniques (SATs) and how it is practiced

Kamila Mazur – ITP
Erik Sindhöj – RISE

For this report, commercially available slurry acidification technologies (SATs) are divided into three types depending on where along the manure handling chain the slurry is acidified. Animal slurry can be acidified either in the animal house (in-house), in the slurry storage (in-storage) or in the field during slurry spreading (in-field). Currently there are five companies that manufacturer commercial versions of the three SATs and all these companies are in Denmark. All systems use sulfuric acid for acidification. Here we will give a brief general description and use of the three types of SATs as well as some key differences between them.

4.1. In-house

In-house slurry acidification is designed to assure that all slurry collected in the animal house is acidified to reduce ammonia emissions from the animal house, the slurry storage and in the field during slurry spreading. Slurry in the animal house is acidified multiple times and only acidified slurry is pumped to the external storage. This reduces emissions also from storage as well as later when the acidified slurry is spread. To assure a stable pH in the acidified slurry during the entire storage period, it is necessary to add enough acid to neutralize the pH buffer system.

Advantages

The main advantage of the in-house system is that it offers the greatest potential for reducing ammonia emissions from animal production since it reduces emissions from the animal house, the storage and during spreading. Since the stored slurry has a stable pH, there are no time limits on how quickly it must be spread as with in-storage acidification (see below). The acidified slurry can be spread with any available slurry spreading equipment; unlike with the in-field SATs (see description below). The in-house system offers totally automatic slurry handling and acidification treatment, so the farmer does not need to handle acid. Furthermore, indoor air quality is greatly improved (Petersen et al., 2016) which will affect both animals and workers.

Disadvantages

The main disadvantage of the in-house system is that it has the highest use of acid since the buffer system must be neutralized to stabilize the pH during the entire storage period. Installing an in-house SAT to an existing animal housing system can involve extensive reconstruction. Since this is a fixed system installed for a particular barn, the potential to acidify slurry is also fixed to that particular barn, i.e., acidification of slurry cannot be shared with other farms as the other systems (see more below).

Currently there is only one company offering a solution for in-house slurry acidification.

JH Agro A/S

JH Agro has systems specifically designed for cattle and pig houses. There is also an adapted version of these for mink farms. The system for cattle slurry was originally designed for housing systems with relatively deep (~1.2 m) manure channels for collection and storage under slatted floors. However, it can be adapted to work in gravity drained cross-channels used in houses with open scraped passageways or scrapers below slatted floors. The in-house system can be installed into existing housing structures although it is often easiest to integrate the design of new livestock housing with the in-house system before building.

System components

The main components of the in-house SAT consist of an acid tank and a processing tank with mixer (Figure 4.1). Other components include pH-meter, pumps, valves, flow meters and a control panel which provides complete automation of the acidification and slurry pumping process. In addition, it is required to have an emergency shower and eye wash nearby in case of an accident. Concentrated sulfuric acid (96%) is used for all acidification treatments with this system.

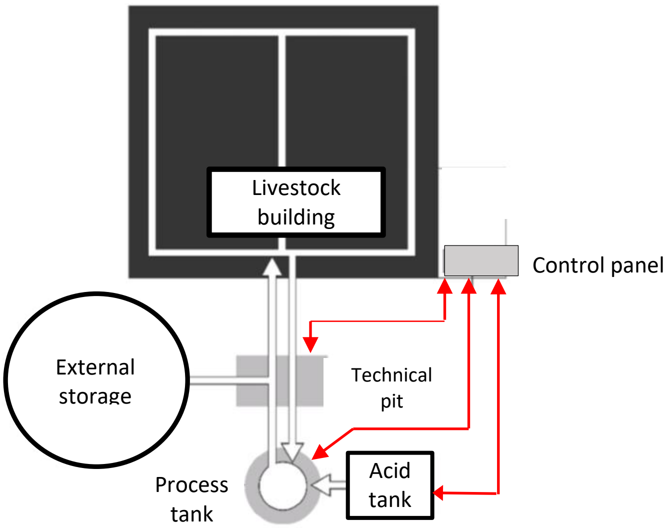

Figure 4.1. Scheme of in-house slurry acidification technology (figure is modified from JH Agro).

The acid tank is double-walled and built on a concrete foundation with an integrated collision protection system (Figure 4.2). The volume of the tank should cover between 6 and 12 months usage of acid. The acid tank should be located close to the processing tank, and easily accessible for filling from a lorry tanker. When the acid is running low, a bulk delivery of acid is ordered from an acid supplier. The supplier is responsible for filling the acid tank, so the farmer never has to handle the acid.

Figure 4.2. Acid tank based on concrete platform outside a pig house.

The process tank is made of concrete and mixers are made from acid resistant stainless steel. The dimensions of the process tank, mixer and pumps are individually dimensioned for the specific situation.

Treatment process

The slurry from the animal house is automatically pumped to the process tank one or more times a day, depending on needs. Here the pH is measured and acid is added to reduce the pH to 5.5. After treatment, part of the slurry is pumped back into the animal house and the excess slurry is pumped to the external storage. This process normally takes about 20-45 minutes. In sectioned pig houses, individual sections will be treated this way sequentially. Since the fresh manure from the animals falls into already acidified manure under the slatted floors, there is no problem with foaming during the acidification process. A dosing rate of approximately 5 kg sulfuric acid per tonne slurry in commonly expected in Denmark (Kurt West, Personal communication).

Because the manure under slatted floors in the house is acidified, the air quality within the house is greatly improved. Since the acidified slurry under the floors has been treated multiple times, the buffer system is essentially neutralized, and the pH remains stable throughout the storage period.

Initialization of the process

Acidification of the slurry at start-ups of newly installed in-house systems must be done gradually by lowering the slurry pH by no more than 0.05 units per day. The process can take several weeks and is necessary to assure that uncontrolled foaming does not occur in the process tank or in the house. Acid consumption during system start-up can be higher than under normal operation conditions since concrete can also have a buffering on pH initially (Kurt West, Personal communication).

4.2. In-storage

In-storage SATs acidify slurry in the storage. The most commonly practiced in-storage acidification in Denmark is slurry acidification just before the slurry is spread and therefore there are no benefits of the acidification during the main storage period. There are two manufacturers that make systems for in-storage acidification and both are modified slurry mixers that add acid to the slurry during the mixing process.

More recently, JH Agro has modified a version of their in-house system that acidifies all slurry sent to the storage, so the benefits of acidification are achieved during the entire storage period. Since the pH of the acidified slurry must be stable for the entire storage period, we call this in-storage, long-term acidification.

All in-storage systems use concentrated sulfuric acid (96%) for the acidification treatment.

4.2.1. In-storage, before spreading

Advantages

Since acidified slurry is not stored but spread directly after acidification, it is not necessary to lower the pH to the same level as with in-house acidification and reduces the amount of acid that is needed. These short-term in-storage SATs are mobile systems, easily transportable and can acidify a large quantity of slurry in a short time. This makes these SATs ideal for agricultural contractors so they can offer acidification services to many customers and thereby spread out the investment costs. The acidified slurry can also be spread with any available slurry spreading equipment, unlike with the in-field SATs (see in-field description below).

Disadvantages

When lowering the pH in slurry during acidification, bicarbonate components in slurry are converted to carbon dioxide which bubbles to the surface and produces foam. Because of the foaming, there must be free space in the storage to assure the foaming does not spill over during the treatment. A height of 0.5 to 1 m is commonly recommended. Different slurries tend to produce different amounts of foam. Typically, the foam settles relatively quickly but, in some cases, it can be persistent for longer periods. This foaming is one of the main constraints of the in-storage SATs.

Another constraint with short-term in-storage SATs is that the slurry pH buffer system increases the pH after the initial treatment and this buffering shortens the time available to utilize the effectiveness of acidification. In Denmark, when using this method to comply with regulations for spreading slurry, the pH must be reduced to 6.0 and then spread within 24 hours. If it is not all spread in 24 hours, the pH must be measured again and the slurry re-acidified if the pH has increased above 6.0. Alternatively, the pH can be reduced to pH 5.5 and then 21 days are available for spreading the slurry. After 21 days the pH must be measured again, and the pH reduced again to either a pH of 6.0 for an additional 24-hour window or 5.5 for 21 more days.

If acidification occurs just before spreading, there is no effect of the in-storage SAT on ammonia emission from storage.

There are two different manufacturers of mixers with acid addition described below.

Harsø Maskiner A/S

The Harsø SAT consists of their acid delivery system which can be integrated with either their 10 inches (about 0.25 m diameter) Compact slurry pump or their 12 inches Jetmixer slurry pump. The Compact pump can easily mix, acidify and empty storages up to 6000 m^3 and the pump capacity is up to 30 m^3 per minute. It can be fitted to work with extra deep storages and can include a flow meter and automatic tractor and pump controls (Figure 4.3).

The “Jetmixer” is a newly developed hydraulic turbine pump with a mixing capacity between 50-100 m^3 per minute. The manufacturers claim that in heavy foaming situations, the turbine mixer can be raised into the foam to effectively help break the foam bubbles while maintaining the mixing and acidification process.

Figure 4.3. The Harsø Compact pump and slurry acidification system. In the foreground is a typical IBC tank used for acid storage. Photo by Harsø Maskiner.

System components

The acid delivery system includes a specialized ejector that is fitted on the pump of choice. An acid nozzle is integrated into the beginning of the ejector for mixing the acid with the slurry. Other components include a check-valve, and a suction hose end that is inserted into an IBC (Intermediate Bulk Container, see Figure 4.3) acid tank (Figure 4.4). Due to the vacuum created at the acid nozzle in the ejector, acid is siphoned (max 3 meter suction head) from the tanks without the use of a pump.

A pH-meter is mounted on the pump to monitor the acidification process. Full body safety gear is necessary during operation. The system also includes a water tank for showering in case of an accident. The water can be used to flush the system after use.

Treatment process

The system pumps slurry from the bottom of the tank and out through the mixer nozzle at the surface of the tank. The negative pressure of the pumped slurry past the ejector effectively sucks the acid from the freestanding IBC tank, through the mixer nozzle and into the slurry. The treatment capacity is 100 litres of acid per minute.

Using IBC tanks for delivering the acid offers logistical flexibility during acidification however it also puts greater responsibility on the farmer/operator for maintaining safety.

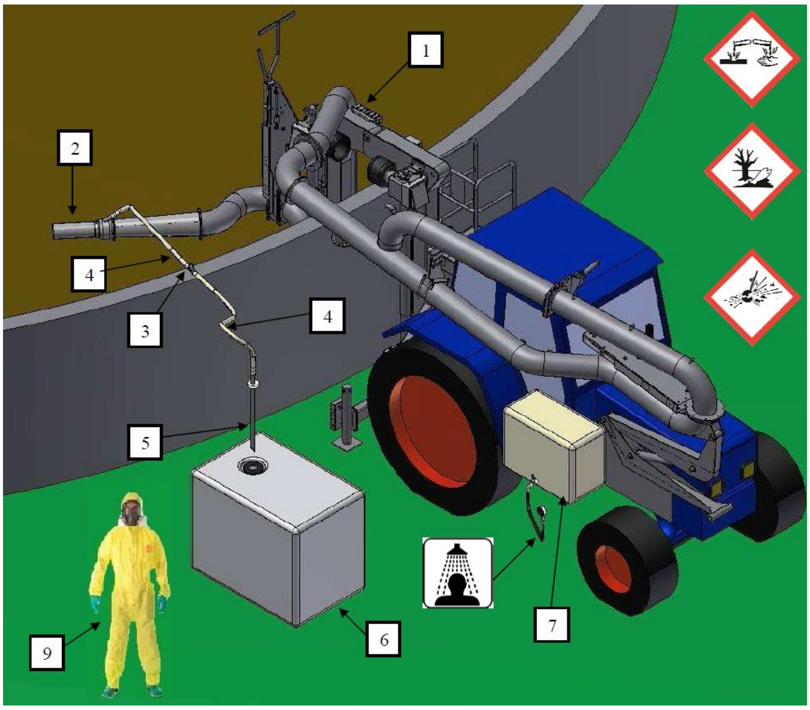

Figure 4.4. 1) Slurry pump with mixer nozzle, 2) ejector, 3) check valve, 4) suction hose, 5) suction end, 6) container with acid, 7) water tank for rinsing and by accident, 8) pH meter, 9) safety equipment/clothing. Figure by Harsø Maskiner.

Ørum Smeden

The Ørum TF-12 acid delivery system can be mounted on either the Ørum GMD 7500 or the GMD 8600 tractor driven propeller slurry mixers. The 7500 has a 7.5 meter mixing arm with a capacity for 3-4000 m^3 storage tanks and the 8600 has an 8.5 meter mixing arm with a capacity for 5-6000 m^3 storage tanks.

System components

The TF-12 consists of high grade stainless steel nozzle system (Figure 4.5) and hoses that connect it to the acid delivery tanker. A pH-meter is mounted to the mixer to monitor the acidification process. There is also a water tank with shower for the tractors front mount in case of an emergency. The pump on the acid delivery tanker is used to dose the acid during slurry mixing.

Treatment process

The tractor driven propeller mixer is used to mix the slurry while the driver of the acid delivery tanker controls the pumping of acid into the slurry (Figure 4.6).

Only the acid provider handles acid and controls the pumping process. The farmer does not have any contact with the acid but only is responsible for operating the propeller mixer and reading the pH meter. Since the acid pumping is done by the delivery driver, it is critical that the driver has experience with how to effectively acidify large volumes, so the foaming does not become an issue. If foaming is an issue, the extra time the driver needs to stay on site to complete the process will increase costs.

When the tanker leaves the farm, there is no longer any risk from stored acid on the farm.

Figure 4.5. Acid delivery system of the Ørum TF-12 slurry acidification system. Photo by Ørum Smeden.

Figure 4.6. The Ørum SAT acidifying slurry in a concrete storage tank.
Photo by Ørum Smeden.

4.2.2. In-storage, long term

Currently there is only one company with a solution for long-term in-storage slurry acidification and that is JH Agro. The previously described in-storage SATs are not used in DK for lon-term acidification of slurry during storage.

Advantages

The main advantage of the long-term in-storage system is that it reduces ammonia emissions from the entire slurry handling chain after the animal house. There is no need for a roof over the slurry storage. The in-house system also offers totally automatic slurry handling and acidification treatment, so the farmer does not need to handle acid.

Disadvantages

The main disadvantage of the in-house system is that it has a higher use of acid than the short-term system since the buffer system must be neutralized in order to stabilize the pH during the entire storage period.

JH Agro A/S

The long-term in-storage acidification system is essentially a modified and simplified version of their in-house system. It treats slurry in a process tank just outside of the animal house; but instead of pumping it back into the animal house it is all pumped directly to the storage tank or lagoon. Less valves and pumps are needed compared to the in-house system, which makes it is easier to install in existing facilities. However, the processing tank is larger than needed for in-house installations and should have a capacity of between 7-10 days of slurry production. In many cases, existing pumping pits outside animal houses may suffice in capacity to function as the processing tank.

Acidification treatment occurs daily to the target pH 5.5 and when the tank is full, part of the contents are pumped to storage. This ensures that slurry is treated multiple times which is needed to neutralize the slurry buffer system, so the pH is stable during storage. Also, this method of acidification eliminates foaming problems (Kurt West, Personal communication).

4.3. In-field

In-field slurry acidification takes place in a mixer installed on the slurry tanker, located just before the distributer to the application hoses. In-field systems can be fitted to many new or existing tractors and slurry tankers and were designed in Denmark to be used with typical band spreading trailing hose booms.

Advantages

Since slurry is acidified during spreading, the acidified slurry will have infiltrated into the ground before the buffer system can effectively raise the pH again. Since buffering is not an issue, it is only necessary to lower the pH to 6.4 which has been shown to reduce ammonia emissions from band spreading with trailing hose applicators by 50% (VERA, 2012). Since the target pH is higher than for both in-storage and in-fields SATs, the amount of acid used in the treatment process can be considerably less. Another major advantage of the in-field SAT is the flexibility to use it only when needed. For example, if the weather is perfect for spreading slurry (i.e., cool and no wind, maybe rain coming soon) then maybe it is not necessary to acidify. However, if it is bad weather for spreading (windy and warm) then the acidification system can be turned on.

In-field SATs are also mobile systems, easily transportable and can acidify a large quantity of slurry in a short time. This makes in-field SATs ideal for agricultural contractors, so they can offer acidification services to many customers and spread out the investment costs.

Disadvantages

The main disadvantage of the in-field systems is that only tractors and tankers fitted with the in-field SAT will be able to spread acidified slurry. So, if multiple tankers are being used to spread slurry at the same time, only those with the in-field system installed will be able to acidify the slurry.

The in-field systems in general are dimensioned for large slurry tankers (20+ m^3) and tractors with at least 230 hp and a front linkage lifting capacity of 4500 kg. This could of course be considered both an advantage and a disadvantage depending on how you are looking at it.

There are two different manufacturers of in-field SATs which are described below.

Biocover A/S

The SyreN system was designed by Biocover from the ground up as a system for treating slurry to reduce ammonia emissions as effectively as injection techniques, however, with a better profitability. Concentrated sulfuric acid (96%) is used for all acidification treatments with this system.

System components

The SyreN acidification system consists essentially of a front cage system with acid tank and pump, an injector, a mixer, a pH-meter and a control unit (Figure 4.7).

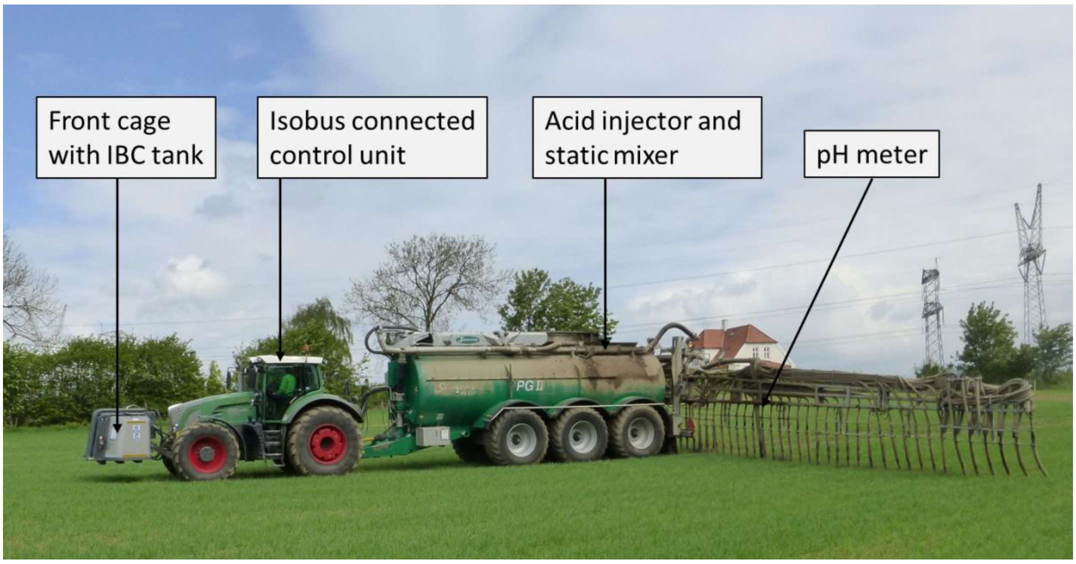

Figure 4.7. Overview of the SyreN slurry acidification unit by Biocover.

The front cage system is mounted on the tractors front lift and made of reinforced steel which crash resistant. The cage is made to protect the acid tank which for SyreN is an easily replaceable IBC container. The cage opens for easy loading and unloading of the IBC tank (Figure 4.8) so it is not necessary to pump acid between the systems tank and the acid storage on the farm. The IBC tank is connected with standard quick connectors to minimize risks of coming in contact with acid when changing tanks. The cage comes standard fitted with lights, video cameras and required safety equipment. There is an extra tank for additional additives that can be dosed with slurry spreading if desired, and another tank for water to rinse the system or use in an emergency. The front cage also houses the hydraulically driven stainless-steel displacement acid pump.

Acid is pumped to the injector attached on a static mixer mounted at the rear of the tanker. The mixer has fixed wings that effectively mix the slurry and acid together. After the mixer the acidified slurry goes directly to the distributor, through the hoses and onto the field. As the acidified slurry leaves the hoses, it passes a pH-meter which monitors and controls the system.

Figure 4.8. The front cage system of SyreN, open during loading of a partially filled IBC tank. The side water tank is also visible. Photo by Biocover.

The computer controller operates through the tractors Isobus terminal, and a data handling system is connected to a built in GPS unit on the front cage. All operating data parameters are logged automatically including slurry dosage rate, acid addition rate, pH, location, speed etc.

Treatment process

With the SyreN system there are two modes of treatment:

1) If conserving nitrogen in the slurry is the objective, set a target pH for acidification on the control panel and let the system dose the amount of acid necessary to achieve the target pH. In Denmark, if SyreN is used to fulfil required use of best available technologies to reduce ammonia emissions, a maximum pH of 6.4 is allowable to conform to regulations.

