

Sustainable manure management in the Baltic Sea Region



Results, cases and project recommendations

Baltic Forum for
Innovative Technologies for
Sustainable Manure Management



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This magazine contains the major results, conclusions and recommendations of the project Baltic Forum for Innovative Technologies for Sustainable Manure Management (Baltic Manure) which via co-funding from Interreg Baltic Sea Region programme has been a Flagship project in the EU Strategy for the Baltic Sea Region from 2010-2013.

The project has involved 18 partners from 8 countries with MTT Agrifood Research Finland as the Lead Partner.

Acknowledgements

These results are compiled by Agro Business Park based on inputs from the whole project group. Without these dedicated inputs and the great spirit of cooperation between the research institutions involved and across borders and scientific traditions and disciplines, the result would have been much less coherent – and much less useful.

It is our hope that the results presented here can inspire to better and more sustainable solutions for animal husbandry as a cornerstone of agriculture in the Baltic Sea Region. Thanks to colleagues in the project who has contributed to the presented results.

The business cases presented are not technologies that have been tested in the project, but cases of technologies on the market addressing the challenges described in the text. Some of the cases have applied for or been awarded the Baltic Manure Handling Award.

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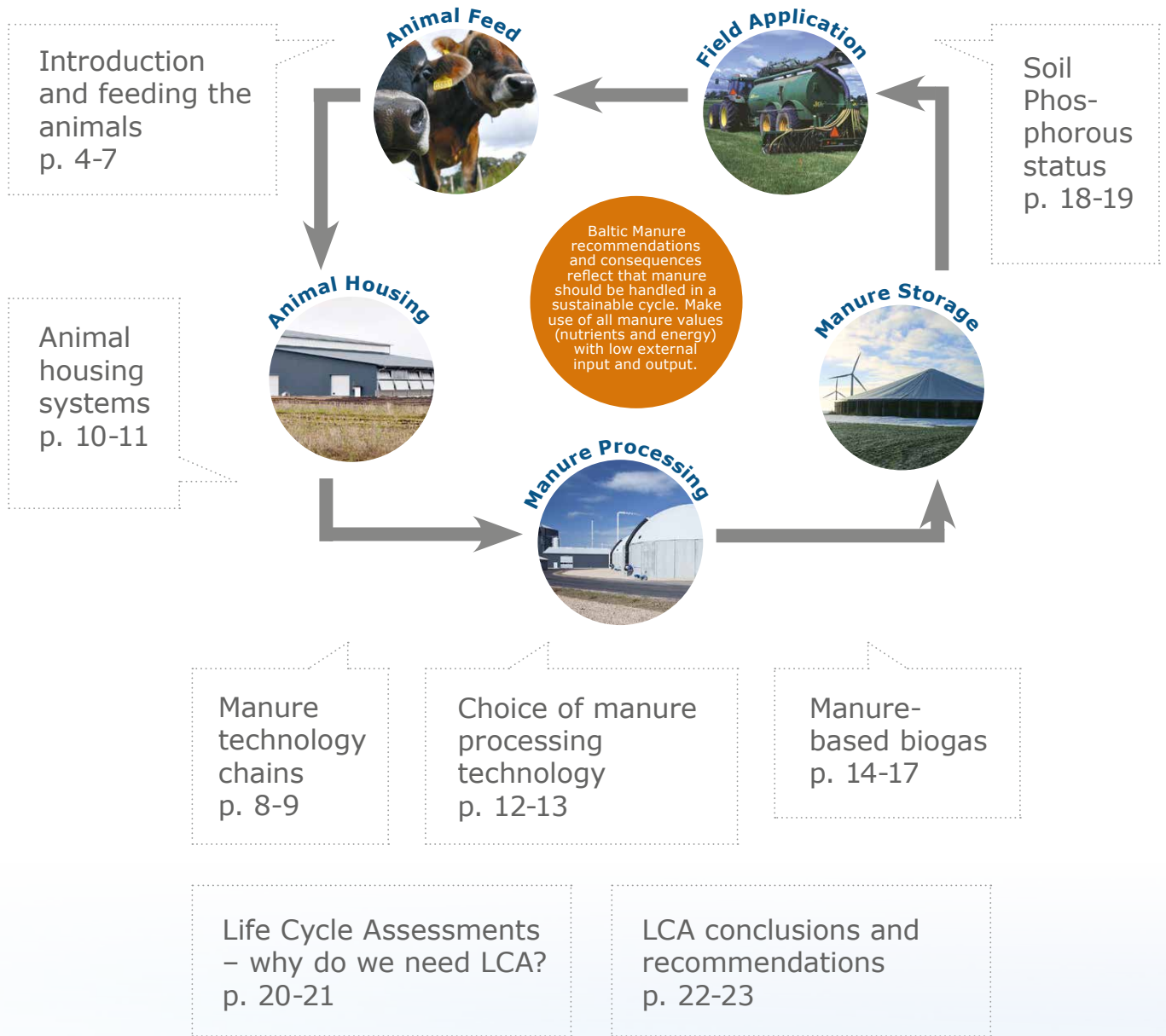


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Magazine content

Results, cases and project recommendations



Introduction

A functional farming system is a key to a sustainable future in the Baltic Sea Region (BSR).