2) If regulations do not require emission reduction measures and for instance weather conditions are ideal for spreading slurry with little losses, set a defined acid dosage rate to be maintained throughout spreading regardless of pH. This could be for example to provide the amount of sulfuric acid as an S fertilizer.

Kyndestoft Maskinfabrik

Kyndestoft in-field SAT is based on their liquid fertilizer equipment that they had developed and sold for years. It is also possible to order the system with up to three separate chambers in the tank which can be used for different additives or liquid fertilizers.

The Kyndestoft acidification system uses 50% sulfuric acid for acidification treatment. They use 50% sulfuric acid because it is less dangerous than 96% in case of an accident, however, 50% sulfuric acid is more corrosive to metal than 96% so the design of all components have been specified for this. This system can also be used with liquid NPK fertilizers instead of acid, or together with acid if the front tank is ordered with separate compartments.

System components

Kyndestoft's acidification system consists of an acid tank, pump, injector, pH meter and control unit (Figure 4.9). Their traditional system is a front mounted fiberglass tank inside a reinforced steel cage. The tank is available in 1000, 1500 or 2000 litre sizes and attaches to the front 3-point hitch. Lights are fitted on the cage. An acid pump is installed behind the tank and can be run in reverse to fill the tank from IBC containers.

Figure 4.9. Kyndestoft front-tank slurry acidification system.

The acid injector is installed on the slurry outlet pipe at the rear of the slurry tank just before the distributor to the trailing hoses. A pH-meter is installed in one of the trailing hoses to monitor the process. A data logging system can be added on to the system.

Figure 4.10. Kyndestoft newly released side mounted slurry acidification system. Photo and drawing by Kyndestoft Maskin.

Kyndestoft released a new acidification system in 2016 that has the acid tanks and pump mounted on the sides of the slurry tank, and nothing on the front of the tractor (Figure 4.10). Aside from that it operates in the same way except that there are 2 acid tanks that need to be filled.

Treatment process

Acid dosage rates are initially fixed at start up according to entered slurry type (cattle, pig or digestate). These amounts are pre-programmed according to typical amounts needed under Danish conditions to reduce the specific slurry to pH to 6.0 but can be modified by the user to reflect common local conditions. After starting up, the pH is monitored, and the acid dosing can be easily adjusted up or down, but there is no controlling system that doses after a specified pH target. Because the acid is only 50% sulfuric acid, a greater total volume will be needed to lower the pH.

In Denmark, when using Kyndestoft's acidification system to comply with regulations for ammonia emission reduction, slurry pH must be lowered to 6.0.

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Personal communications

Kurt West, Acidification expert at JH Agro.

5. Overview of manure handling systems in countries around the Baltic Sea

Justin Casimir – RISE

The currently available SATs presented above were developed in Denmark for Danish conditions. The SATs were developed primarily for dairy cow and pig production systems and all require manure handling as slurry and will not work with solid or semi-solid manure. This chapter is an initial overview of the animal production and manure handling systems in countries around the Baltic Sea, with the aim to help evaluate the potential to implement these SATs with currently existing manure handling systems in each country. The manure management systems include animal type, housing types, storage systems, and spreading techniques. Specific definitions can be found in Appendix 1.

The results presented here are based on statistics from the Eurostat database. The advantage using this database is that it is easy to compare between countries, however, the statistics available are often older and less detailed than those available at the national level. A more detailed analysis for specific countries is reported in Appendix 2.

5.1. Livestock production

There is a clear predominance of cattle and pig production in terms of total livestock production in all countries in the Baltic Sea Region (Figure not shown). Poultry is the next most significant livestock type in the region, however, since very little of this poultry manure is handled as slurry (Sindhöj & Rodhe, 2013) it is excluded here. There is a relatively large difference in terms of livestock production between countries in the Baltic Sea Region (Figure 5.1). Germany has by far the highest livestock numbers, followed by Poland and then Denmark. However, only a portion of the production in Germany is within the Baltic Sea drainage basin, but this specific data was difficult to find so data for the entire country is presented.

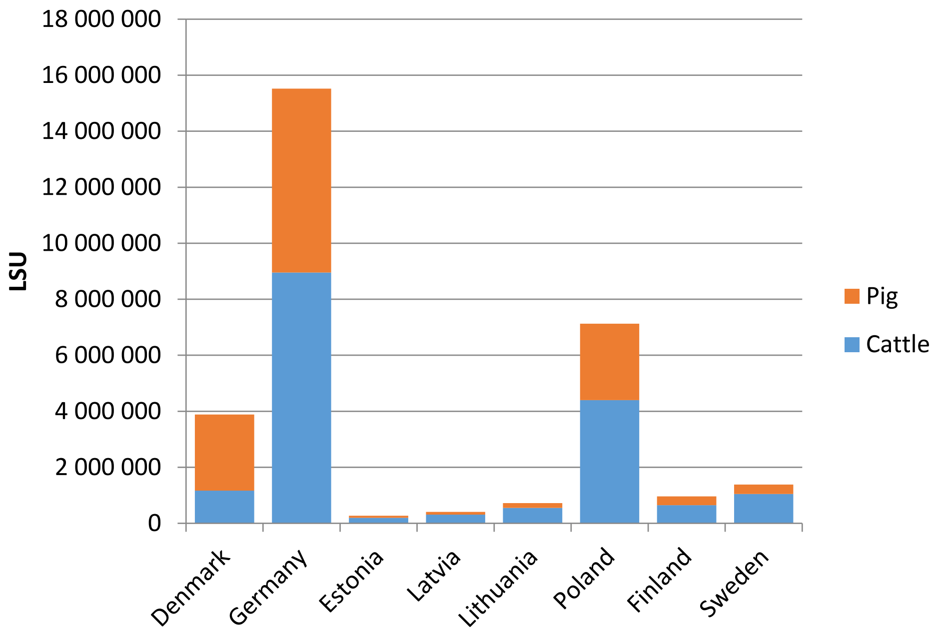

Figure 5.1. Livestock unit number (LSU) in countries in the BSR (Eurostat, 2013).

5.2 Housing systems and manure management

Regarding the type of housing, different systems may be used within the same farm. For instance, dairy farms may have slurry manure handling for the milking cows while other groups (dry cows, heifers etc.) are housed with solid manure management. Therefore, the housing types are presented in terms of the relative portion of total number of places available in each country.

Definitions of the different kind of housing systems are found in Appendix 1.

Cattle

There is a large difference in housing type and manure handling for cattle in the Baltic Sea countries (Figure 5.2).

The housing systems with slurry manure handling, both “loose housing” and “stanchion tied stables”, can more than likely be readily applicable for implementing SATs. In percentage of total number of places in housing types with only slurry handling, Germany has 62%, Denmark 59%, Finland 48%, Sweden 33%, Estonia 20%, Lithuania 9%, Latvia 6% and Poland less than 4%.

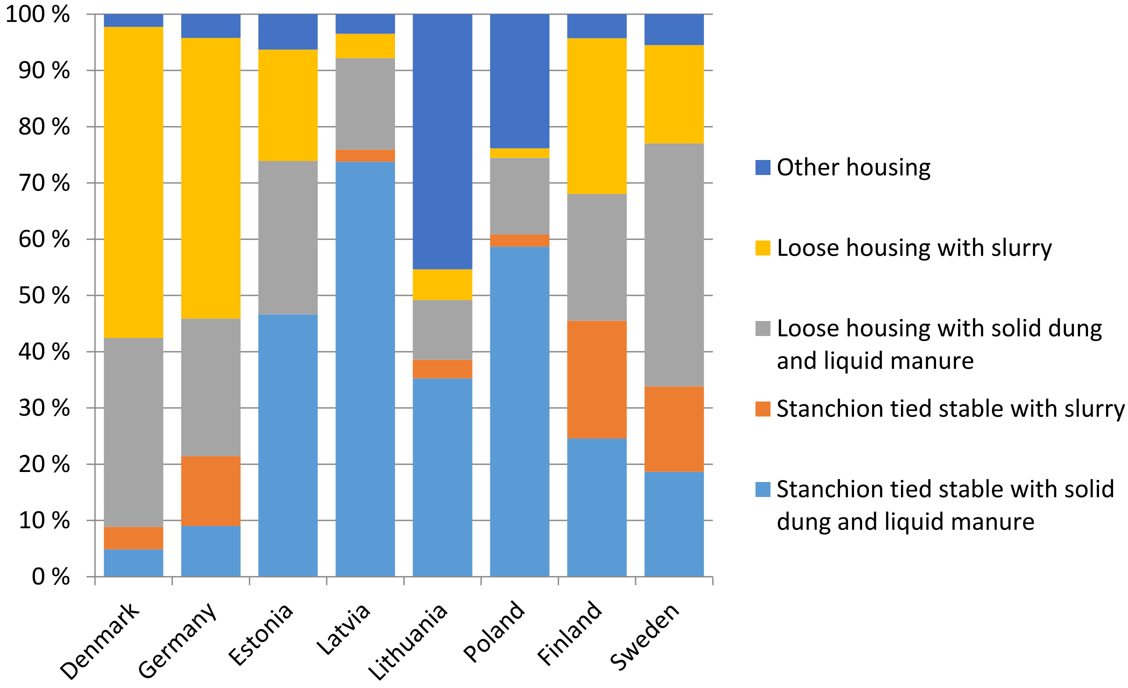

Figure 5.2. Cattle housing types in BSR countries, in % of places (Eurostat, 2010a).

For the housing types with "solid dung and liquid manure", it is only the liquid manure portion that is applicable for SATs. Unfortunately, the relative portion of "liquid manure" produced in this housing type cannot be determined here.

All BSR countries have some slurry and liquid manure handling so all countries could implement SATs on at least a portion of their cattle production. Even in Poland where the percentage of places on slurry is relatively low, in absolute numbers it is almost 275,000 places which is quite significant none the less.

Pig

Between 60-95% of pigs in each country are kept on slatted floors, either partially slatted or completely slatted (Figure 5.3). The exception is Poland where just over 22% of the farms have slatted floors and over 55% fall under the "other" category, which is generally a combination of deep litter (sows before farrowing) and slurry channels systems on slated floors (National Agricultural Census, 2010). Housing systems with slatted floor generally handle their manure as slurry, and therefore, there is a great potential in pig farms in the BSR for the implementation of SATs.

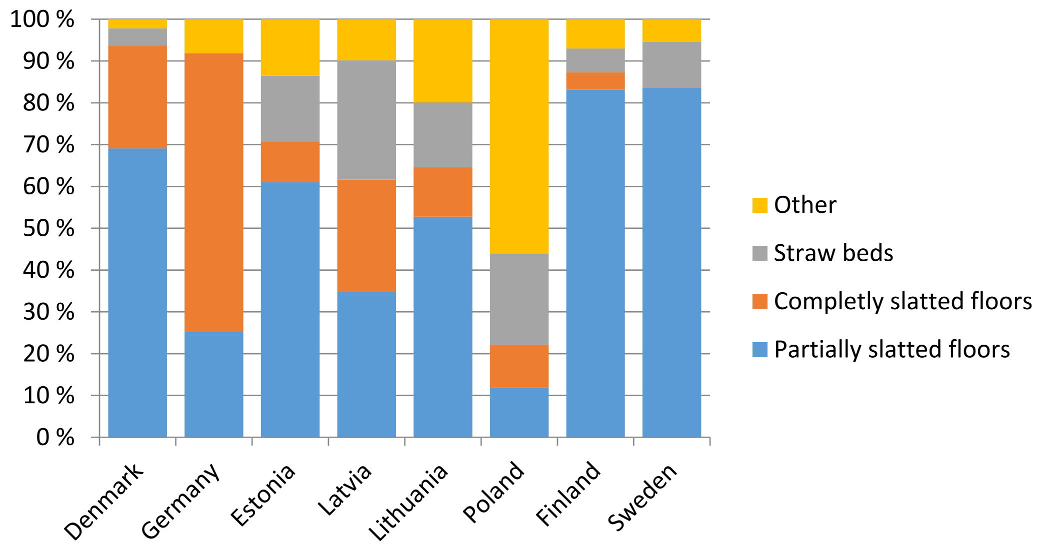

Figure 5.3. Pig housing in different countries, in % places (Eurostat 2010b).

5.3 Slurry storage systems

The uncertainties in summarizing the total amount of slurry and liquid manure from the housing system statistics are clarified by the statistics on manure storage systems (Figure 5.4). Figure 5.4 clearly shows that in total, slurry and liquid manure are the dominating storage systems used in all BSR countries. This indicates strong potential for implementing in-storage or in-field SATs in all countries.

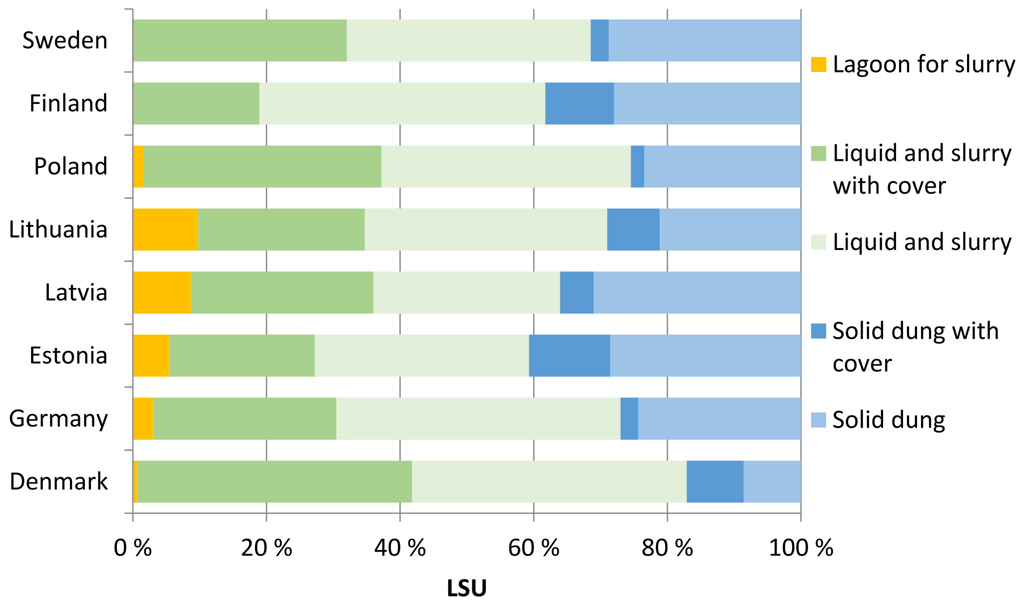

Figure 5.4. Distribution of the manure storage systems in term of percent of total LSU for that country (Eurostat, 2010c).

5.4 Slurry spreading systems

Slurry injection spreading techniques have long been shown to be effective at reducing ammonia emissions compared to band spreading with trailing hoses or broadcast spreading (Rodhe & Etana, 2005; Smith et al., 2000), however, there is comparatively little slurry spread by injection compared to other methods (Table 5.1). Estonia is the exception to this where 60% of all slurry in pig and cattle farms, which belong in group of intensive rearing of cattle and pigs according the Industrial Emissions Directive (IED), is spread by injection, due largely to strict environmental regulations. In Denmark the portion spread by injection would be much higher except that acidification is considered equivalent and more often used instead.

Using SATs together with injection techniques would be redundant; however, using SATs with trailing hoses could effectively replace the use of injection techniques since they have been shown as equally effective in terms of reducing ammonia emissions (Seidel et al., 2017). This is the case in Denmark where there are requirements to use either injection techniques or SATs to reduce ammonia emission and the predominated method chosen is SATs.

Both broadcast and trailing hose spreading techniques have the potential to benefit from SATs. Currently SATs have only been used with trailing hose techniques; however, using it together with broadcast techniques would be a way to greatly improve the effectiveness of broadcast spreading. This could make a big difference in countries that still rely heavily on broadcast methods for spreading slurry such as Germany and Latvia.

Table 5.1. Percentage of slurry spread by various technics in the Baltic Sea Region. For more details and references, see national chapters in Appendix 2

Country	Broadcast spreading	Band spreading	Injection
Denmark[a]	0	85[d]	15
Estonia	5	35	60
Finland[a]	35	34	31
Germany	70	22	8
Latvia	60	30	10
Lithuania[b]			
Poland[a]			
Sweden[c]	28[c]	68[c]	4

[a] Estimation made by national experts
[b] No statistics available
[c] According to Statistics Sweden (2014), 24% of the surface spread manure (solid and liquid) is incorporated directly, 11% within 4 hours, and 9% within 24 hours after spreading.
[d] Including 20% acidified slurry

References to chapter 5

Eurostat, 2010a. Database available at: http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=ef_pmhouscatlaa&lang=en

Eurostat, 2010b. Database: ef_pmhouspigec available at: http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=ef_pmhouspigec&lang=en

Eurostat, 2010c. Database ef_pmmanstolsu available at: http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=ef_pmmanstolsu&lang=en

Eurostat, 2013. Database available at: http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=ef_olslsuft&lang=en

National Agricultural Census, 2010. ISBN: 978-83-7027-485-6, pp. 139. Available at: http://stat.gov.pl/obszary-tematyczne/rolnictwo-lesnictwo/psr-2010/powszechny-spis-rolny-2010-zwierzeta-gospodarskie-i-wybrane-elementy-metod-produkcji-zwierzecej,5,1.html

Seidel, A., A. Pacholski, T. Nyord, A. Vestergaard, I. Pahlmann, A. Herrmann, H. Kage. 2017. Effects of acidification and injection of pasture applied cattle slurry on ammonia losses, N2O emissions and crop uptake. Agriculture, Ecosystems & Environement (247), 23-32.

6. Conditions for implementation of SATs on a national level

In this chapter, representative/s from each country gave their expert judgement on how to implement SATs in their country. In this work, national networks including for example manufactories of slurry equipment, advisor service, and farmers have been consulted. The national experts have also described the relevant slurry handling systems in their country as a background to this analysis (see Appendix 2).

For the most common manure handling systems in use, the possibility and relevance of implementing the three SAT's are analysed as well as potential bottlenecks that might arise during implementation. Suggested implementations could differ from solutions found in Denmark, when taken into account the specific country conditions. For Denmark, which already has implemented SAT, aspects and experiences on implementations are presented.

For general descriptions of SATs and how they are used in Denmark, see Chapter 4.

6.1 Estonia

Kalvi Tamm, Raivo Vettik, Jaanus Siim, and Taavi Võsa, ECRI

In general

Estonian agriculture has the infrastructures and systems needed to implement SATs as most of the manure is handled as slurry, especially on larger farms. Today, there are at least three actors who could supply acid to farms, but some farmers buy acid also from abroad (from Lithuania, for example). Today the primary reason to use sulfuric acid is to supply plants with S fertilizer for favourable price.

In-house

Acidification of the slurry in the barn is not likely in existing animal houses in Estonia since removing of slurry from the barn is done daily with scraper systems and cross channels. The slurry is not circulated in channels and therefore it may is not suggestable to acidify the slurry in the channels. However, stationary acidification systems could instead be used for the slurry leaving the stable. For stationary acidification systems in Estonia, the minimum animal number for profitable slurry acidification should be determined with economic analyses.

In-storage, long term

In Estonia it is common with pumping pits between the stable and the slurry tanks. The pit could be used as a buffer tank to acidify the slurry before being stored in the main tank(s) as the system described in section 4.2.2. This gives the effect for the whole storage period plus spreading. Stationary systems to be used for continuously acidification are applied on larger farms.

In-storage, before spreading

Mobile acidification equipment could be suitable for acidifying the slurry in storage during mixing just before spreading. Such equipment could be invested in by the farmer. Mobile equipment implies that the cost can be shared if the same equipment is used on several farms. The service could also be hired from a contractor, under the conditions that there is a contractor in the neighbourhood providing this service. In Denmark, after lowering the slurry pH to <6, spreading should occur within 24 hours according to the rules. As the spreading season last for longer times, this could mean that the contractor needs to be hired for a period of several weeks per year. Economical calculations are needed to compare which solution is most profitable for individual farms. When hiring the acidification service, the technology will be available also for smaller farms. Also, if surplus storage volume is needed because of foaming when adding acid, it may make this alternative non-profitable compared to the other two alternatives.

In-field

In-field technic is technically easy to implement in Estonia, either that the farmers hire the service from nearby contractors or mount it on existing tankers. Today, quite a lot of the slurry is already spread by contractors. When hiring the service of acidification, the technology will be available also for smaller farms.

6.2 Finland

Sari Peltonen, Association of ProAgria Centres

In general

In Finland, the potential for implementation of SAT is relevant because remarkable share of the manure is handled as slurry, especially in larger farms. However, the technology for using acid is not developed in addition to that handling of acid in farms has big safety risks. Also, clear benefits for using acid needs still to be clarified as well as the costs.