For the sustainability of the farming system, farming practices and consumer requirements have a strong impact on the condition of the Baltic Sea. In the BSR, there are varying densities of animal husbandry – and thus production of manure. It is calculated that all manure in the BSR contains 981,000 tonnes of Nitrogen and 281,000 tonnes of Phosphorus.

Some of these nutrients are currently not efficiently utilised and partly leach into the Baltic Sea causing algae bloom and eutrophication in some regions of the sea.

Few people remember that in fact they themselves produce manure – indirectly, of course. If you are not a vegan, you create the market for different animal products from meat, milk and leather to riding lessons. It is our common responsibility to handle manure with proper care and to find optimal handling solutions.

The long-term strategic objective of the Baltic Manure project is to change the general (public) perception of manure from a waste

product to a resource, while also identifying its inherent business opportunities.

Farmers know that manure is a resource, but the project results can improve the utilisation efficiency via recommendations for farmers, policy makers and businesses.

The livestock production chain may be summarised as five main stages on which technologies can be applied:

- 1) feed and feeding systems,
- 2) housing systems,
- 3) manure processing and management,
- 4) manure storage, and
- 5) field application of manure.



This manure nutrient cycle is not at present a closed cycle. We import nitrogen and phosphorus from other regions and lose them as emissions to air and waters.

In the project, the basic assumption has been that the level of livestock production is market driven due to the global demand for meat and dairy products – and that this level can become more sustainable through optimal utilisation of the manure resource. Thus, we do not attempt to promote less animal husbandry or other radical changes in the agricultural system, rather we suggest improvements of the present production systems.

Another basic approach of the work in Baltic Manure is to take a





The intention is to continuously improve the nutrient and energy efficiencies, thereby reducing the losses into the environment. This is where the recommendations presented here are relevant.

In this context, also farm size and farm structure in different regions/countries matter significantly. Animal density has its influence, but definitely also the farm size is important for the profitability of new technological investments to improve the utilisation of the manure resource.

Focused and coordinated research and development on manure handling has never before been conducted in the BSR to the extent as in Baltic Manure. In the following, we will extract recommendations based on the research and experience of the cross-disciplinary team in Baltic Manure. Many project partners have given inputs and this is a first draft of a common communication of these recommendations.



holistic supply chain with recycling of resources into account. This requires a strong focus on all input (including animal feeding) and output resources of the animal husbandry and manure production.



Feeding the animals

The increase in number and productivity of farm animals in the BSR has for decades increased the demand for imported feedstock, especially protein sources like soy bean meal and mined phosphates from other continents.

This creates the largest global environmental impact from animal husbandry in the BSR as confirmed by Life Cycle Assessments. In addition, the import of nitrogen and phosphates has resulted in an increase in manure nutrient content, leading to nutrient supply to the crops that is above the crop demand.

Animals need protein and amino acids - containing nitrogen - for growth and production. In former days, amino acids could only be provided by the feedstock. The required dietary crude protein was very high resulting in a corresponding low net utilisation and large excretion of nitrogen into manure.



Phosphorus is also an essential nutrient for animals to ensure production and health. The addition of mineral feed phosphate became widely used for decades because the digestibility of phosphorus in cereals was too low to fulfil the animals' need. As a result, the net utilisation of phosphorus was low, resulting in large excretion of phosphorus into manure.

However, increased focus on the aquatic environment has been one of the main driving forces for improvements in nutrient utilisation and derived reductions in excretions of phosphorus and nitrogen in farm animals.

The work in Baltic Manure on feeding has focused on the present feeding practices and the overall potential for future reductions in the nutrient excretion through improved feeding strategies.

This requires specific knowledge on the nutrient concentration and quality of the feed, e.g. the amino acid profile of crude protein. Dietary crude protein can be replaced by industrially produced amino acids like lysine, methionine, threonine, and tryptophan, which re-



Standard values for one Danish pig (32-107 kg) ¹⁾

Kg feed/kg gain	2.72
Crude protein	140.4 g/kg feed
Phosphorus	4.6 g/kg feed
Nitrogen excretion	2.84 kg
Phosphorus excretion	0.62 kg
Manure volume	0.52 ton
Nitrogen concentration	4.54 kg/ton
Phosphorus concentration	1.19 kg/ton

Standard values for one Danish dairy cow, heavy breed ¹⁾

Milk yield	9374 kg
Milk protein	319 kg
Milk protein	3.40 %
Feed intake	6998 FE
Crude protein	172 g/FE
Phosphorus	4.15 g/FE
Feed efficiency	83 %
Nitrogen excretion	140.9 kg
Phosphorus excretion	19.6 kg
Manure volume	31.4 ton
Nitrogen concentration	4.27 kg/ton
Phosphorus concentration	0.62 kg/ton

Feeding recommendations and tools to reduce the excretion of phosphorus and nitrogen

- Reduce the import of crude protein by replacing soybean meal by industrially produced amino acids for pigs and poultry.
- Reduce the import of mined phosphates by replacing feed phosphates by microbial phytase for pigs and poultry.
- Use protein and energy optimised diets for dairy cattle.
- Use multiphase feeding as a tool to supply the animals with the nutrients required for optimal health and production.
- Use liquid feeding as a powerful tool to improve the utilisation of phosphorus and protein in animals.