In-house

Acidification of the slurry in houses could be difficult in Finland because of the safety issues and risks for harmful gases affecting animals and people. However, stationary acidification systems can possibly be used for the slurry leaving the stable in transient containers in bigger farms.

In-storage, long term

In Finland, slurry is pumped from the transient containers form the stable to the main slurry storage tanks. If there are pumping pits between the stable and the slurry tanks, the pit could be used as a buffer tank to acidify the slurry before being stored in the main tank.

In-storage, before spreading

Acidification can be done in storage tank during mixing just before spreading. It needs a pumping system that could be invested by the farmer. The same equipment can be used (rented) by several farms. The acidification can also be done by a contractor who is also spreading the slurry. Foaming which can increase the volume significantly should be taken into account. Also, acidification can take lots of time as slurry storage tanks are big in volumes.

In-field

Acidification can be done directly in slurry spreading tank just before spreading. It needs a pumping system that could be invested by the farmer. The same equipment can be used (rented) by several farms. The acidification can also be done by a contractor who is also spreading the slurry. Foaming which can increase the volume significantly should be taken in to account. Also, acidification can take lots of time.

In-field acidification system SyreN is not any more available in Finland. During 2014-2015 this technique was tested experimentally in Finland but since that the contractor stopped the business because of problems in economy. SyreN or corresponding systems can only be invested in Finland if enough potential users exist. In-field acidification is naturally a work of contractors, and it is estimated that half of the slurry is already spread by contractors in Finland.

It can be roughly estimated that if about 15% of dairy farms in Finland would use SAT, that means 1 200 dairy farms and 1.94 Million m^3 of slurry. If about 20% of pig farms would use SAT, that means 240 pig farms and 720 000 m^3 of slurry. Totally this means 2.66 Million m^3 of slurry per year under SAT and corresponds 25% of total slurry produced per year in Finland.

6.3 Germany

Michael Zacharias, LLUR

In general

More than half of the farmers fertilizes with liquid manure in Germany.

About 166.000 agricultural holdings (total 280.800 (Source: Federal Statistical Office, 2015)) have in 2010 fertilized on her agricultural used area with liquid manure and liquid digestate from the biogas plants. This was 55% of all agricultural holdings in Germany, which farmed agricultural lands in the year 2010 (Federal Statistical Office, 2016).

In the course of the new legal regulations a big chance and also a need exists to implement the SATs in Germany.

In-house

The acidification of liquid manure in the house is in Germany rather no option, because the stable buildings are not constructed for an acidification. Besides, the demands for the concrete would lead to a bigger expense of the single farmers. Here to implement the SATs is rather unrealistic.

In-storage, before spreading

The storage capacity of liquid manure is not bigger on many farms than this legally prescribed minimum of six months. For acidifying in the storage a considerably bigger storage volume is required. No farmer would invest this; also the regulations are attached for the construction of bigger liquid manure storage to conditions. There must be a need to build such storage; this would be given if the farmers acquire more productive livestock. Possibly it would be an option for biogas plants if the suitable legal basic conditions are given.

In-field acidification during spreading

In-field technic is technically not easy to implement in Germany, because the rules for using and transporting acid are strong. We need a new system with for the in-field technic and then it will be cost too much money for a single farmer. The best option is that the farmers hire the service from nearby contractors. In Germany they are mostly use their own broadcast spreading technic, the costs are cheap for this system. At the 31.03.2017 in Germany adopt a new fertilization decree (DüV) with strictly rules for fertilization. The use broadcast spreading technic will be forbidden as from the 1st February 2020 on arable land and as from the 1st February 2025 on grassland. The band spreading technic costs more and more farmers will use more nearby contractors possibly.

6.4 Latvia

Janis Kazotnieks, LRATCL
Raimonds Jakovickis and Inga Berzina, FP

In general

There are possibilities to implement SATs in Latvia, as more than half of the manure is handled as slurry, in first hand on larger farms. However, the necessary infrastructure and systems are present only in few larger farms. Today, there are acid suppliers present, so, there would be no problems with transportation.

Economical calculations are needed to compare which solution is most profitable for individual farms.

In-house

Not applicable in the first hand in Latvia.

In-storage, long term

Practically is not possible as the existing storage facilities are not built to adjust SAT technologies usage. But for new storage building the farmers should have economic justification if it is more efficient type then built the separate storage place.

In-storage, before spreading

Mobile acidification equipment is also possible for acidifying the slurry in storage during mixing just before spreading. Mobile equipment can be shared if the same equipment is used on several farms. The service could also be hired from a contractor, under the conditions that there is a contractor nearby providing it.

In-field acidification during spreading

In-field acidification during spreading is the most suitable to implement in Latvia. Farmers could jointly invest in the equipment and use it more efficient, or there is great potential for contractors.

6.5 Lithuania

Rimas Magyla, LAAS

In general

Slurry acidification technology makes it possible to reduce nitrogen losses from manure thus paving the way for more efficient use of manure and saving of mineral fertilisers. Therefore, this system is relevant for pig and dairy farms in terms of liquid manure handling.

Certain pig complexes sell some part of slurry to farmers, i.e. slurry is used to fertilise soils of other farms and therefore, an interest in slurry acidification technology may be higher among farms which use liquid manure on their land.

On the other hand, large-scale livestock farms in an effort to reduce its cost of production, use available means in more optimal ways and try to introduce advanced technologies, thus slurry acidification technology can serve as well as a mean of manure use efficiency and saving of mineral fertilisers. All the more, that large-scale livestock farms feel ever increasing public pressure regarding proper utilisation of manure – especially those that are located in close proximity to larger settlements due to olfactory reasons.

In-house

Acidification of manure inside barns might not be an acceptable technology due to excessive risks associated with the use of hazardous substances in closed premises.

In-storage, long term

Stationary manure acidification systems between a barn and manure reservoir can be installed, for example, in the section of manure pumping into the reservoir.

However, the implementation of this system is more likely on large-scale dairy and pig farms, which use its liquid manure/slurry for applying on their own soils.

In-storage, before spreading

Mobile manure acidification systems may be applied in a liquid manure reservoir before transporting it to spread in fields. This may be either a farmer’s investment or that of a contractor, who could provide such a service. If manure acidification operations were performed by contractors, manure acidification technology could be made available to smaller farms. However, currently there is no demand and supply for such operations.

On the other hand, since much slurry is spread using old type manure broadcast spreading tankers, the manure acidification system would be acceptable in a slurry reservoir.

In-field

The fact that in Denmark this is the most widespread manure acidification technology suggests that in Lithuania it could be popular as well. This may be relevant for pig farms with several thousand pigs and over, as well as on dairy farms with over 500 cows, and those using manure for fertilisation of their own soils.

6.6 Poland

Kamila Mazur, Witold Wardal and Bogdan Lochowski, ITP

In general

It could be stated, that slurry systems in tied-up cattle barns are not suitable, because small amounts of slurry are obtained (only 2% of cattle is kept in fully slurry systems) and collected in small storages (most of cattle are pastured). With such background, SAT could be implemented only in fully “slurry” systems for cattle and pigs.

Non-littered livestock housing systems in Poland for dairy cattle, especially with robotization of milking treatment and modern buildings for slaughter pigs are good area for SATs implementing. Both techniques like “in-storage” and “in-field” could be implemented in cases, where we have collecting pit for slurry and main storage tank.

Anyway, there could be technical problems in implementing of SATs in case of some manure spreading applicators. For example companies like Joskin, Pichon offer application equipment which is not resistant on low slurry pH and corrosion may appear according to Polish firm representatives. There is the possibility to use plastic slurry tankers on spreader and one company offers such solution, in order to avoid corrosion. From the other side: the POMOT company offers the special steel containers for liquid and semi-liquid substrates, dedicated to pH from 1 up to 12.

In-house

Regarding in-house SAT, the implementation of this technique could be possible for cattle barns as well as in piggeries with deep slurry channels. In existing live-stock buildings, there might be necessity to rebuild. High investments costs because of complicated technical solutions will be necessary and implementation will likely depend on donations from government. It would likely be more relevant in newly built animal houses. In Poland the number of large scale pig farms is growing, and these would be ideal for implementing in-house SAT.

In-storage, long term

The majority of Polish manure storages are circular and they will be facilitation for technical possibility of slurry acidification. Anyhow, small effect will be observed, because the majority of slurry storages have a capacity enough for 4 months storage period (in winter season). On the other hand, also the quality of concrete of existing manure storages probably is not adjusted for low (5.5) slurry pH. Special additives to concrete should be foreseen. Only one company in Poland confirmed during consultations that their storages are adjusted to slurry pH even about 3.

In-storage, before spreading

"In storage" system characterizes simple construction, easy to move from one farm to the other and safe in utilization. The main part of the machinery is installed on three point tractor suspension unit and is powered from tractor PTO system. It consists from: frame, gearbox, slurry mixer, acid sprayer and pH meter. To provide slurry acidification process in the slurry tank, it is important to have agreement with sulfuric acid supplier, who delivers acid to the farm in a tanker equipped in acid pump. During acidification process mixer is immersed in the slurry and acid from the tanker is delivered directly to the area of acidification work. Thanks mixer rotation acid particulates can penetrate the slurry in a tank or lagoon. When slurry in a big tank will reach pH value equal about 6, the process is stopped. Acidified slurry can be transported in a tanker to the field and spread using different technology as: splash, injection or trailing hoses. It becomes more popular to buy and use machinery together, so this system also could be bought System of acidification in-storage is cheaper comparing to "in field" or "in house" and can be the most popular in Poland among all SATs.

In-field

Probably only big investors will be interested in "in-field" slurry implementing. These investors could be contractors for spreading to e.g. biogas stations owners. In Poland there is small amount of spreading contractors. The number of individual farmers with larger slurry production is still small, but increasing. There are 85 agricultural biogas stations, according last information from national register of these (National Register of Agricultural Biogas Producers 2017). The problem is in this, that splash broadcast spreading of slurry is most common practice of slurry application in Poland.

6.7 Sweden

Lena Rodhe & Erik Sindhöj, RISE

In general

Swedish agriculture has the infrastructures and manure handling systems needed to implement SATs as most of the manure is handled as slurry, especially on larger farms. It is presumed, that agricultural contractors would take the lead when introducing in-storage and in-field SATs, since they can spread out investment costs by acidifying more slurry than most individual farmers.

The acid suppliers in Sweden currently do not have experience dealing with farm-level acidification, but several of the companies here are international with locations in Denmark and therefor can acquire experience from colleges there.

Other issues could be safety regulations, where it must be clear for authorities and users how to implement and control safety in practice.

In-house

There is a long tradition in Sweden of building animal houses with shallow manure channels with frequent manure removal to meet regulations for ammonia and hydrogen sulphide concentrations in the housing environment. So traditionally, manure is not stored under slatted floors but is removed often to a storage outside the house, at least twice a day (see more in Appendix 2). This building technique is considered a best available technology (BAT) for reducing ammonia emissions from animal houses according to the Industrial Emissions Directive BAT list.

Flushing systems for mucking out from cattle and pig stables and manure storage under slatted floors have not been permitted in Sweden for the last 30 years. It is based on the risk of high concentrations of dangerous gases as hydrogen sulphide when slurry is mixed or pumped (Skarp, 1971). According to the directions SJVFS 2010:5 from the Board of Agriculture (SJV, 2010), animals may only be occasionally exposed to air concentrations above 0.5 ppm of hydrogen sulphide (H_2S). This direction is based on the regulations of animal protection (1988:539). According to the VERA certification of the in-housing system (JH Forsuring NH4+), increased H_2S concentration where observed when daily flushing of the manure took place during acidification treatment (ETA-Danmark, 2011). Even if the total H_2S emissions were significantly lower for the acidification system than the control (ETA-Danmark, 2011), the spikes of H_2S during daily pumping will make permit approval for in-house systems difficult.

Due to the commonly used building techniques for animal houses and regulations that steer permitting, installing an in-house SAT, as commonly used in Denmark, into an existing animal house is not likely. Since current building systems are already approved BAT for reducing ammonia emissions it is unclear if there would be a need, however, with some adaptions and/or reconstruction it could be possible.

The manure removal system in animal housing in Sweden is transport with scrapers from passageways or gutters below slatted floors into a deeper cross-channels leading to a pumping pit outside the barn. For these, the adapted version of the dairy in-house SAT where the slurry in the cross-channel is acidified could be a solution, and the pumping pit or the cross-channel itself could function as the processing tank.

For pigs, vacuum manure removal systems of the type shallow pit with pull plugs and frequent removal are the next most common system in Sweden. In-house SATs can usually be installed on a pull plug drainage system. However, it would depend on just how shallow the channels are built.

The easiest and probably most effective way to implement in-house SAT in Sweden would likely be for newly constructed animal houses that are designed specifically for the in-house system. However, permit approval might still be a challenge due to current regulations and the long tradition of building techniques in Sweden.

In-storage, long-term

In Sweden, both pig and cattle manure handling systems commonly have pumping pits between the livestock house and the long-term slurry storage. The pumping pit, depending on its capacity, could be used as the processing tank to acidify the slurry before being pumped to the main storage. Alternatively, an extra processing tank would need to be built. This would give the acidification effect for the whole storage period plus during spreading.

There are regulations that require slurry storage to be covered with a natural crust or other cover effective at reducing ammonia emissions (SJVFS 2015:21). Often a surface crust is formed naturally, meaning no costs for the farmers. Long-term acidification in-storage without a crust would produce about the same effect of reducing ammonia emissions, but it is possible the regulations would need amending before a permit for such a system would be approved.

For long-term acidification, the effects of acidified slurry on concrete could be an issue.

In-storage, before spreading

Mobile equipment that acidifies slurry directly in the storage tank could be suitable for acidifying the slurry in storage during mixing just before spreading. Such equipment could be invested in by the farmer. Mobile equipment implies that the cost can be shared if the same equipment is used on several farms. The service could also be hired from a contractor, under the conditions that there is a contractor nearby providing this service. This technique could be relatively easy to implement in Sweden. If agricultural contractors invest in these SATs, then slurry acidification will be available also for smaller farms. There is also the advantage that any available slurry spreading equipment could then be used to deliver the acidified slurry to the fields, including small tankers that could be used on small fields or when risks are high for soil compaction.

One constraint would be the needed empty space when acidifying in order to accommodate the foaming, since farms generally do not “over dimension” the capacity of their storage tank to that degree. However, this can be dealt with by first spreading some of the slurry when the storage is full, so there is enough buffer for the foaming, and then acidify the remaining slurry.

Another constraint is that when lowering the pH 6.0 the slurry should be spread within 24 hours due to pH buffering. As the spreading season lasts for longer times, this could result in having to hire the service multiple times per year or acidifying to 5.5 to lengthen the window for spreading. Both alternatives would increase the cost. Economical calculations are needed to compare which solution is most profitable for individual farms.

The Harsø system has the advantage of using the flexible IBC tanks for delivering acid and the simplicity of not needing an acid pump inject the acid into the slurry. The high capacity pumping capabilities of their systems might also come in handy for manure management on the farm, although most slurry tankers nowadays have a filling pump and crane and therefore this feature might not really be needed. The Ørum system, on the other hand, is a simple propeller mixer however it requires that acid is delivered from a tanker that will also pump the acid into the slurry during mixing. This means the acid delivery company has to be present during the entire time for acidification and in the event of excessive foaming could be awhile.

In-field

In-field SATs should be technically easy to implement in Sweden, either farmers hire the service from nearby contractors who have the technique, or they mount it on their own existing tankers. Today, quite a lot of the slurry is already spread by contractors, especially in the intensive agricultural areas of Sweden (small distance between farms and contractor station). Most slurry is spread with trailing hose applicators which the in-field SATs are designed for.

If agricultural contractors invest in these SATs, then slurry acidification will be available also for smaller farms. We estimate based on search on the Internet and telephone interviews, that there are about 30 contractors offering slurry spreading services (WP 6.1. report: Market potential analysis). In average, the contacted contractors owned 2.3 spreaders and spread about 50 thousand tonnes slurry yearly.

Since the in-field SATs are installed on the slurry tanker and a specific tractor, then only that system can acidify slurry while spreading. This might create logistical bottlenecks if the contractor only has one in-field SAT, or if the farmer uses more than one tanker to spread slurry. Another bottleneck that will limit implementation is that the in-field SATs currently available are designed for the large tankers with high capacity and will likely not work on small tankers without modification. They also require tractors with a minimum of 230 hp and a front linkage lifting capacity of 4500 kg. This requirement for large tanker and tractor could limit implementation in certain areas as well as increase the risk for soil compaction, which depending on the soils and local conditions could be a constraint to implement in-field.

6.8 Summary of potential for implementation of SATs in countries in the Baltic Sea Region

In general, all country partners concluded that SATs were relevant for agriculture in their country and that technically it should be possible to implement todays' commercially available SATs, however, some technical bottlenecks were found. Aside from technical bottlenecks, some economic and regulatory barriers for implementation were identified as well. While these are explored in more detail in other reports from the Baltic Slurry Acidification project, some have also been addressed here.

Apart from evaluating bottlenecks and barriers to implement SATs, the country experts (see Section 7 for author list) made judgements concerning likelihood of initial SAT implementation for each respective country. These judgements were made halfway based on the above stated criteria; however, it is possible these conclusions could change during the remaining course of the project and as more experience with implementation is achieved. See Table 6.1 for a summary of these country-level judgements.

The in-field technology was for most countries considered to have the greatest potential for implementing slurry acidification on a large scale. This was mainly due to the mobility of the system and its flexibility to easily adjust acid addition according to conditions when spreading slurry. The main technical bottleneck for implementation of in-field SATs is related to the tractor requirements and slurry tanker size since these systems are dimensioned for large tankers (20 + m^3) and require tractors with power of at least 170 kW and 4500 kg front linkage lifting capacity. Furthermore, only the particular tractor/tanker that the system is installed on can be used to acidify slurry. At the same time, in-field SATs would be well suited for agricultural contractors or farmer cooperation's which would spread investment costs and make acidification available for small farms. In-field SATs are also well suited for larger farms that have their own machine parks.

Secondly, in-storage short-term acidification before spreading could easily be implemented in most countries. These SATs are mobile and also mix the stored slurry before spreading. An advantage over in-field SATs is that any tractor and slurry tanker combination can be used to spread the acidified slurry. However, the major bottleneck concerns the foaming during acidification as it is often difficult to increase the storage capacity to deal with this issue. Slurry storages are dimensioned according to slurry production and there is often no extra storage capacity after long winters. This could be solved by first spreading untreated slurry until there is enough room for acidification but would lower the total positive potential of acidification. In-storage SATs are well suited for agricultural contractors and farmer cooperation's who would also gain more experience dealing with foaming.

The long-term in-storage system, which is a modified in-house SAT, would most likely be easy to implement in most countries. Most current housing systems have a pumping pit outside the animal house to collect manure before pumping it to storage and it is likely the long-term in-storage system could easily be installed here. It is still a stationary system for a specific farm, but installation would be simpler and emissions decreased from both storage and spreading.

In-house SAT has the advantage that it offers the best potential for reducing ammonia emissions along the entire manure handling chain (animal house, storage and spreading) and thereby resulting in the largest reduction in total emissions. This could be a particularly relevant solution for livestock production in sensitive areas or for large IED farms that must implement BATs for reduction of ammonia emissions. In-house is also the easiest for the farmer to maintain since everything is automatic and the farmer never has to handle the acid. However, in-house was also considered most difficult for wide implementation since installations are fixed to specific barns, only have potential to acidify a fixed quantity of slurry and are without possibility to share costs with other farms. A bottleneck for in-house SAT implementation is that reconstruction needs for installation in existing animal houses are uncertain and could be substantial. Therefore, in-house SAT solutions were considered most relevant for newly built livestock houses where it could be integrated into the overall design, thus wider dissemination of in-house SATs is likely to occur at a relatively slow rate. In some countries, like Sweden, certain regulations would need to be addressed and additional tests needed before permits for the use of this system would likely be granted (See Section 6.7).

Figure 6.1. Estimate (expert judgement, see Chapter 7 Contact information) from country partners on likely potential for early SAT implementation on farms in each country (Denmark not included as SAT is already implemented). Farm-level investment (FLI), agricultural contractor or farmer cooperation (AC/FC).

	SATs	In-house	In-storage			In-field	
			Long-term*	Before spreading		Acidification during spreading	
Country	Relevant	FLI	FLI	FLI	AC/FC	FLI	AC/FC
Estonia	Yes		x	x	x	x	x
Finland	Yes		x		x	x	x
Germany	Yes						x
Latvia	Yes				x(2)		x(1)
Lithuania	Yes		x	x	x	x	x
Poland	Yes	x	x	x	x(1)	x	x
Sweden	Yes		x		x(2)		x(1)

x(1) means most likely and x(2) second most.
*Acidification in pumping pit outside the animal house (modified in-house SAT)

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Appendix 1. Definitions

In general, we try to use terms according to the "Glossary of terms on livestock and manure management" (KTBL, 2011).

According to the glossary, "**liquid manure**" and "**slurry**" mean essentially the same thing. "Liquid manure" is a general term that denotes manure from housed livestock that can flow under gravity and can be pumped. "Slurry" means faeces and urine produced by housed livestock, usually mixed with some bedding material and some water during management to give liquid manure with dry matter content in the range of 0-10%. In general we refer this as slurry.

Below is defined the Livestock Unit (LSU) according to Eurostat (2013). It should be observed that there are other national definitions of LSU.

Livestock Unit (LSU)

The size of a herd is either expressed in term of head (number of animal) or Livestock Unit (LSU) where one LSU is the grazing equivalent of one adult dairy cow. LSU are used in this report in order to estimate the division between the main livestock productions. The data in Table 1-1 were used to convert from head to LSU when needed.

Table 1-1. Conversion head to LSU, Eurostat

Bovine animals	Under 1 year old	0.4
	1 but less than 2 years old	0.7
	Male, 2 years old and over	1
	Heifers, 2 years old and over	0.8
	Dairy cows	1
	Other cows, 2 years old and over	0.8
Pigs	Piglets having a live weight of under 20 kg	0.027
	Breeding sows weighing 50 kg and over	0.5
	Other pigs	0.3
Poultry	Broilers	0.007
	Laying hens	0.014

Cattle housing

Stanchion-tied stables: Stanchion-tied stables are animal houses where the animals are tied to their places and are not allowed to move freely.

They can contain manure in the form of solid dung and liquid manure when the floors of the stalls are on sloping concrete with bedding (e.g. straw, chopped straw, sawdust) and a shallow gutter at the rear of the animals to collect part of the faeces and the urine, whilst part is regularly removed as solid manure. In some cases the gutter is equipped with a drainage pipe to collect seepage or there can be a deeper channel instead of a gutter to collect and store the liquid fraction.

The manure is normally removed mechanically outside the building as solid dung/farmyard manure.

They can also contain manure in the form of slurry when the floors of the stalls are level concrete with a channel covered by a grid at the rear of the animals or fully slated floor to collect faeces and urine as slurry. The manure and urine drop down below the floor into a pit, where they form slurry

Loose-housing: Loose housing barns are animal houses where the animals are allowed to move freely and have free access over the whole area of the building or pen (a small enclosure for livestock). Cubicle house are also included here. Cubicle housings are buildings divided into rows of individual stalls or cubicles in which animals lay when at rest but are not restrained.

Loose housing may contain manure in the form of solid dung and liquid manure when there is a concrete floor which is cleaned more frequently by scraping may be provided in the area where the animals stand to feed and/or drink. It is common for a deep layer of bedding (usually straw) to be spread over the floor that is removed from the building, typically once or twice per winter, as farmyard manure.

Loose housing may also contain manure in the form of slurry when the manure and urine drop down below the floor into a pit, where they form slurry or where it may be scraped from concrete passageways and collected in storage tanks or lagoons, along with slurry deposited on outside yards

Pig housing

Partially slatted: part of the floor has slats where the manure and urine drop down below the floor into a pit, where they form slurry

Completely slatted: the floor has slats where the manure and urine drop down below the floor into a pit, where they form slurry

Straw beds: Pig housing on straw-beds (deep litter-loose housing) are animal houses where the floor is covered with a thick layer of litter (straw, peat, sawdust, or other similar material binding the manure and urine) that is removed only at intervals that may be several months apart.

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Appendix 2. Manure handling systems on a national level

Estonia

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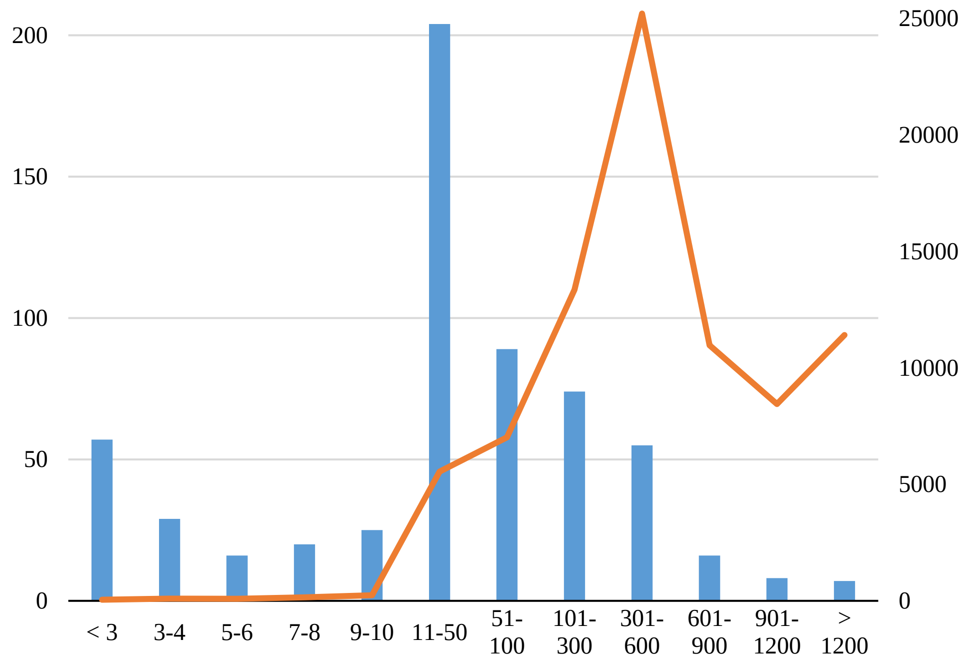
82,591 dairy cows in 600 house holding were registered in the database of Estonian Livestock Performance Recording Ltd. on 02.04.2017. (ELPR)

Figure 2.1 shows the number of farms and dairy cows, respectively divided on herd size. The biggest number of farms (204, 34%) is with herd size between 11-50 cows. 147 (25%) farms have 10 or less cows in the herd with 616 (0.7%) cows in total. Biggest portion of cows (30%) are on farms with herd size 301-600 animals.



	< 3	3-4	5-6	7-8	9-10	11-50	51-100	101-300	301-600	601-900	901-1200	> 1200
Farms	57	29	16	20	25	204	89	74	55	16	8	7
Cows	48	98	86	147	237	5545	7018	13362	25218	10974	8447	11411

Number of animal in farm

Figure 2.1. Number of farms and number of dairy cows by size of herd. Estonian Livestock Performance Recording Ltd. on 02.04.2017. (ELPR)

According to Eurostat, it was 86,100 dairy cows in Estonia in 2016 (Eurostat 1). By the data of Estonian Statistics, there were 86,300 dairy cows in Estonia in the last quarter of 2016.

The reason for the smaller number in 2017 compared with 2016 is because of some decrease of dairy cows number after drastic fall of milk price in 2016.

The number of beefs was in Estonia 69 990 in the database of ELPR on 02.04.2017.

10 031 breeding pigs were registered in the database ELPR on 31.12.2016. The number of fattening pigs in 2017 is shown in Table 2-2. 90 % of the pigs belong to the farms with over 2000 animals.

Table 2-1. Number of farms and number of pigs by size of herd. Estonian Livestock Performance Recording Ltd. on 02.04.2017

Pigs in farms	1-2	3-9	10-49	50-99	100-199	200-399	400-999	1000-1999	>=2000
Farms	27	30	29	8	6	7	5	11	29
Pigs	46	156	603	453	866	1 685	3 189	16 451	256 422

Data about slurry amounts are collected about Estonian pig and cattle farms which belong in group- intensive rearing of cattle and pigs according the Industrial Emissions Directive (IED).

The minimum number of animals on IED farms is:

1) 2000 fattening pig places (weight over 30 kg) or 750 sow places;

2) 400 dairy cows or 533 nurse cows or 800 young cattle;

3) 40 000 birds.

According to Figure 2.1, about 50% of the cattle belong to IED farms. And according to Table 2-2, about 90% of pigs belong to the IED farms. Thera are no data about manure amounts from non-IED farms.

On the IED cattle farms, 1,735,100 t liquid manure and 380,400 t solid manure is produced. Corresponding figures for pig farms are 434,500 t and 40,300 t, respectively. Thus in total 2,169,600 t liquid and 420,700 t of solid manure or proportionally 84% and 16% of total amount of manure. The data are collected from IED permission documents (Environmental Board).

Typical handling systems/handling chains in three production systems

Housing systems and manure management
Number of farms and animals by cattle housing system in Estonia in 2010 is given in Table 2-3 (Eurostat 2). The number of cattle was 258,108 in 2016.

In IED farms are over 45000 (68%) dairy cows in loose housing in 2017 (Table 2-3). In 2010 were in loose housing with slurry 47,700 cattle, which is 20% from total number of cattle (Table 2-4). There are several new big loose housing farms built between 2010 and 2017 in Estonia. Generally, the cows are moved to the new barns from old stanchion tied stables, which are later pulled down or rebuilt for young cattle. Thus the number of stanchion tied cattle stables is decreasing at the same time.

Table 2-2. Housing systems on IED cattle farms

Housing system	Number of dairy cows	Number of farms
Stanchion tied housing	2344	5
Loose housing	45233	66
Loose housing and stanchion tied stable	19150	34

Table 2-3. Number of households and animals by cattle housing system in Estonia in 2010

	Holdings		Places	
	Number	% of total	Number	% of total
Holdings with cattle	4620	100	240 920	100
Stanchion tied stable with solid dung and liquid manure	3660	79.2	112 380	46.6
Loose housing with solid dung and liquid manure	920	19.9	65 700	27.3
Loose housing with slurry	120	2.6	47 690	19.8
Other housing	120	2.6	15 150	6.3

Number of households and animals by pig housing system in Estonia on 2010 is given in Table 2-5 (Estonian Statistics 1). 70% of Estonian pigs were kept on partially or completely slatted floor, 13 % were housed on straw beds and the rest of the pigs were supposedly on some other type of bedding. Since 2015, there has been serious problem with African Swine Fever Disease in Estonia, the conditions for pig production is getting stricter and therefore lot of smaller households quit from pork production.

Table 2-4. Number of holdings and animals by pig housing system in Estonia on 2010

	Holdings	Pigs	Average number of pigs in holding
Partially slatted floor	46	238897	5193
Completely slatted floor	17	37961	2233
Straw beds	1417	62041	44
Other	106	52870	499
Total	1586	391769	247

Manure storage systems

The lagoons and round storages are both used on Estonian farms. Lagoons have plastic bottoms on sand layer underneath plastic geomembrane. Round storages are built mostly from concrete, but there are also some of them with steel walls.

In Estonia, manure storage facilities must have the capacity of accommodate >8 months manure and, if applicable also waste water. During pasturing time, manure left directly to pasture can be excepted from the storage demands of manure, when estimating the storage capacity. When manure storage is subcontracted to other enterprises, the animal housing must still have a leak-proof storage facility for one month storage capacity (Estonian Water Act, 2017).

Number of manure storages in Estonian farms in 2010 is given in Table 2-6 (Eurostat 2).

Table2-5. Number of Estonian farms with manure storages in 2010

Manure storage type	Number of storages
Farms with storage facilities for solid dung	2887
Farms with storage facilities for liquid manure	445
Farms with storage facilities for slurry: tank	242
Farms with storage facilities for slurry: lagoon	28

By Eurostat, 78% of Estonian liquid manure storages were covered on 2010. Very few liquid manure storages are covered in Estonia with artificial cover. Mostly the only cover is natural crust on the slurry storages. There is one known 5000 m^3 storage, which has a tent roof (50,000 Euro) and another one which is covered with a concrete roof (Ülenurme trial farm).

Table 2-7 shows the uses of different types of slurry storage in Estonian pig and cattle IED farms. About 50% of cattle farms and 20% of pig farms have lagoons. Round storages are mostly (90%) built from concrete elements and 10 % from steel plates.

Table 2-6. Slurry storages in Estonian on cattle and pig IED farms (Environmental Board). Data collected in March 2017

	Cattle farms		Pig farms	
Storage type	Number of farms with this type of storage	Total volume of storages, m^3	Number of farms with this type of storage	Total volume of storages, m^3
Lagoons	59	1 003 280	7	59 874
Round, concrete elements	42	428 180	25	230 048
Round, steel plates	6	56 000	2	12 250
Under floor	1	8 000	0	0
Total	108	1 495 460	34	3 027 178

Table 2-8 shows that in IED cattle farms with over 900 dairy cows is dominating (79%) lagoon type storage and there are farms which have several types of storages. In the group with 600-<900 dairy cows has some predominance (60%) the round storage type. In group 400-<600 is the relation near 50:50% and in group with smallest herds size are preferred (64%) again the lagoons.

Table 2-7. The number of the cattle IED farms by type of storages. The percentage shows the portion farms (in this size group) with this type of storage (Environmental Board). Data collected in March 2017

Dairy cows, number on farm	Total number of farms with storages	Farms with lagoons	Farms with round concrete storage	Farms with round steel storage	Farms with storage inside barn, below slatted floors
<400	22	14 (64%)	8 (36%)	0	1 (5%)
400-<600	40	21 (53%)	16 (40%)	4 (10%)	0
600-<900	22	9 (41%)	12 (55%)	1 (5%)	0
900-<1200	10	7 (70%)	3 (30%)	1 (10%)	0
>=1200	9	8 (89%)	3 (33%)	0	0

Table 2-8 shows that there is at least one farm with lagoon in every farm size group. Round concrete storages have biggest domination in size group 6000-9000 pigs.

Table 2-8. The number of the pig IED farms by type of storages. The percentage shows the portion farms (in this size group) with this type of storage. (Environmental Board). Data collected in March 2017

Pig number in farm	Total number of farms with storages	Farms with lagoons	Farms with round concrete storage	Farms with round steel storage
<3000	5	1 (20%)	4 (80%)	0
3000-<6000	14	3 (21%)	9 (64%)	2 (14%)
6000-<9000	12	1 (8%)	11 (92%)	0
>=9000	3	2(67%)	1 (33%)	0

Spreading systems

The Estonian Chamber of Agriculture and Commerce made a survey about liquid manure usage in Estonia. The survey was made in the beginning of 2016 and collected results from 51 cattle and 9 pig farms. Most of farms were in size group with 400–600 dairy cows.

Table 2-9. The slurry amounts on survey farms (The Estonian Chamber of Agriculture and Commerce, 2016)

Number of animals in farm	Number of farms	Slurry amount spread annually, m³		
		min	max	average
Up to 200 dairy cows	7	200	8 000	5 957
200–400 dairy cows	10	8 000	20 000	13 000
400–600 dairy cows	19	12 000	35 000	18 737
600–800 dairy cows	6	7 000	35 000	23 333
800–1 000 dairy cows	5	17 000	50 000	32 800
Over 1 000 dairy cows	4	42 000	140 000	78 000
Up to 750 sows	1	3 000	3 000	3 000
2 000–5 000 pigs	4	5 000	12 000	7 900
5 000–8 000 pigs	1	8 000	8 000	8 000
Over 8 000 pigs	3	10 000	120 000	50 667

The overview about slurry spreading technologies used on survey farms is presented in Table 2-10. It shows that most farms are using injection or incorporation technologies, smaller part trailing hose spreading and some farms are still using the broadcast spreading.

Table 2-10. Spreading technologies and manure amounts (The Estonian Chamber of Agriculture and Commerce, 2016)

Spreading technology	Number of farms	Annual slurry amount, m^3 $year^{-1}$	
		Min	Max
Broadcast spreading	3	200	12 000
Trailing hose spreading	14	5 000	120 000
Injection or incorporation spreading	25	3 000	75 000
Broadcast and trailing hose spreading	2	7 000 7 000	7 500 7 500
Broadcast and injection spreading	2	4 500 7 200	4 800 10 500
Trailing hose, and Injection spreading	9	1 100 4 000	28000 112000
Broadcast, Trailing hoses, and Injection spreading	5	2 000 2 000 2 800	6 750 18 000 33 000

For all slurry in IED farms, only 5% was spread with broadcast spreader, 35% was spread with trailing hoses and most popular was injection or incorporation technologies, which were used for 60% of the slurry (Table 2-11). In Estonia, there are no umbilical hose systems in use of today, meaning the spreading is done with tankers.

Table 2-11. Slurry amounts spread with different technologies as sum for all farms in the survey (The Estonian Chamber of Agriculture and Commerce, 2016)

Spreading technology	Sum of slurry spread with that technology, m^3	Percentage from total slurry amounts on farms, %
Broadcast spreading	65 850	5
Trailing hose spreading	461 400	35
Injection or incorporation spreading	811 050	60

Service provider is used for slurry spreading on 60% of survey farms, from which 18% are not using own spreader at all (Table 2-13). Only own spreader is used by 40% of farms. 55% of slurry is spread by service providers and 45% by own equipment.

Table 2-12. Service usage for spreading

Usage of service	Pig farms	Dairy farms	Number of days used for spreading, average (min-max)	Amount of slurry on farm, m^3 average (min-max)	Sum of slurry amounts on farms, m^3
Only service is used	1	10	27 (7–75)	21 191 (5 000–50 000)	369 200
Only own spreaders are used –service is not used	4	20	64 (10–145)	15 383 (200–55 000)	233 100
Own machine plus service is used (part of service 10–90%)	4	21	85 (30–240)	29 440 (8 000–14 0000)	362 100 service, 373 900 own

Table 2-13. Number of farms by the slurry spreading technology on IED farms (Environmental Board). Data collected in March 2017

Slurry spreading technology	Number of cattle farms	Number of pig farms	Total
Broadcast	1	0	1
Broadcast and trailed hose	2	0	2
Broadcast and injektor	1	0	1
Trailed hose	42	23	65
Trailed hose and injektor	21	6	27
Injektor	15	1	16
Service provider	12	3	15
Total	94	33	127

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Finland

Author: Sari Peltonen, Association of ProAgria Centres

Typical handling systems/handling chains in three production systems

The most common manure handling system is manure handling as slurry both in dairy and pig farms. In this system slurry is collected automatically from the stable first to transient containers and then pumped into the actual slurry storage tank made of concrete situated outside the stable. The next common manure handling system is handling of solid manure in (small) dairy farms where manure is collected (by hand or by tractor) from the stable to a storage silo.

Housing systems and manure management

In dairy farms loose housing system is getting more common in Finland and the number of stanchion-tied stables is decreasing. In loose housing, manure handling as slurry is the most common. Typical handling system for slurry is to collect it (automated system) from the stable first to transient containers and then pump it into slurry storage tanks which are situated outside the stable. From there it is during the growing season mixed and pumped to the spreader. Slurry storage tanks are circular, made of concrete and partially dug into the ground.

In pig farms partially, slatted stables are the most common from where slurry is collected to storage tanks like in dairy farms.

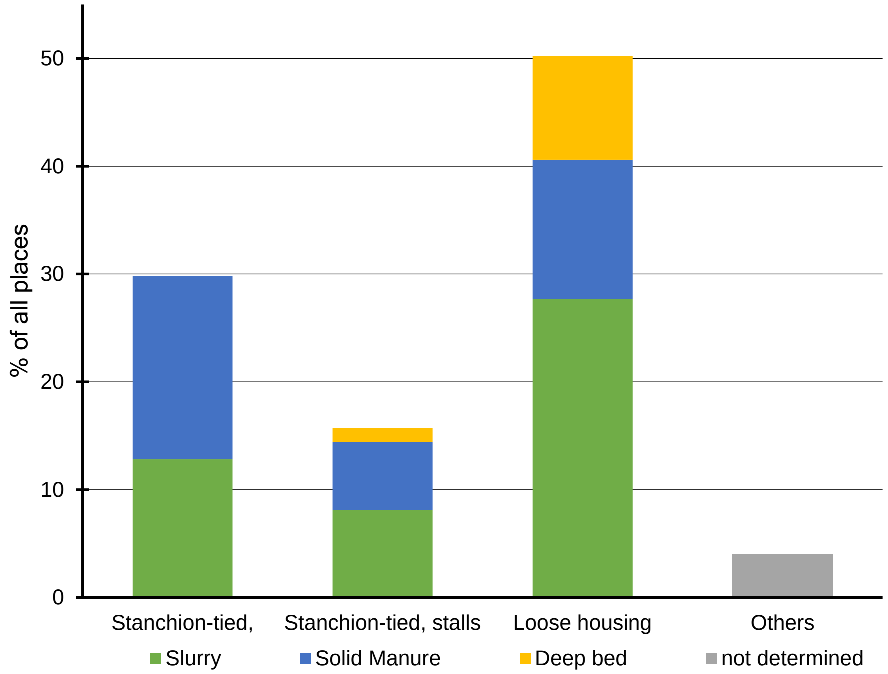

Figure 2-2. Housing and manure systems for cattle in Finland. Natural Resources Institute Finland, Statistical Services, 2010. stat.luke.fi.

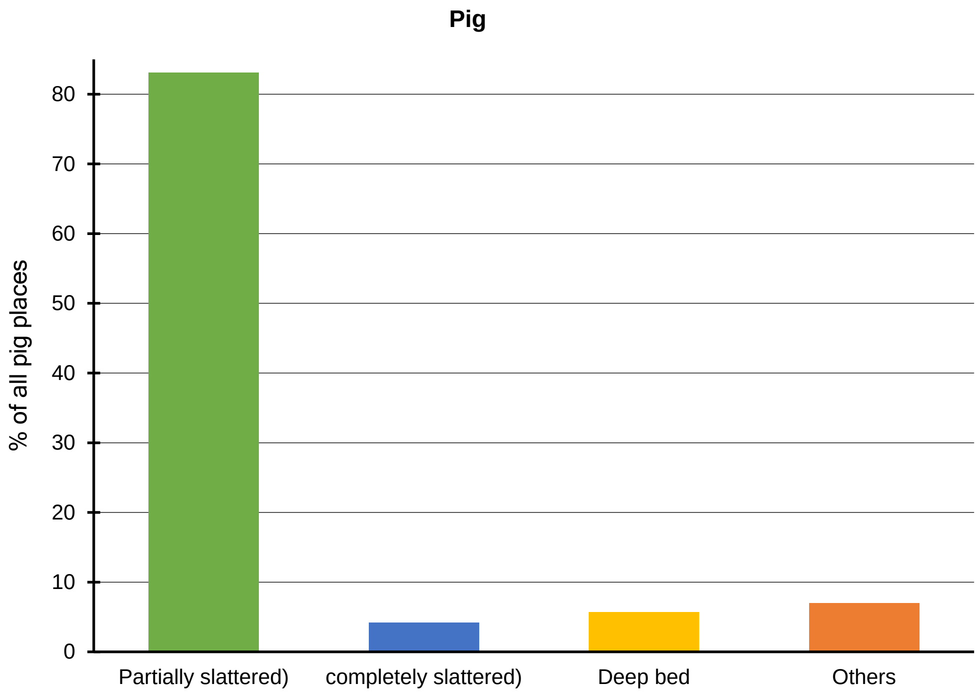

Figure 2-3. Housing systems for pig farms in Finland. Natural Resources Institute Finland, Statistical Services, 2010. stat.luke.fi.

Manure storage systems

Slurry storage tanks are the most common systems for manure storage both in pig and dairy farms in Finland. In poultry farms, solid manure storages are prevalent.

In dairy farms 20% of manure storages is permanently covered while in pig farms half of the storages is covered. Systems with built permanent roof coverings are getting more and more common.

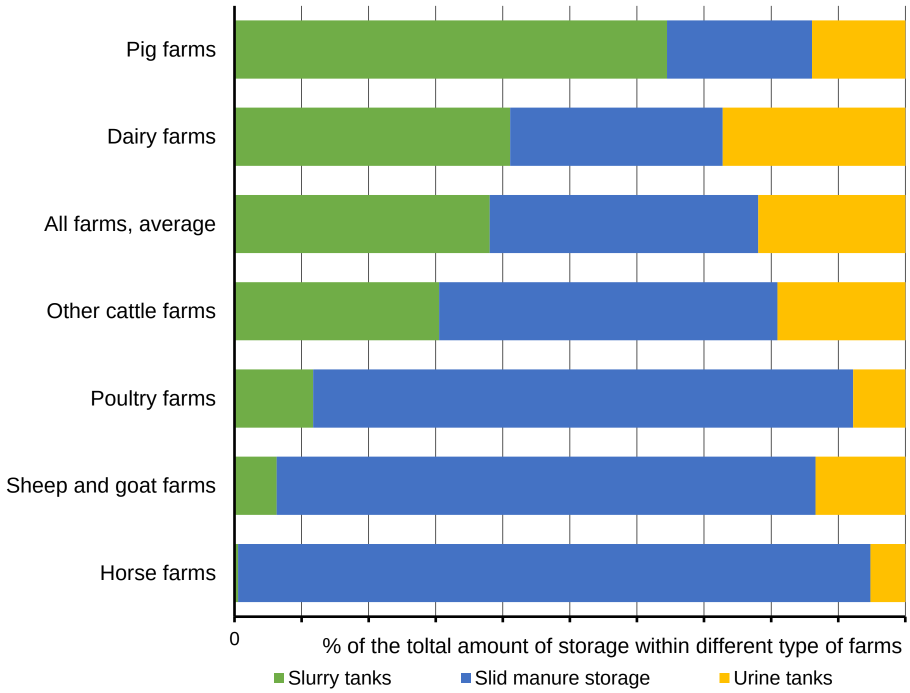

Figure 2-4. Slurry storage systems in Finland. Source: Natural Resources Institute Finland, Statistical Services, 2010. stat.luke.fi.

Spreading systems

In Finland, 48% of the slurry is surface-spread either by broadcasting or with trailing hoses and tilled within 24 hours after spreading, and 31% of the slurry is injected into the soils. Injection has become more and more common because of the agri-environmental subsidy it gets, and because of the number of contractors spreading slurry has increased.

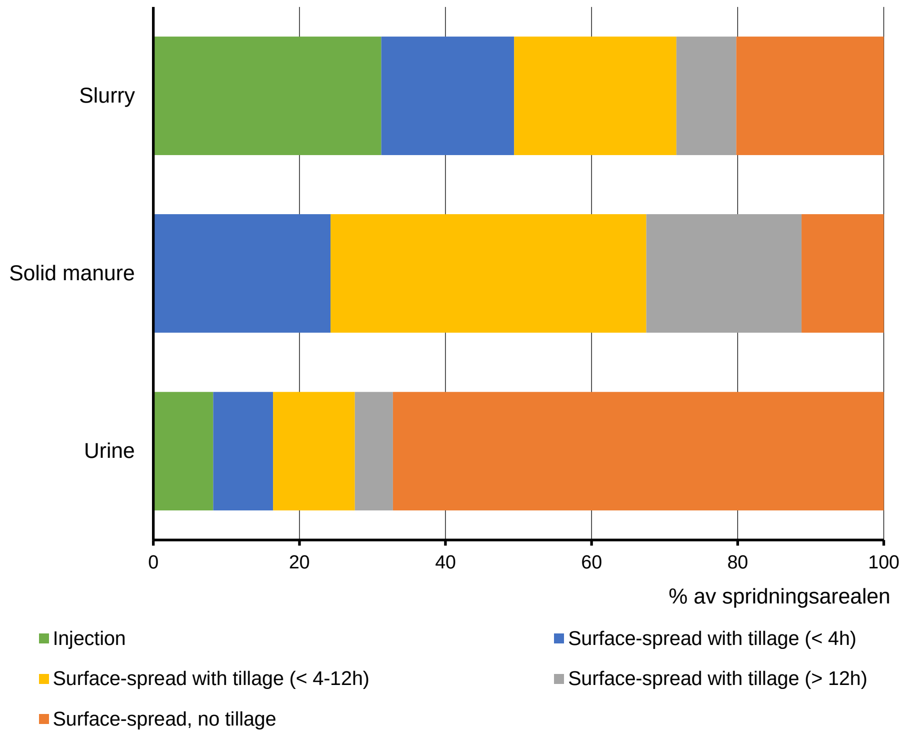

Figure 2-5. Manure spreading in Finland. Source: Natural Resources Institute Finland, Statistical Services, 2010. stat.luke.fi.

Germany

Author: Michael Zacharias, LLUR

Typical handling systems/handling chains in three production systems

Overall 191 Million cubic meters (Federal Statistical Office, 2010) of liquid live-stock manure and digestate of biogas plants were applicate on 7.5 Million hectares of agricultural area in 2010. This complied about 45% of the area under cultivation. About two-thirds of liquid livestock manure and digestate were applied on arable land and one third on permanent grassland.

With a proportion of about 60% cattle slurry was the most applied organic fertilizer. But also, pig slurry (19%) and digestate from biogas plants (17%) were often used. The remaining amount accounted for sewage and other slurry.

Figure 2-6 below shows that the number of biogas plants has increased strongly since 2004 in Germany. After information of the trade association biogas and the German maize committee (DMK) the number of biogas plants has increased twentyfold between 1995 and 2011. The average plant size increased since the year 2000 from 75 kW up to about 400 kW installed electrical power. The strong growth of biogas production and plants are strongly linked to the increase between 2004 and 2006 and shows in consequence the positive effects of the renewable energy law in Germany (EEG) of the year 2004 on the biogas sector. A comparable increase could be observed since the year 2009, were effects of the amendment of the EEG (01.01.2009) become important (DMK).

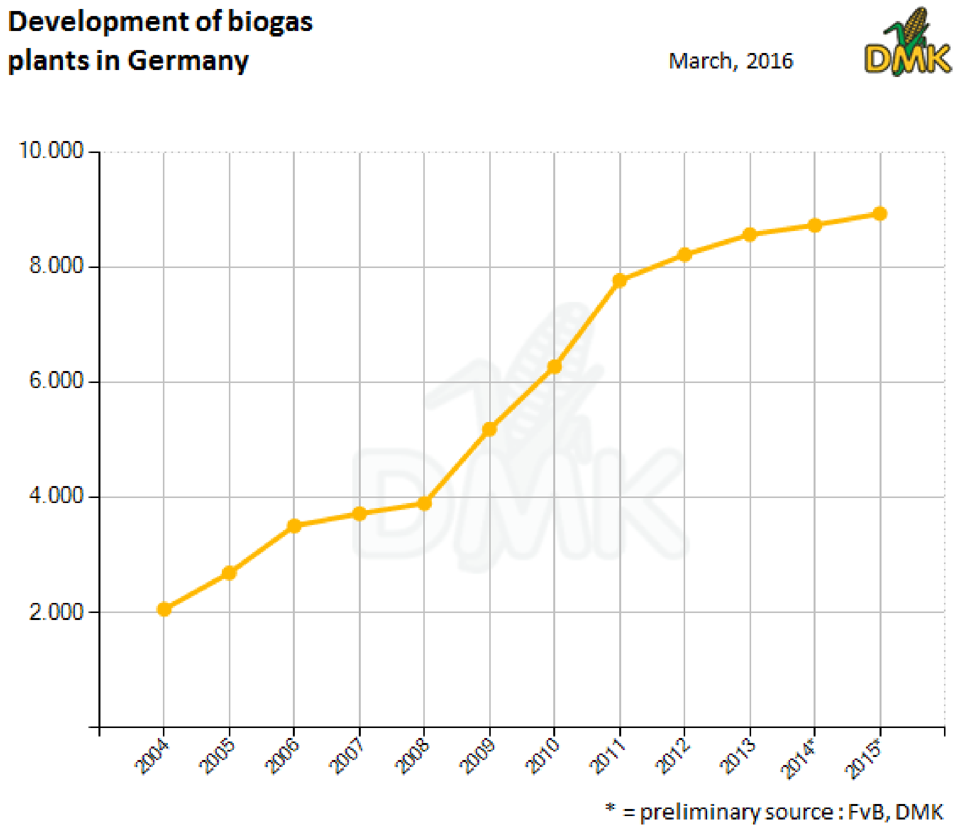

Figure 2-6. Number of biogas plants in Germany from 2004 to 2015 (Source: FvB, DMK, March 2016).

The following *Table 2-14* shows the current statistics and characteristics of biogas plants in Schleswig-Holstein (status 17.01.2017).

Table 2-14. Statistics and characteristics of biogas plants in Schleswig-Holstein (status 17.01.2017, LLUR internal information)

Plant type		No	Capacity/power/Energy	
Biogas production plant	Require approval	399	10075 Mio N m³/a raw gas	
	Not subject to approval	123	80 Mio N m3/a raw gas	
Combined heat and power plants (CHP)		495	660 MW rated thermal input	266 MW el.
Satellite CHPs	Requires approval	85	134 MW rated thermal input	52 MW el.
	Not subject to approval	76	50 MW rated thermal input	20 MW el.

Housing systems and manure management

In Germany, there are 15969 farms with buildings for more than 200 animals in 2016. Table 2-16 shows the number of farms for cattle in Germany, the federal state of Schleswig-Holstein and Mecklenburg-Vorpommern.

Table 2-15. Number of farms and their stock density in Germany, Mecklenburg-Vorpommern and Schleswig-Holstein (Source: Federal Statistical Office, November 2016 and 2013)

National/County	Number of farms with buildings for cattle. Slurry system				
	Total	50 - 99	100-199	200-499	500 and more
Germany (total, information from 2016)	147094	25351	22404	13351	2618
	Total	<50 LSU	50-100 LSU	100-200 LSU	200 LSU and more
Schleswig- Holstein (information from 2013)	4700	500	900	2000	1200
Mecklenburg-Vorpommern (information from 2013)	700	100	100	200	400

Circa 14 million housing systems for cattle are exist in Germany at 2010. The important housing systems are tie-stall and free stall, it will be in addition differentiating between liquid and solid manure. Table 2-16 shows the quantity of the different types of housing systems for cattle.

Table 2-16. Different housing systems for cattle (Source: Federal Statistical Office, 2010)

	Number of systems		
Barn type	Germany	Mecklenburg-Vorpommern	Schleswig-Holstein
Tie-stall liquid manure	1746600	900	41900
Tie-stall solid manure	1269000	11900	102900
Freestall liquid manure	7016800	260300	834600
Freestall solid manure	3434700	274100	254200
Other housing systems	594400	88500	31200
total	14061500	635700	1264800

Table 2-17 below shows that Germany has 2800 pig farms in 2016 exceeding 2000 animals.

Table 2-17. Number of farms and their stock density in Germany, Mecklenburg-Vorpommern and Schleswig-Holstein (Source: Federal Statistical Office, November 2016 and 2013)

National/County	Number of farms with buildings for pigs, slurry system divided in different stock sizes				
	Total	500-999	1000-1999	2000-4999	5000 and more
Germany (total, information from 2016)	24400	5900	6400	2300	500
	Total	<50 LSU	50-100 LSU	100-200 LSU	200 LSU and more
Schleswig- Holstein (information from 2013)	1300	300	300	400	300
Mecklenburg-Vorpommern (information from 2013)	400	200	0	0	200

More than 28 thousands housing systems for pigs are subsist in Germany. The mostly using system is the completely slatted floor system with over 66 percent. 25 % of the total systems are using is partially slatted floors. The following Table shows the number of using systems in Germany for pigs.

Table 2-18. Different housing systems for pigs (Source: Federal Statistical Office, 2010)

	Number of systems		
	Germany	Mecklenburg-Vorpommern	Schleswig-Holstein
Completely slatted floors	19058400	526700	922600
Partially slatted floors	7199000	263800	660000
Straw beds	1709500	38400	54700
Other	581300	20100	/
Free-range	/	6700	/
Total	28548200	855700	1637300

Manure storage systems

Generally, the storage must be waterproof[1]. In case of non-visible deep storage tray or in water protection areas is often required to have a leak detection system with ring drainage. For the reduction of emissions, the TA-Luft[2] for liquid manure

[1] see DIN 11622-2:2015-09; Silage and liquid manure containers, containers in biogas plants, bunker silos and trench silos - Part 2: Silage and liquid manure containers and containers in biogas plants made of concrete.

[2] https://www.umweltbundesamt.de/sites/default/files/medien/1/dokumente/taluft_stand_200207241.pdf

container, claim a cover with an efficiency of 80%. It is definitely the conditions to the generally accepted rules of technology must be adhered to.

To include liquid manure storage you need a liquid manure tank, a slurry pit with pumping station and depending on the location of the farm it is important to have a leak detection system and, optionally, a cover. Figure2-7 shows a rough schematic construction of liquid manure storage system. Also mixers can be integrated, in order to homogenize the slurry, but this can also be carried out by a mobile mixer. From the slurry pit the manure in the manure tank for spreading pumped.

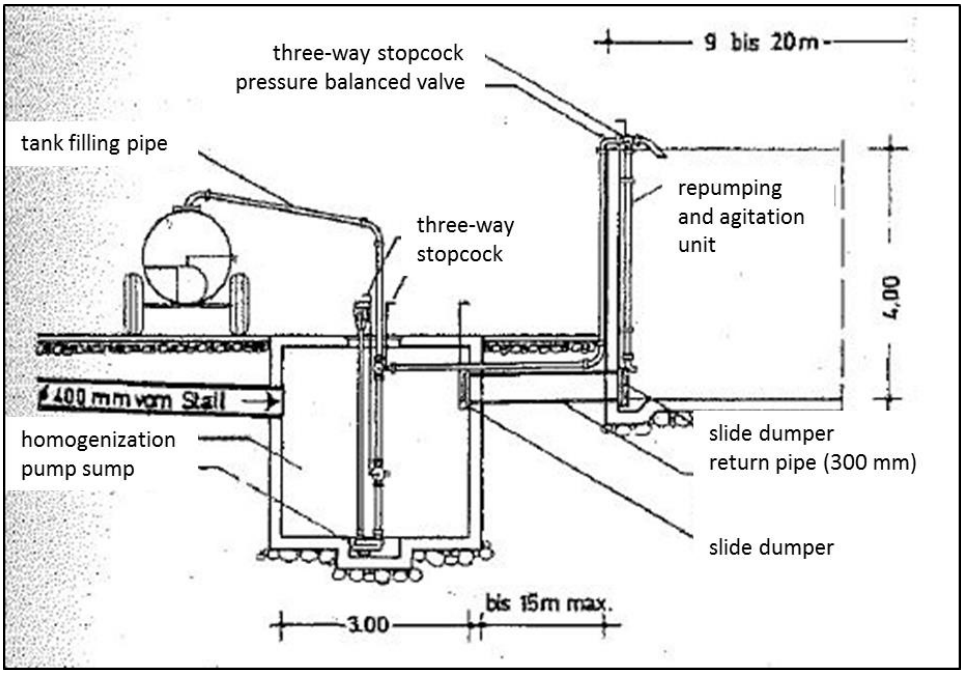

Figure2-7. High storage inclusive slurry pit (Source: Boxberger et al., 1994 in KTBL 2009).

Spreading systems
In Germany the common application technique for livestock manure was still broad spread application in 2010, were slurry is wide spread on soil and crop surface. About 132 Million cubic metre of liquid livestock manure were applied with this technique on arable land and grassland in Germany. About 58 Million cubic metres were applied with trailing hose, trailing shoe, slit injection technique, or slurry cultivator. These application techniques of livestock manure are accepted as an effective and environmental friendly application method, because of its low nutrient losses and emissions due to the near-ground application or rather due to the directly following incorporation into soil.

Figure 2-8 shows the percentage distribution of the different spreading systems which using in Germany.

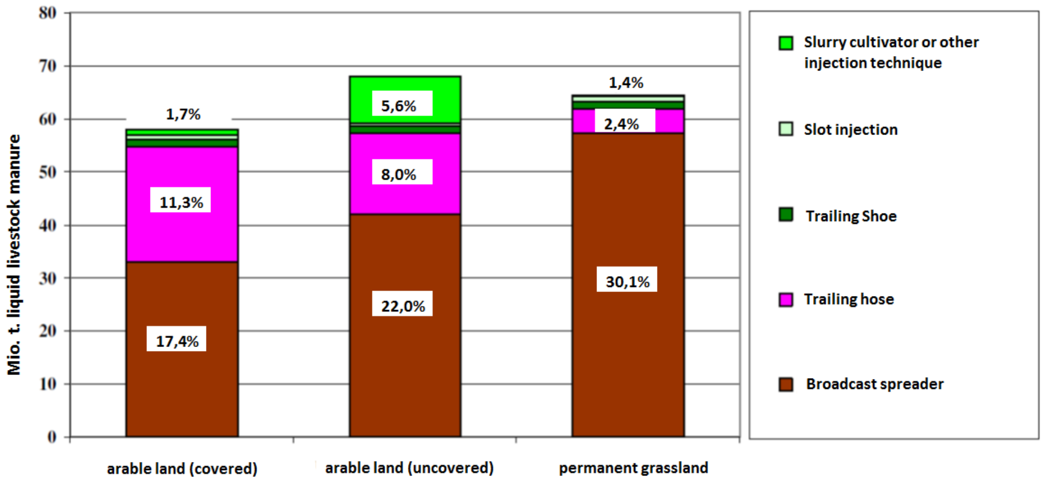

Figure 2-8. Application technique of liquid livestock manure in Germany 2010, differentiated after arable land and grassland (Proportion of the whole spreading amount of 190, 7 Mio. t of liquid manure (Source: Federal Office of Statistics, 2011; Thünen-Institut).

Figure 2-9 shows the currently most widely used slurry application technique (broadcast spreading) and trailing hose spreading technic with 36 m working width on arable land. In 2020 the trailing hose spreading technic on arable land will be forbidden. The differences in the Ammonia emissions are significant and can be greatly reduced if the manure is directly incorporated after application to the soil.

Figure 2-9. Broadcast spreading (left) is the dominating application technic in Germany. In 2020 on arable land and in 2025 on permanent grassland broadcast spreading will be not allowed.

Some Federal States in Germany already now, are using with more than 50% the trailing hose spreading technic. For this purpose, especially in Thuringia, Saxony and Saxony-Anhalt belong to the persistent. These federal states have significantly fewer Livestock holdings, and their manure more frequently applicate by nearby contractor, than in Schleswig-Holstein. Many farmers also have no own spreading technique.

Figure 2-10 shows the distribution of the application of technology in the different Federal States.

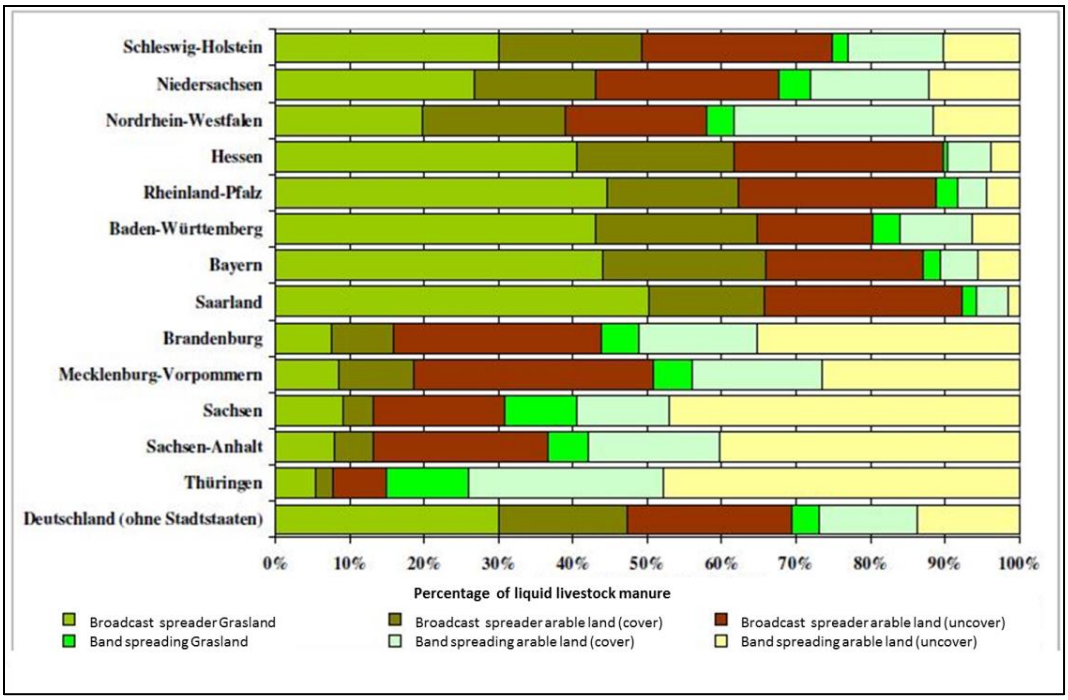

Figure 2-10. Application technique of liquid livestock manure in Germany 2010, differentiated after arable land, grassland and the federal states of Germany (Source: Federal Office of Statistics, 2011; Thünen-Institut).

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Latvia

Authors: Janis Kazotnieks, LRATCL, Raimonds Jakovickis and Inga Berzina, FP

Current manure handling systems

Manure management systems that are classified in the 2006 IPCC terminology and for classification of farm animals are presented in Table 2-20. Systems used in Latvia are marked with an “x”.

Table 2-19. Manure management systems used for different farm animal groups in Latvia (Agricultural Data Centre, Republic of Latvia)

	Manure management systems						
Animal group	**Pastures**	**Litter manure**	**Slurry**	**Anaerobic digester**	**Ewes and goat deep bedding**	**Poultry manure with litter**	**Poultry and fur animal manure without litter**
Milk cows	X	X	X	X			
Other cattle older than 2 years	X	X					
Young stock 1-2 years old	X	X		X*			
Calves till 1 year old	X	X		X*			
Swines		X	X	X			
Pigs, gilts, fattening pigs		X	X	X			
Sheep	X				X		
Goats	X				X		
Horses	X	X					
Laying hens	X	X		X			X
Chicken and pullets	X	X		X			X
Broilers						X	
Geese						X	
Ducks						X	
Turkeys						X	
Rabbits		X					
Fur-bearing animals							X
Deer	X						

*only milk cow calves and young stock

According to the Cabinet Regulations No.829 (23.12.2014) "Īpašās prasības piesārņojošo darbību veikšanai dzīvnieku novietnēs“ (Special requirements for polluting activities in animal houses) the requirements are:

Animal houses with more than 10 animal units (AU) are required to have suitable manure storage facilities according to animal type, production level and housing type. The same applies to the animal houses with more than 5 AU in Nitrate Vulnerable Zones (NVZ). (More details about more specific requirements are available through www.likumi.lv).

Manure storage facilities are required to have capacity for storing manure (rain and snow water) for at least 8 months. Pasturing time, manure left directly on fields (if applicable) is allowed be deflated from total capacity. It is allowed to subcontract the exceeding amount to another enterprise.

Liquid manure and slurry storages should either have constructed cover or floating cover for all the storage period.

All storage facilities and deep litter technology housings are required to be leak-proof and durable to withstand manure-handling machinery.

It is exceptionally allowed to store solid manure (with DM not lower than 30%) outside the storage no longer than 5 months in a period between May 1 and September 30 or when new storage is built or existing one reconstructed. This storage exception is required to be approved by State Environmental Service.

There are some general requirements for this type of storage:

- It has to be made on a field which area is not smaller than to be fertilised the amount of storage in one year;
- It has to be made on flat area (slope not more than 5 degrees);
- The distance to open water body or drinking water well is required to exceed 50 m;
- The distance to drainage ditch or drainage well is required to exceed 30 m;
- It has to be protected against leaching.

According to the Figure 2-11, 98.76% or 24136 cattle farms produce 53.13% or 3139 kt/year of solid manure. Liquid manure is produced by 1.24% or 302 of cattle farms which by amount is 46.87% or 2770 kt/year respectively. In total, there is produced 3207 kt liquid manure/year and 3154 kt solid manure/year from cattle and pigs in Latvia.

However, 1.84% (68) of pig farms did produce 96.78% or 437 kt/year of liquid manure.

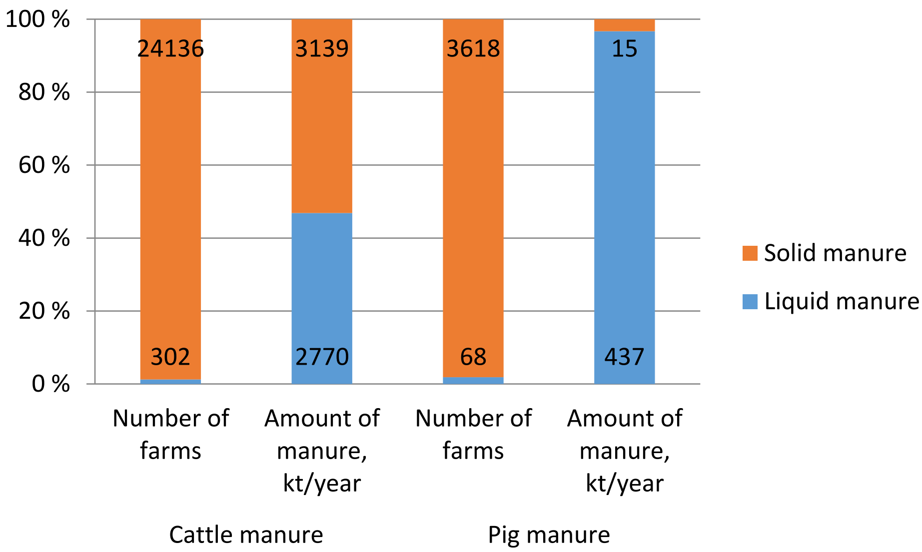

Figure 2-11. Production of manure on cattle and pig farms (Statistics Latvia, 2017).

There are totally 3207 kt/year of liquid manure produced by 370 cattle and pig farms (more detailed information in the Annex, Latvia).

Housing systems and manure management

Cattle

Solid manure is produced in:

- 100% when housing up to 50 animals;
- 70% when housing 50 - 100 animals;
- 5% when housing over 100 animals generally tethering of cattle.

For the beef cattle free range of keeping is mostly (85%) used with light construction buildings, the remaining 15% of cattle farms use permanent housing.

Figure 2-12. Free range keeping of beef cattle.

Liquid manure is produced keeping animals in free range. Liquid manure is removed using underfloor canals to intermediate storage and pumped to large manure storage facility outside the shed.

Pigs

Solid manure is produced in housings up to 50 animals, keeping them on dense floor with manual (85%) or partially mechanized (15%) systems for removing manure.

Liquid manure is produced in:

- old housings on dense floor removing manure by conveyor (10%),
- re-constructed or new housings (90%) on slatted floor removing manure by draining or flushing to intermediate storage, then pumped to large manure storage facility outside the shed.

Manure storage systems

Cattle

Solid manure from farms with animals up to 5 in Nitrate Vulnerable Zones (NVZ) or up to 10 in the rest of territory is stored without specially built storage.

Figure 2-13. Storage for solid manure, concrete platform with walls.

For the rest (85%) they mainly use open concrete areas and slurry collection containers. In the small farms the storages are actually symbolic and do not function as a proper storages.

Liquid manure is stored in open storages (artificial or natural cover is required):

- 60% lagoons;
- 20% above ground round shape concrete made;
- 15% above ground round shaped coated metal;
- less than 5% above ground round shape metal frame.

Pigs

There are no storage facilities storing solid manure when there are up to 50 animals in herd.

Liquid manure (more than 50 animals in herd) is stored in:

- 40% lagoons;
- 40% above ground round shaped concrete made;
- 20% open concrete made with sidewalls.

Figure 2-14. Slurry storage; container with roof (left) and open lagoon (right).

Spreading systems

Most of the solid manure spreaders for big farms have horizontal beaters (60%). The rest have vertical beaters (40%).

Figure 2-15. Solid manure spreader with vertical beaters.

The trailed, semi-trailed or self-propelling spreaders are used to transport and apply slurry to the fields near to the storage. For the longer distances tankers with volume up to 30 m^3 are used for transportation of slurry.

Figure 2-16. Mobile buffer tank for slurry placed in field.

Slurry tankers are equipped with following spreading devices:

- 60% splash plate;
- 30% boom with trailing hoses;
- 10% injector.

Incorporation spreading using disc devices is suitable to make the stubble or green manure tillage and slurry fertilising in one pass getting even mixture of soil, manure and plant residues. Slurry is bound with soil and plant residue particles and the emissions of ammonia and odour is therefore kept at low levels. Slurry is not buried too deep and emerging crops sown after some weeks are able to use nutrients from upper layer of soil.

Alternative way is to use a spreader tanker with a boom with trailing hoses. Use of trailing hose spreader, however, results in higher ammonia emissions than injection, and need separate tillage after application, if slurry is not acidified.

Figure 2-17. Injection of slurry after maize growth.

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Annex Tables, Latvia

1. Number of cattle

CATTLE (data on 01.01.2017.)	
Dairy cows	162414
Suckler cows	59250
Heifers up to 6 months	30195
Heifers after 6 months	126037
Breeding animal	1536
Fattening young cattle	41272
SUM	**420704**

2.Herds with dairy cows and the produced amount of manure

Dairy cows					
Size of herd	Farms		Number of animals		Manure, kt/year
	pcs.	%	pcs.	%	
Up to 5	15428	76.8	26614	16.3	359.3
6 to 9	1715	8.5	12473	7.7	168.4
10 to 19	1457	7.3	19635	12.1	265.1
20 to 29	525	2.6	12472	7.7	168.4
30 to 49	419	2.1	15904	9.8	214.7
50 to 99	316	1.6	21364	13.2	
100 to 199	130	0.6	17606	10.8	
200 to 299	36	0.2	8704	5.4	
300+	52	0.3	27642	17	
SUM	**20078**	**100**	**162414**	**100**	

3. Herds with Beef cattle and suckler cows and the produced amount of manure

Beef cattle with suckler cows					
Size of herd	Farms		Number of animals		Manure, kt/year
	pcs.	%	pcs.	%	
Up to 5	2675	61.2	5206	8.8	62.5
6 to 9	436	10	3208	5.4	38.5
10 to 19	487	11.2	6616	11.2	79.4
20 to 29	243	5.6	5659	9.6	67.9
30 to 49	243	5.6	9361	15.8	112.3
50 to 99	179	4.1	12039	20.2	144.5
100 to 199	70	1.6	9271	15.6	111.3
200 to 299	20	0.5	4776	8.1	57.3
300+	7	0.2	3114	5.3	37.4
SUM	**4360**	**100**	**59250**	**100**	**711.0**

4. Herds with heifers up to 6 months and the produced amount of manure

Dairy cow herd size	Farms		Number of animals		Manure, kt/year
	pcs.	%	pcs.	%	
Up to 5	15428	76.8	4922	16.3%	12.8
6 to 9	1715	8.5	2325	7.7%	6.0
10 to 19	1457	7.3	3654	12.1%	9.5
20 to 29	525	2.6	2325	7.7%	6.0
30 to 49	419	2.1	2959	9.8%	7.7
50 to 99	316	1.6	3986	13.2%	10.4
100 to 199	130	0.6	3261	10.8%	8.5
200 to 299	36	0.2	1631	5.4%	4.2
300+	52	0.3	5133	17.0%	13.3
SUM	**20078**	**100.0%**	**30195**	**100.0%**	**42.1**

5. Herds with heifers (6+ months) and produced amount of manure

Heifers 6+ months					
Dairy cow herd size	Farms		Number of animals		Manure, kt/year
	pcs.	%	pcs.	%	
Up to 5	15428	76.8	20544	16.3%	164.4
6 to 9	1715	8.5	9705	7.7%	77.6
10 to 19	1457	7.3	15250	12.1%	122.0
20 to 29	525	2.6	9705	7.7%	77.6
30 to 49	419	2.1	12352	9.8%	98.8
50 to 99	316	1.6	16637	13.2%	
100 to 199	130	0.6	13612	10.8%	
200 to 299	36	0.2	6806	5.4%	
300+	52	0.3	21426	17.0%	
SUM	**20078**	**1**	**126037**	**100.0%**	

6. Herds with breeding animals and produced amount of manure

Breeding animals					
Dairy cow herd size	Farms		Number of animals		Manure, kt/year
	pcs.	%	pcs.	%	
Un to 5	15428	76.8	250	16.3	3.5
6 to 9	1715	8.5	118	7.7	1.7
10 to 19	1457	7.3	186	12.1	2.6
20 to 29	525	2.6	118	7.7	1.7
30 to 49	419	2.1	151	9.8	2.1
50 to 99	316	1.6	203	13.2	2.8
100 to 199	130	0.6	166	10.8	2.3
200 to 299	36	0.2	83	5.4	1.2
300+	52	0.3	261	17.0	3.7
SUM	**20078**	**1**	**1536**	**100.0**	**11.5**

7. Herds with fattening young cattle and produced amount of manure

Fattening young cattle					
Dairy cow herd size	Farms		Number of animals		Manure, kt/year
	pcs.	%	pcs.	%	
Un to 5	15428	76.8	6727	16.3	74.7
6 to 9	1715	8.5	3178	7.7	35.3
10 to 19	1457	7.3	4994	12.1	55.4
20 to 29	525	2.6	3178	7.7	35.3
30 to 49	419	2.1	4045	9.8	44.9
50 to 99	316	1.6	5448	13.2	
100 to 199	130	0.6	4457	10.8	
200 to 299	36	0.2	2229	5.4	
300+	52	0.3	7016	17.0	
SUM	**20078**	**1**	**41272**	**100.0**	

8. The amount of manure from dairy cow herds

Dairy cow herd	Solid manure, kT	Liquid manure, kT
Number of cows up to 49	1175,8 (100%)	-
Number of cows 50 – 99	201,9 (70%)	173.0 (30%)
Number of cows 100	51,3 (70%)	1691.4 (95%)

9. The amount of manure from heifers (6+ months) herds

Herds with heifers 6+ months	Solid manure, kT	Liquid manure, kT
Heifers up to 49	540,4 (100%)	-
Heifers 50 – 99	93,2 (70%)	74,9 (30%)
Heifers over 100	16,7 (70%)	596,3 (95%)

10. The amount of manure from fattening young cattle herds

Fattening young cattle herds	Solid manure, kT	Liquid manure, kT
Young cattle up to 49	245,6 (100%)	-
Young cattle 50 – 99	42,3 (70%)	26,1 (30%)
Young cattle over 100	7,6 (70%)	208,3 (95%)

Beef cattle herds altogether produce 711.0 kT solid manure.
Herds of heifers up to 6 months produce 42.1 kT solid manure.
Herds with breeding bulls produce 11.5 kT solid manure.

11. Total number of cattle and amount of manure

Total number of cattle in Latvia	420 704
Solid manure per year	3 139,4 kT
Liquid manure per year	2 770,0 kT
Average per cattle	14,0 t

12. Number of pigs

PIGS	
Sow	26684
Piglets up to 30kg	148708
Fattening 30-100kg	168063
Male pigs	627
SUM	**344082**

13. Herds with sows and produced amount of manure

Sows					
Total herd size	Farms		Number of animals		Manure, kt/year
	pcs.	%	pcs.	%	
Up to 9	3056	82.9	747	2.8%	1.12
10 to 50	498	13.5	827	3.1%	1.24
51 to 100	51	1.4	294	1.1%	0.73
101 to 500	42	1.1	801	3.0%	2.00
501 to 1000	8	0.2	507	1.9%	1.27
1001 t0 5000	14	0.4	2935	11.0%	7.34
5001 t0 10000	7	0.2	3976	14.9%	9.94
10000+	10	0.3	16597	62.2%	41.49
SUM	**3686**	**100**	**26684**	**100.0%**	
Farmyard manure (In heards up to 50 sows)					**2.36**
Liquid manure (heards with 51+ sows)					**62.77**

Lithuania

Author: Rimas Magyla, LAAS

Typical handling systems/handling chains in three production systems

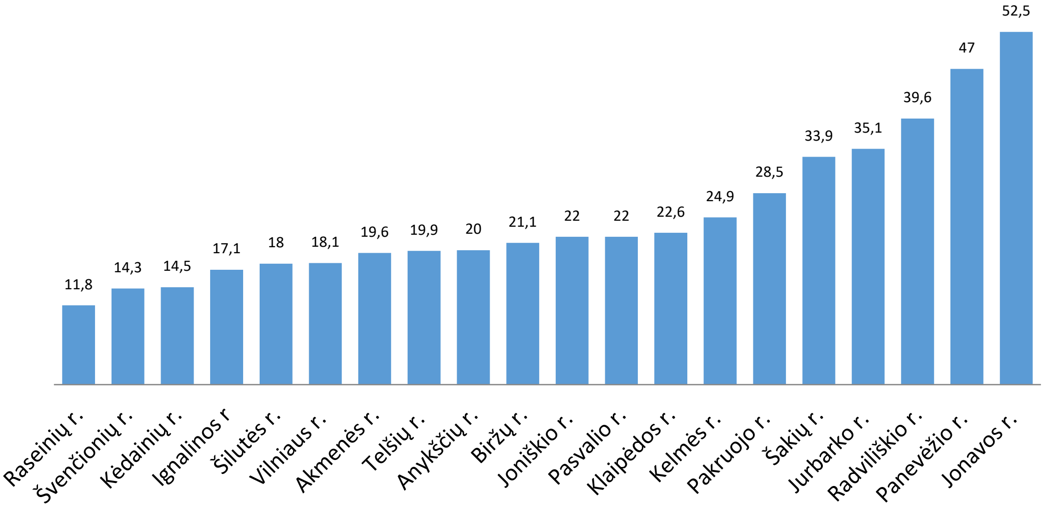
Housing systems and manure management and storage systems
The major type of manure collected in Lithuania is cattle manure (76%), pig manure accounts for (15%) and chicken manure – (7%). Other types of manure collected (sheep, rabbits, goats and horses,) account for 2% (H. L. Foged/LAAS/ Statistics of 2017). There are only a few farms where manure is processed.

Currently, there are 8 biogas plants production from manure and slurry and 4 applications for authorization under preparation (MoE, 2017).

In Lithuania animal husbandry farms are located in the central, northern and western regions where plant production activities are also intensive (Figure 2-23). Statistics show that the number of cows has decreased since 2003 – from 492,000 to 284,000 cows in 2017.

Figure 2-18. Distribution of number of cows by districts (Agricultural Information and Rural Business Centre, 2017).

Pig husbandry farms are mainly concentrated in the central, northern and western areas of Lithuania where plant production farms have also been developed. (a total of 598,458 pigs are raised in pig husbandry farms (statistics of quarter 3, 2016).



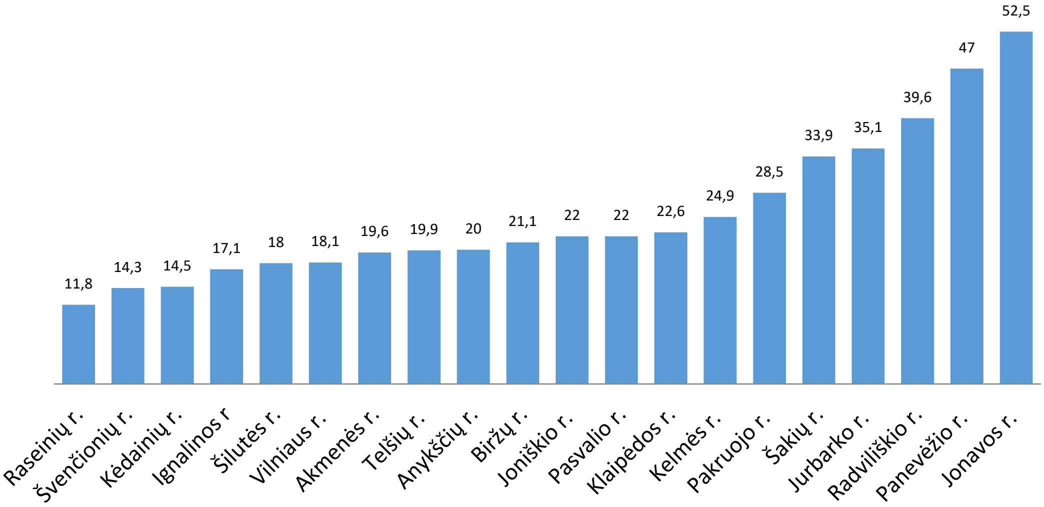


Figure 2-19. Number of pigs in districts with 10,000 pigs or more (Agricultural Information and Rural Business Centre, 2017).

Manure storage facilities have to be installed and requirement fulfilled on farms keeping over 10 livestock units. Whereas environmental protection requirements are linked to EU payments, farmers, especially large-scale ones, have installed manure storage facilities meeting environmental requirements. There are more environmental problems related with small-scale livestock farmers keeping over 10 livestock units, which are obliged to store manure in stacks or install manure storage facilities in accordance with the requirements. However, this category of small farms are not always full-filling the requirements.

Manure management on farms depends on animal housing. Table 2-21 illustrates liquid manure/slurry handling systems.

Table 2-20. Liquid manure/slurry handling systems

Housing type	Type of manure	Manure removal	Storage	Application
Pig housing with slatted flooring (90%). Loose cubicle housing of cows (26%).	Liquid manure/slurry	Scraper or gravity flow into a receiving pit and pumping into a reservoir	Concrete/metal reservoirs, lagoons	Hose spreaders of slurry as well as slurry spreading tankers

Liquid manure management is prevalent in a slatted floor housing type on pig husbandry farms with over 1,000 fattening pigs. Those types of pig complexes raise around 530,000 or 90% of the pig population.

Liquid manure management is popular on dairy farms of new construction with 100 or more cows and stables where the loose cubicle housing system is used. There are over 250 of such farms with 74,000 cows in Lithuania.

Manure is removed from barns using hydraulic scrapers or gravity flow into a receiving pit from which manure is pumped into liquid manure storage tanks – concrete or metal reservoirs or lagoons – the latter option in Lithuania is not frequent.

Figure 2-20. Slurry system in loose housing system for dairy cows (left) and concrete slurry storage tanks (right).

Cubicle housing for cows and liquid manure storage facilities

Liquid manure is mixed in reservoirs before being taken to the fields. The most commonly used are mobile propeller mixers with varying length of elbows to mix manure within a distance of up to 30 meters. Mixers are attached to the hydraulic system of a tractor, backhoe, front-end or telescopic loader and controlled from the cab. Solid manure handling system is illustrated in Table 2-22.

Table 2-21. Solid manure handling systems

Type of housing	Type of manure	Manure removal	Storage	Application
Bedding: Pigs 2%, Cows 50%	Solid manure/slurry, liquid manure on larger farms	Scraper or tractor powered	Concrete manure storage facilities for solid manure with capacities for slurry accumulation	Spreaders, slurry spreading tankers

Solid manure management is mainly popular in pig farms of up to 500 pigs and dairy farms of up to 100 cows kept in old design barns with tie-stall housing systems.

It is estimated that 13.7 thousand pigs (2% of all pigs) and 141,000 (50%) of all cows are kept in this type of farms with tie-stall systems. Manure is removed mechanically, with the help of scrapers or tractors into solid manure storage facilities and slurry is accumulated in reservoirs. In some of the larger farms with 90–100 cows and about 500 pigs only liquid manure may be handled.

Those livestock farmers that rear animals for their own needs keep them on deep litter. There are 14,000 pig farmers in Lithuania keeping 1–10 pigs which totals to about 50 thousand pigs. It is also estimated that there are 38,000 farmers keeping 1–5 cows, with a total of about 69 thousand cows. Small-scale barns are equipped with deep or semi-deep litter stalls and manure is removed several times a year.

Figure 2-21. Tie-stall type barn and solid manure storage facility.

Table 2-22. Semi-deep or deep litter manure handling systems

Housing type	Type of manure	Manure removal	Storage	Application
Semi-deep – deep litter Pigs 8% Cows 24%	Solid	Tractors, manual labour	Manure stacks near barns	Spreaders, manual labour

Spreading systems

Manure spreading on large scale farms.
It is estimated, that there are 526.980 pigs on 67 large pig farms, having more than 500 pigs. According to the preliminary calculations, 1.760.000 t of slurry is produced during one year. There are 263 large dairy farms (>100 cows), of 74.000 cows, producing in total 3.540.000 t of liquid manure.

Large-scale dairy and pig farms use hose spreaders for liquid manure; however, old type slurry tankers are also used. Most of the large pig complexes do not own large areas of land and therefore, they sell slurry to farmers who use it for soil fertilisation. As a rule, application services are provided by the same pig complexes.


Figure 2-22. Slurry tanker spreading with a splash plate (left) and trailing hoses mounted on a boom (right).

Manure spreading in medium scale farms
According to our calculations, 2.848.000 t of solid manure and 1.624.000 t of liquid manure in total is collected yearly in dairy farms with 6-100 cows. Pig farms with 11-500 pigs produces 18.000 t of solid manure and 8000 t of slurry.

Medium-scale dairy and pig farms apply manure on nearby land area using solid manure spreaders and slurry is broadcast spread by using a splash plate.

Manure spreading in small scale farms
According to the calculations 1.459.938 t of solid manure and 824.880 t of liquid manure in total might be produced in small farms with a few animals. Those farmers that keep a few cows and pigs store manure in stacks near barns and spread it in nearby vegetable gardens or small fields.

In Lithuania, it is required that manure should be incorporated into soil within 24 hours following its spreading. This requirement is followed by larger farms. It is also forbidden to spread manure from 15 November to 1 April. During summer manure fertilisation is forbidden from 15 June to 1 August, except meadows, pastures and areas planned for winter crops.

Whereas liquid manure is mainly spread by using the old type slurry tankers (broadcast), it is applied on bare soil in autumn or spring.

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Poland

Authors: Kamila Mazur, Witold Wardal and Bogdan Lochowski, ITP

Typical handling systems/handling chains in three production systems

In Poland, the slurry has typical DM content from 3 to 7%. The slurry consists of faeces, urine and small amounts of bedding material (no more than 0.3-0.5 kg/day/cow). The reason of lower DM content in stored slurry is that additionally water from cleaning of channels is collected.

Only in systems other than slurry, such as systems with bedding material (from 2-3 kg/LU/day; boxes, solid floor) there are separated liquid manure with very low dry matter content (even below 1%).

Housing systems and manure management
The most common cattle housing system in Poland is tied up system with solid dung and only small amount of liquid manure (with dry matter content up to 1-1.5%). In these systems bedding material (in most cases as chopped straw) is added from 2-3 kg/LU/day). In such systems solid dung is collected on the manure plates where small amounts of liquid manure leaks from the plate and is collected nearby in the small pit. Additionally, the water from cleaning the channels is added. These systems are not under consideration when implementing SATs in Poland.

Typical slurry systems are minority among all housing systems. In Poland cattle slurry has DM content from 6.5% to 10.5%. In most cases, typical DM is equal 7.5%.

Main Agricultural Inventory conducted in Poland in year 2010 only indicated number of places in cattle barns with solid or slatted floor and other system (mixed system). According to last Polish Main Statistical Office (2010), Poland had following numbers of livestock stands in particular cattle housing systems, shown in Figure 2-23. Because of fact, that slurry could be produced also in barns with solid floor, the number of such solutions was estimated by ITP based on national statistics and use of expert method.

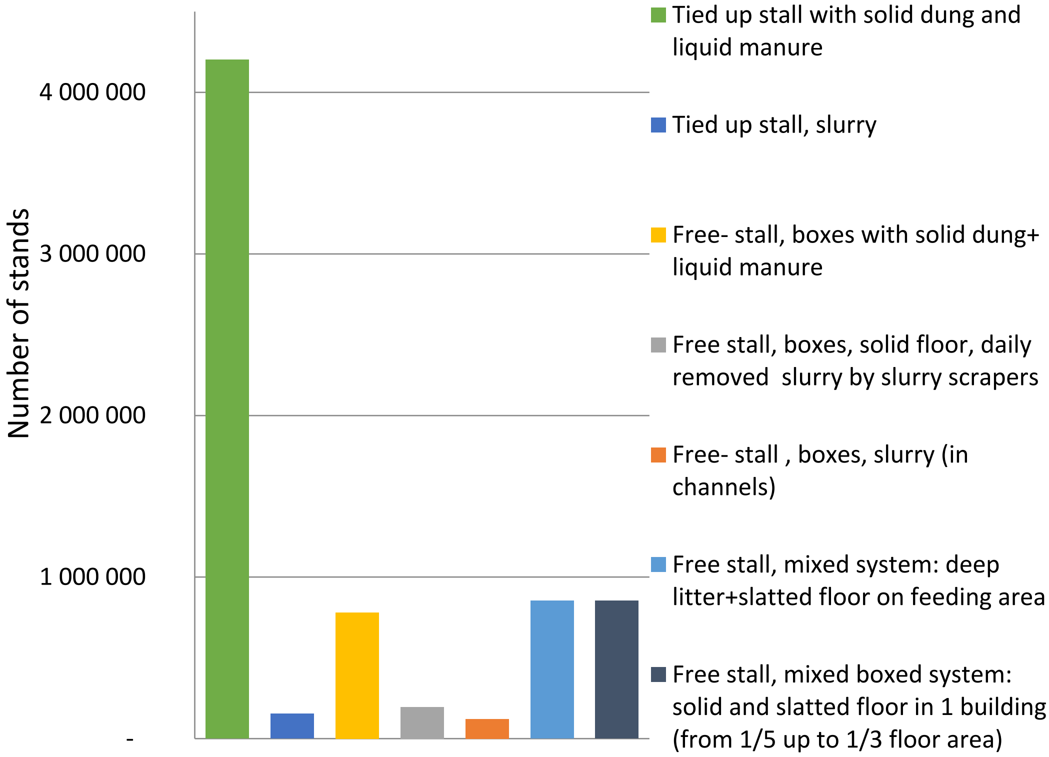

Figure 2-23. Number of stands for cattle in Poland in 2010 in different housing systems. Source: own elaboration based on Polish Main Statistical Office, 2010.

Most of the cattle (52.5%) are kept in farms with cattle herd size below 30 cows and majority of it is kept only on bedding (without typical slurry, but with solid manure and small amounts of liquid manure). The rest, 47.5% of the total number of cattle, are kept in more intensive production both on litter or in slurry systems (Polish Main Statistical Office, 2015).

Pigs

Table 2-23. Table 2-24 shows amount of cattle and amount of pigs in last years (LSU) 2010-2017.

Table 2-23. Cattle and pigs in Poland in years 2010-2017 (in LSU), Source: Polish National Main Statistical Office (2010), Polish Ministry of Agriculture and Rural Development (2017)

Cattle	**2010**	**2014**	**2015**	**2016**	2017[3]
Bovine under 1 year	585 210,4	643 400	646 760	687 120	707 733
Heifers	891 225,3	1 003 030	1 072 050	1 146 110	1 274 192
Dairy cows	2 516 725	2 247 800	2 134 100	2 334 100	2 500 000
2 years old and over (without dairy cows)	507 655	504 960	384 000	236 720	349 440
LSU Cattle	**4 500 816**	**3 949 630**	**3 810 090**	**4 404 050**	**4 831 365**
Pigs	**2010**	**2014**	**2015**	**2016**	2017 prognosis based on data from March 2017
Piglets up to 20 kg	119 018	76 518	69 539	75 411	3 017 457,00
Pigs from 20-50	1 401 426	977 130	890 970	950 700	3 442 140,00
Pigs weighing 50 kg and over for slaughter	2 373 297	2 105 400	2 107 100	2135000	4 342 700,00
Breeding sows weighing 50 kg and over for breeding	725980,5	515 250	415 300	437750	919 000,00
LSU Pigs	**4 619 722**	**3 674 298**	**3 482 909**	**3 598 861**	**-**

Figure 2-24 presents the number of stands for pigs in Poland in 2010 in different housing systems.

3 prognosis based on data from March 2017

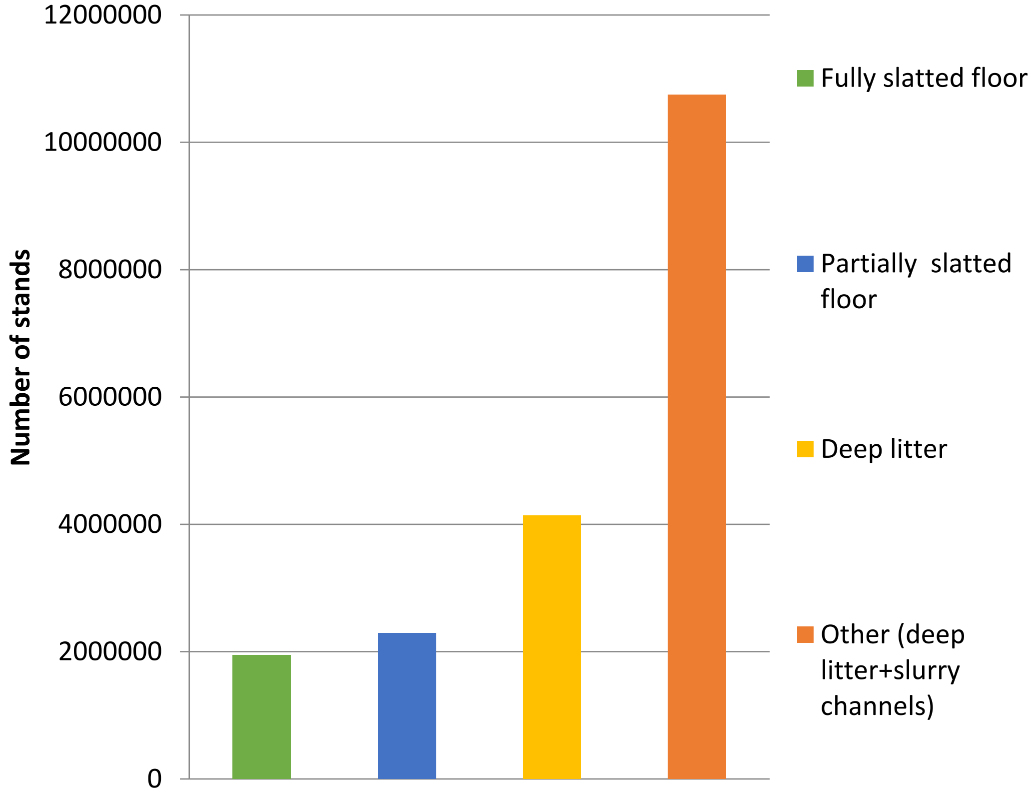

Figure 2-24. Number of stands for pigs according to Main Agricultural Inventory 2010. Source: Polish Main Statistical Office, 2010.

Based on the data from the Polish Main Statistical Office (2010) it was approximated the number of livestock in different housing systems for 2016 year (Table 2-25).

Table 2-24. Livestock in different housing systems for cattle and pigs in year 2016 (Source: own elaboration, based on Polish Main Statistical Office 2016)

			2016 heads	2016 LSU
Cattle- housing systems				
Tied-up systems	with solid dung (solid floor)		3 471 358	2 554 349
	with slurry (slatted floor)		119 702	88 081
Loose housing systems	with solid dung (boxes)		658 361	484 445
	with slurry (boxes)		299 255	220 202
	Other (mixed)	deep litter+ slatted floor on feeding area	718 212	528 486
		boxes, partially slatted floor, partially solid floor	718 212	528 486
TOTAL Cattle			**5 985 100**	**4 404 051**
Pigs- housing systems				
Loose housing systems	Fully slatted floor		1 527 805	461 972
	Partially slatted floor		1 833 366	554 367
	Deep litter		3 361 171	1 016 339
	Other (deep litter+slurry channels)		8 555 709	2 587 044
TOTAL Pigs			**15 278 051**	**4 619 722**

Typical housing systems for cattle in Poland are tied-up barns with shallow litter (about 1-2 kg/LU/day, solid floor) (Romaniuk, Overby 2004a). 54% of buildings for cattle are in tied-up system with solid dung and about 46% of cattle barns are as free stall buildings. Among all cattle, 11% are kept on deep litter with slatted floor on feeding area and 12 % are in boxes with shallow litter and only small amount of liquid manure (with dry matter content about 1%). About 12% of buildings has mixed system with boxes, that means solid floor in main manure alleys, but additionally also slatted floor, for example in waiting area before milking parlour or in other places (in case of modernisation).

In this report, due to its main purpose, tied-up system for cattle will not be discussed further. In Poland the most modern and most state-of-the-art system for intensive dairy cattle production are boxes with deep slurry channels in the walking alleys. Anyway, the loose housing system with deep litter (group keeping) on resting area and with slatted floor on the feeding area and manure channel is worth to mention. Figure 2-25 shows the most typical manure handling chains for cattle manure.

Manure handling chains - cattle

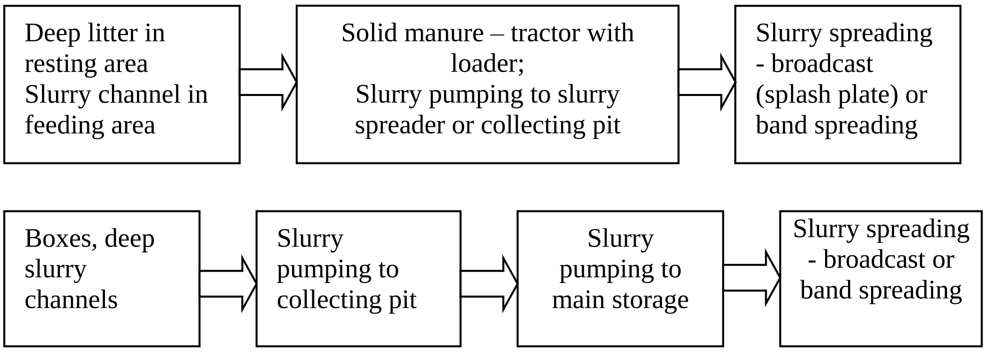

Figure 2-25. Cattle manure handling chains in Poland.

Regarding housing systems for cattle with deep litter and deep slurry channels on feeding area, tractor with loader for removing solid dung is used and slurry pumps for emptying the channels, or directly filling the manure spreading tank. In boxed system typically slurry is collected in channels and pumped into collecting pit or directly to the main storage or to slurry spreader. Broad spreading is mainly used, apart band spreading for slurry application on field.

Anyway for purposes of implementing SATs, it was proposed boxing system with slurry channels. In case of the most modern and the newest buildings with intensive production, there is also tendency to build big cattle barns with solid floor in manure alleys but boxes are bedded in minimum level, then slurry is produced, as showed on Figure 2-26.

Figure 2-26. Slurry scraper on solid floor in walking alley (left) and modern free-stall cattle barn with intensive milk production (right). Photo: B. Lochowski, ITP.

Manure handling chains - pigs

Regarding cattle and pig manure, almost 77% of the manure produced in Poland originates from cattle and 23% from pigs.

In Poland many pig farms produce both solid and liquid manure. In traditional housing of pigs there is open cycle-production system which is based on separate production of piglets and slaughter pigs.

Typical pig slurry in Poland is with DM content about 1,8% to 7,5%, in most cases 5,0%. Especially, where channels are emptied and flushed with water, lower DM is observed and by dry feeding method and narrow slits in slatted floor. In non-litter housing systems of pigs with continues self-flushing of slurry to ensure better flushing of slurry, some water should be added to bottom of channel at the beginning of slurry collection and temporary storage in channels.

There is trend for constructing new piggeries for slaughter pigs with slurry. Regarding housing systems for slaughter pigs, the most modern and popular now and in the future is the system with fully slatted floor. Slurry is collected under slatted floor in manure channels from 1 up to couple of weeks. Next, they are transported gravitationally using natural differences in terrain height or pumped to collecting pit or directly to main slurry storage tank.

Average pigs with weight 30 kg are moved to separate pens. Often, slaughter pigs are separately housed from elder piglets and only small amounts of straw are used or neither. The alley is by one side or between two rows of pens.

Regarding housing system for sows and piglets up 4 weeks, most typical is system on solid floor (deep litter) and slatted floor on slurry channels in manure area of 0.5 m depth and 0.8 m width. There is a tendency in separate collecting urine and faeces in order to lower ammonia emissions. By using the large amount of straw for bedding there is solid manure forming, which should be regularly removed every 1st, 2nd or 3rd day from piggery for saws and piglets.

But, the most modern and most recommended in the future for saws and piglets, as well as for slaughter pigs is system with slatted floor in all areas with management chain showed on Figure 2-27.

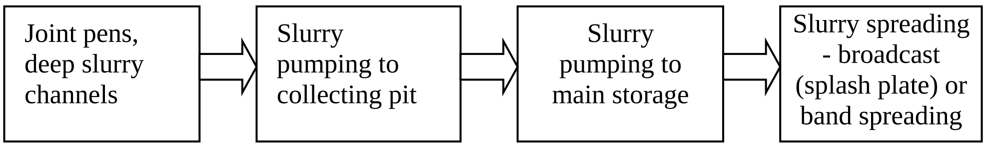

Figure 2-27. State-of the art manure management chain for pig's manure.

Based on number of livestock (according to latest inventories), the annual production of slurry and solid manure last year (2016) in Poland is showed in Table 2-26.

Table 2-25. Yearly production of animal manure in Poland. Source: own elaboration, based on Farm Standards (Danish and Polish experts in PHARE project 2004), Polish Main Statistical Office 2016

Housing systems	Solid manure	Slurry
Tied up system for cattle Fully slatted floor	-	2 499 061
Tied up system for cattle, Fully solid floor	44 678 332	-
Deep litter for cattle, slatted floor on feeding area	6 028 944	2 403
Boxes, slurry in channels, cattle	-	3 446 481
Free- stall, boxes with solid dung and liquid manure, cattle	6 988 902	-
Free stall, mixed boxed system: solid and slatted floor, cattle	4 031 790	1 382 328
Fully slatted floor, pigs	-	4 500 231
Partially slatted floor, pigs	8 019 838	2 874 974
Deep litter for pigs	4 539 439	-
TOTAL	**74 287 245**	**14 705 478**

Manure storage systems

Large amount of manure is collected in different types of storages both circular and rectangular. Basically, the shape of tank does not influence the process of filling, storing and emptying, but it plays role by slurry mixing.

System with collecting slurry pit
Such system consists of submerged inlet connecting the livestock building (channels in building) with manure collecting pit, pipes connecting collecting pit with main storage tank. Collecting pit should have a capacity of at least the amount of slurry in the largest slurry channel in the livestock building. The connection of collecting pit has a water trap to avoid poisoning of animals and staff.

The pump from collecting pit could be used both for pumping the slurry to main storage tank or filling the tanker used to spread the slurry.

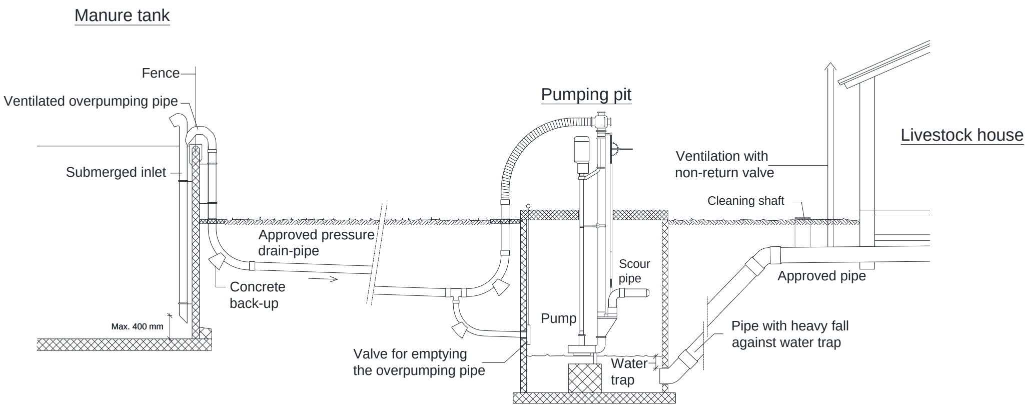

Figure 2-28. Pumping system from collecting pit to storage tank. Source: Romaniuk, Overby, 2004b

Figure 2-34. Left: Collecting pit for slurry. Niechłód Farm, photo by B. Lochowski ITP. Rigth: Concrete tank for cattle slurry. Niechłód Farm, photo by B. Lochowski ITP.

System with main storage tank
95% of slurry storage tanks in Poland are made from concrete. Slurry tanks with larger capacities are circular. There could be ground-based tanks, partially digged into the ground tanks and underground tanks. Tanks could be either open or covered. According to Standards for Manure Management the tanks with concrete covers have access openings with dimensions at least 0.8 × 0.8 m or 0.5×1.0 m when opening is rectangular. In case of circular opening the diameter must be at least 0.8 m. Outside the storage, there are working platforms with safety rails ensuring safety for personnel. Opened tanks could be ground-based or partially digged into the ground.

System without slurry storage tank
Collecting the slurry in deep channels is more or less popular in Poland. In winter, meaning during period when the application on field is forbidden (from end of October to end of February), especially in housing systems for cattle with deep litter, the slurry is collected in slurry channels and in spring it is pumped out and directly spread on fields.

The share of types of storing for solid manure, liquid manure and slurry is showed on Figure 2-29.

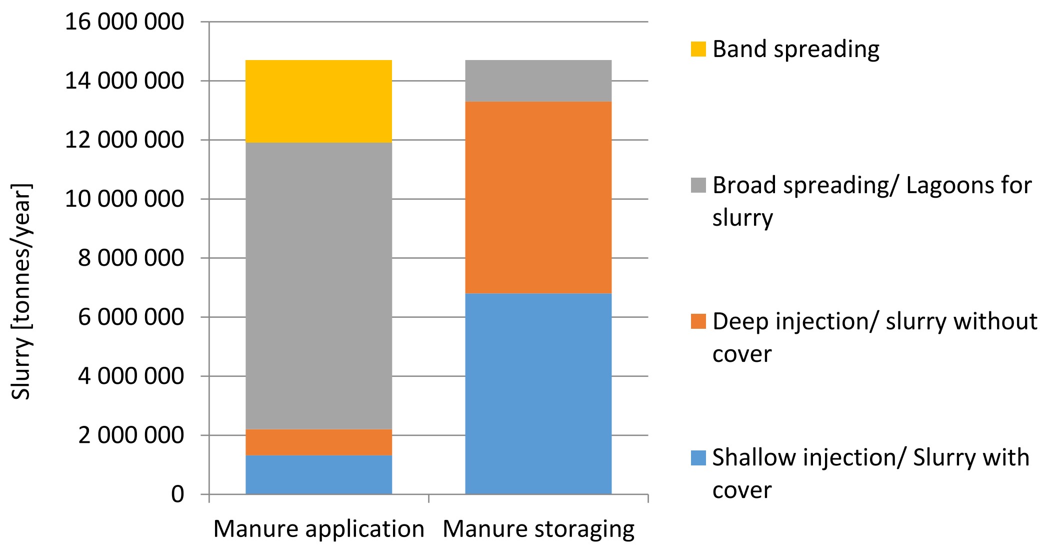

Figure 2-29. Division of the different manure storage systems and types of application/amount of yearly produced animal manure in Poland. Source: ITP elaboration.

Spreading systems

Slurry spreaders available in Poland are produced by following companies: Joskin, Meyer-Lochne (Recordia), Ursus, Meprozet, Sipma, Pomot Chojna, Pichon and Wielton. The filling in majority of the models is made due to vacuum pumps. In some slurry spreaders there are filling pumps. The most popular method for slurry spreading is still in Poland broadcast spreading with splash plate.

Types of slurry applicators mounted on slurry spreaders used in Poland

a. Applicators to bare soil: splash plate for arable lands. The slurry is broadcast spread with splash plate.

b. Slurry injectors: shallow injection with open slot (with the depth of injection up to 5 cm) and deep injection with closed slot.

c. Band spreading- row slurry spreader. From the cistern with slurry, a special pipe is merged, from which the slurry is transported to the row of small pipes. The working width is up to 12 m. The distance in between the rows of outlet pipes is 30 cm.

d. Slurry spreaders on grasslands with trailing shoes, which surface avoiding wetting the plants.

Slurry applicators other than splash plates are rarely used. It is showed on Figure 2-29.

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Sweden

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Typical handling systems/handling chains in three production systems

Table 2-27 presents the amount of manure used in Sweden for the growing season 2012/13 from agricultural animals (Statistics Sweden, 2014), and also amount of solid manure from horses estimated from number of horses (Statistics Sweden, 2017). In total of the manure produced in Sweden, 83% originates from cattle and 10% from pigs, the rest is from horses (5%) and other animals (2%). Manure are mostly handled as slurry or diluted urine, so about 84% the total amount of manure from cattle and pigs was handled with slurry technology at the latest inventory (Statistics Sweden, 2014).

Table 2-26. The use of animal manures by Swedish agriculture in the growing season 2012/13 (1000 tonne)

	Manure types					
Animal species	Solid	Semisolid	Deep litter	Urine	Liquid	Total
Cattle	2 680	510	790	1 010	19 200	24 190
Pigs	140				2 460	2 750
Other animals						470
Horses	1 422					1 422
Total	4 242	510	790	1 910	21 660	28 832

There is hardly any processing of slurry on Swedish farms, except digestion on a small number of animal farms. According to Swedish Energy Agency (2016), there were 40 farm based biogas plants in Sweden in 2015, of which 37 were in use. The digesters produced about 307.2 thousands of tonnes digestate, which is about 1.3% of the animal slurry handled in Sweden per year.

In Figure 2-35 the main steps are presented of slurry handling, and they are more detailed described in text. On the whole, about the same technology is used both for cattle and pig slurry, so it is for Swedish conditions not meaningful to distinguish between the animal species concerning SAT.

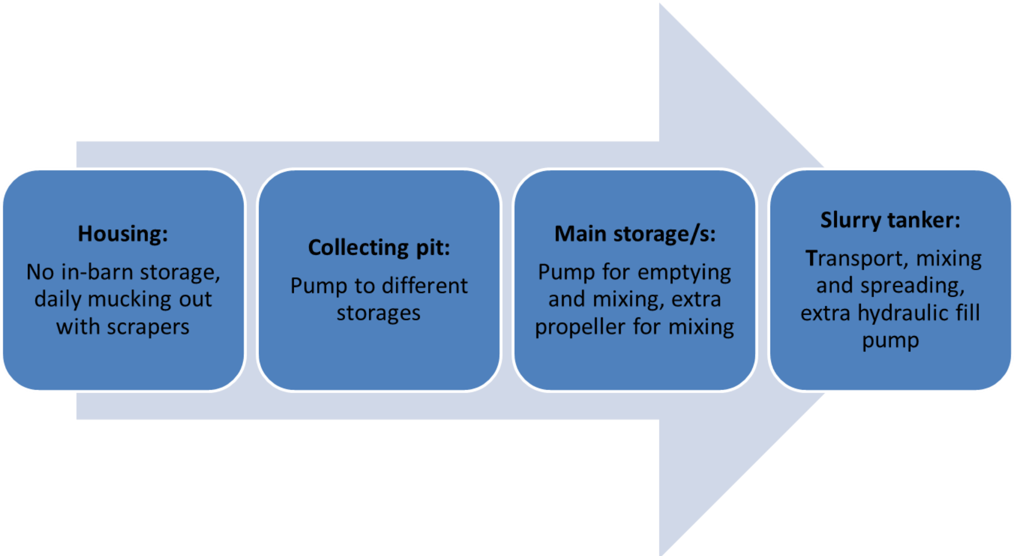

Figure 2-30. Main steps for slurry handled on Swedish animal farms.

Below are more technical descriptions of equipment used and measures implemented in Sweden for reducing ammonia emissions.

Housing systems and manure management

Key animal protection legislation is responsible for current standards and norms in livestock housing and manure removal systems in Sweden. These regulations were set up primarily due to risks of harmful gases affecting animals (21§ Kap.1 SJVFS 2010:15). As a result of these regulations, storing manure under slatted floors and flushing manure removal systems have not been permitted for the last 40 years. Instead, frequent manure removal, in practice often twice a day, with scrapers has become the norm building technique which is also considered BAT for reduction of ammonia emissions from animal houses (BREF 2015). During the official evaluation of the in-house SAT, JH Forsuring NH4+, elevated hydrogen sulphide emissions were measured when the daily flushing of manure took place during acidification (VERA, 2016). These reported elevated hydrogen sulphide emissions on a daily basis, even if overall emissions were lower, will likely make it difficult to get permits approved for in-house system without further testing or amending the regulations.

Housing systems with These regulations would also hinder the implementation of in-house SATs in livestock housing as flushing or pumping manure inside the barn is not allowed and manure cannot be stored under slatted floors but must be removed frequently, in practice often twice a day (15§ Kap.3 SJVFS 2010:15). There are also strict regulations that hydrogen sulphide cannot exceed 0.5 ppm in livestock housing (21§ Kap.1 SJVFS 2010:15), which might be an issue when using sulfuric acid for acidification.

The barns are either designed with slatted floors with slurry gutters with scrapers below or floors with scrapers (Oostra et al., 2006). Daily, the slurry is transported out from the barn by the scrapers often via transversal gutters to a collecting pit/buffering tank. The cross-channel drains or transport with scrapers the slurry out of the barn. It means, no slurry is stored in-housing, and consequently the in-housing SAT is not applicable for Swedish farms. Today, some farmers are building new barns also with scrapers on the slatted floors, despite the higher investment costs, because they feel they offer better hygiene for cows.

Figure 2-31. Slurry handling in barns. The transport area for the cows with slatted floor, with mechanical scrapers in the below gutter for removing the slurry from the barn daily.

The most common housing and manure removal systems in pig houses in Sweden are partially slatted floors over shallow manure channels that are mechanically scraped several times a day to an external storage tank (Wallgren et al., 2016). This system is considered to be best available technology (BAT) for reducing ammonia emissions according to the Industrial Emissions Directive BAT list (BREF 2015).

Vacuum manure removal systems of the type shallow pit with pull plugs and frequent removal are the next most common system in Sweden but accounts for less than 15% of pig houses (Wallgren et al., 2016).

Manure storage systems

The slurry from barns are first mucked out to a buffer tank (pumping pit), from where it is pumped to the main storage/s. The buffer tank has often a storage capacity of one to two weeks and is equipped with a stationary electricity powered centrifugal pump, used both for mixing and pumping. It is made from concrete and most part of it is below ground level. From the buffering tank, the slurry is pumped on to the main storage/s.

According to legalisations in Sweden, based on EU nitrate directive 91/676/EEG, most slurry storages must have a cover and the slurry should be filled under the cover. A stable crust is considered as a cover, and it is in most cases naturally formed, especially on cattle slurry surface. Therefore, according to the inventory of manure use 2012/2013, it is most common to cover the slurry with a stable crust (95% of the storages), and secondly to have a roof (4%) (Statistics Sweden, 2014). Nearly all (97%) of the storages with cover have the filling below the cover (Statistics Sweden, 2014).

The main storages are mainly made of concrete, where the walls are of concrete elements, see Figure 2-32. The depth of the storages are often between three to four meters, where about half of the height is usually placed into the ground, if not the ground conditions prevent it.

Figure 2-32. Slurry crust or roof as measure to reduce ammonia emissions on slurry storages. Filling is done below cover.

Mixing the slurry in storage before spreading is done with the stationary pump, but often you also need an additionally propeller mixer for mixing the crust into the liquid phase (Figure 2-39). Such mixers are often mounted on a tractor, driven by the PTO or by the tractor’s hydraulically system. The mixer could be mounted to tractor with different adapters, so it will be possible to mix even when the walls are 4 m high (http://starspridaren.se/forhojningsstativ/).

Figure 2-39. Use of a separate tractor driven mixer to mix in the straw crust just before spreading.

In Sweden, slurry lagoons are less common, as it is hard to get a good mixing of the slurry in those storages.

Spreading systems

Figure 2-40 presents how the slurry has been spread from 2003 till 2013 (Statistics Sweden, 2014). In Sweden slurry is mostly spread with band-spreading technology and its use has increased over the years.

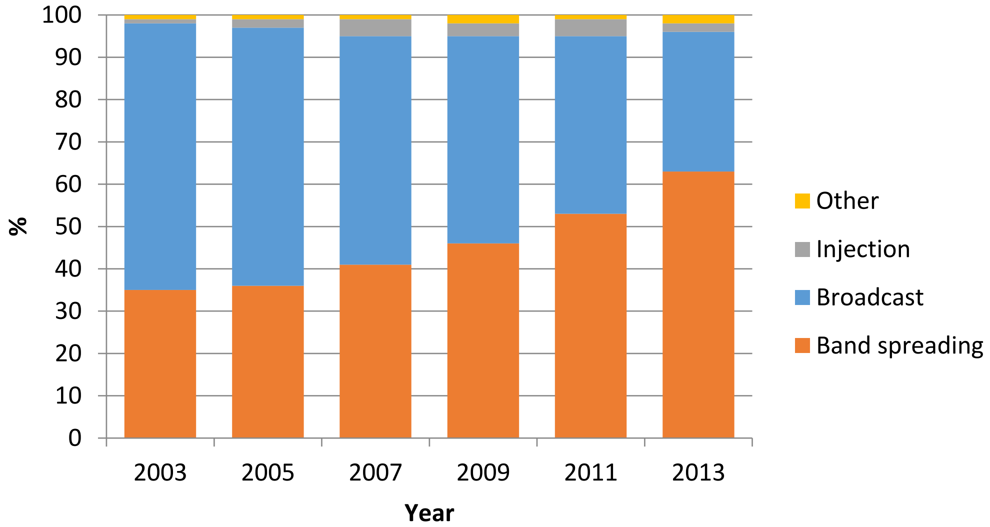

Figure 2-40. Statistics of spreading technologies used in Sweden for several years (Statistics Sweden, 2014).

At the last inventory, 63% of the slurry was field applied with band spreading technology. Injection techniques were only used for 2% of the slurry (Statistics Sweden, 2014) and injectors are mainly used for grasslands. The technique has not become popular in Sweden, as it has not proven to be economically profitable although reducing ammonia emissions.

Figure 2-41.Band spreading is the dominating spreading technology in Sweden (left), but some slurry is spread also with injectors (right).

In growing cereals, slurry could be band spread and thereby protected at the bottom of the plant canopy, which limits the ammonia emissions. On open arable land, it is in most regions compulsory to incorporate the slurry into the soil within certain hours after surface application with broadcast or bandspreading techniques. According to the inventory, 44% of the slurry spread on open soil was incorporated directly after spreading by harrowing or similar, and additional 25% within four hours after spreading (Statistics Sweden, 2014). Only 17% of the slurry was incorporated later than after one day.

We estimate, based on search on the Internet and telephone interviews with 30 contractors in Sweden that about 25 of them in total spread about 3.5 million tonnes of slurry per year in Sweden. It corresponds to about 15% of the slurry produced per year.

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Interreg
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EUROPEAN REGIONAL DEVELOPMENT FUND

Baltic Slurry Acidification

www.balticslurry.eu

Summary of the project

Baltic Slurry Acidification is an agro-environmental project funded by the Interreg Baltic Sea Region program in the priority area Natural Resources focusing on Clear Waters. The aim of the project is to reduce nitrogen loss from animal production by testing, demonstrating and promoting the use of slurry acidification techniques in countries around the Baltic Sea.

Summary of the report

The aim of this report is to: 1) give a brief technical description of the different slurry acidification techniques (SATs), and 2) have experts from each country analysis how the SATs can be implemented on manure handling systems in their country and to point out current technical bottlenecks for implementation of SATs in the Baltic Sea Region.

Contributing partners:

- **RISE – Agrifood and Bioscience, Sweden**
- **Association of ProAgria Centers, Finland**
- **ECRI – Estonian Crop Research Institute, Estonia**
- **ITP – Institute of Technology and Life Sciences, Poland**
- **Latvian Rural Advisory and Training Centre, Latvia**
- **Lithuanian Agricultural Advisory Service, Lithuania**
- **State Agency for Agriculture, Environment and Rural Areas of German Federal State Schleswig-Holstein, Germany**
- **Union Farmers Parliament, Latvia**