1) 2013 <http://anis.au.dk>



sults in a lowered inclusion rate of soybean meal and thus reduced import of nutrients.

The enzyme phytase stimulates the degradation of phytate (the chemical form of phosphorus in plant tissue) rendering phosphate available for uptake by the animals. When the phytate is degraded and phosphates released, the need for imported feed phosphates is lowered. The increased use of microbial and plant phytase can diminish the need for feed phosphates and reduce the excretion of phosphorus.

Facts about animal needs

- Livestock require nutrients to produce milk, meat and eggs. The essential nutrients and energy is obtained by the feed offered.
- Different animals require different amounts of nutrients and the supply has to be tailored to the animal-specific need.
- Farm animal feed consists typically of locally or regionally grown crops together with imported feedstock, such as processed soy bean meal from other continents.
- Mined phosphates are imported to the livestock sector and used to fulfil the animals' requirements.
- The utilisation of nutrients is generally between 15 to 45% of the nutrient intake and is the highest in meat producing animals.

Also more precise feeding strategies like phase feeding are important tools for reducing the need for imported feedstock.

Liquid feeding seems to be valuable to increase the digestibility of phosphorus and to some extent also protein.

Find more details on www.balticmanure.eu



Manure technology chain overview

Livestock manure consists of faeces, urine, food residues, bedding materials and water.

It contains nitrogen (N), phosphorus (P), potassium (K) and micro-nutrients which should be utilised by plants. Manure is by no means a uniform product; instead it varies between animal species, from farm to farm and also during the year on the same farm.

Manure facts

In the Baltic Sea Region, there is approximately 187 million tons of cattle, pig and poultry manure produced each year.

Most of it can be found in Poland, Denmark and the northern German states with coastline to the Baltic Sea.

The Russian manure production is significant, but was not included in this project.

The highest share of slurry, 80%, is in Denmark, while in Poland 90-95% of all manure is solid. Overall nearly 50% of the manure in the BSR is solid.

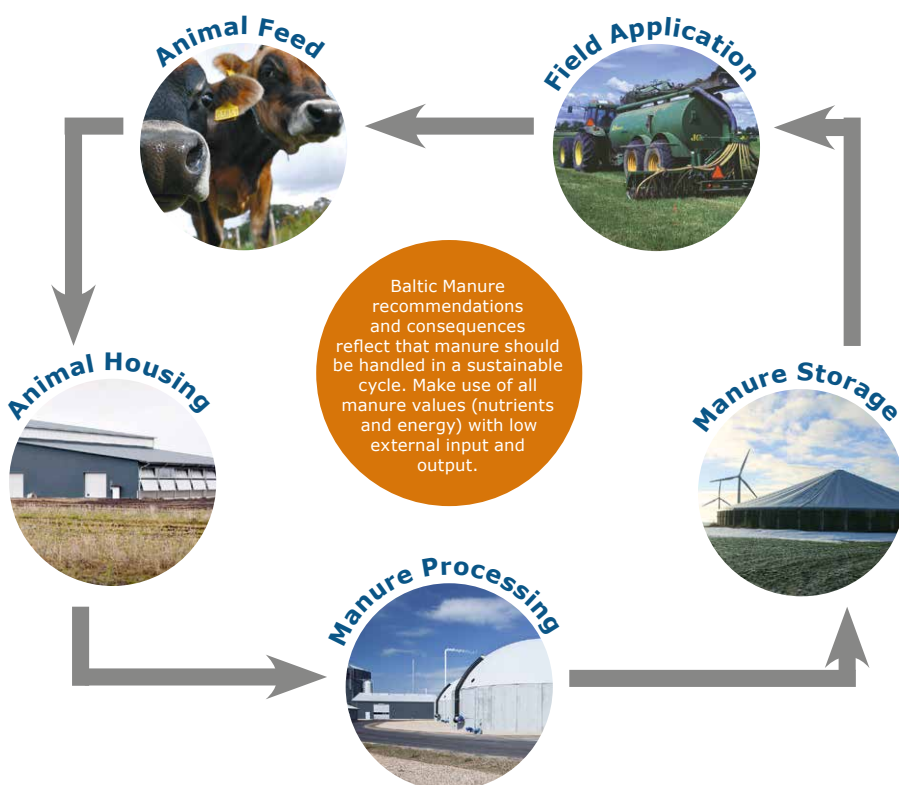
Properties like consistency, density, and nutrient content depend not only on the type of animal production (e.g. species, age and feeding ratio), but also on the type of the animal housing and subsequently on the required additives, removal systems and storage for the manure produced.

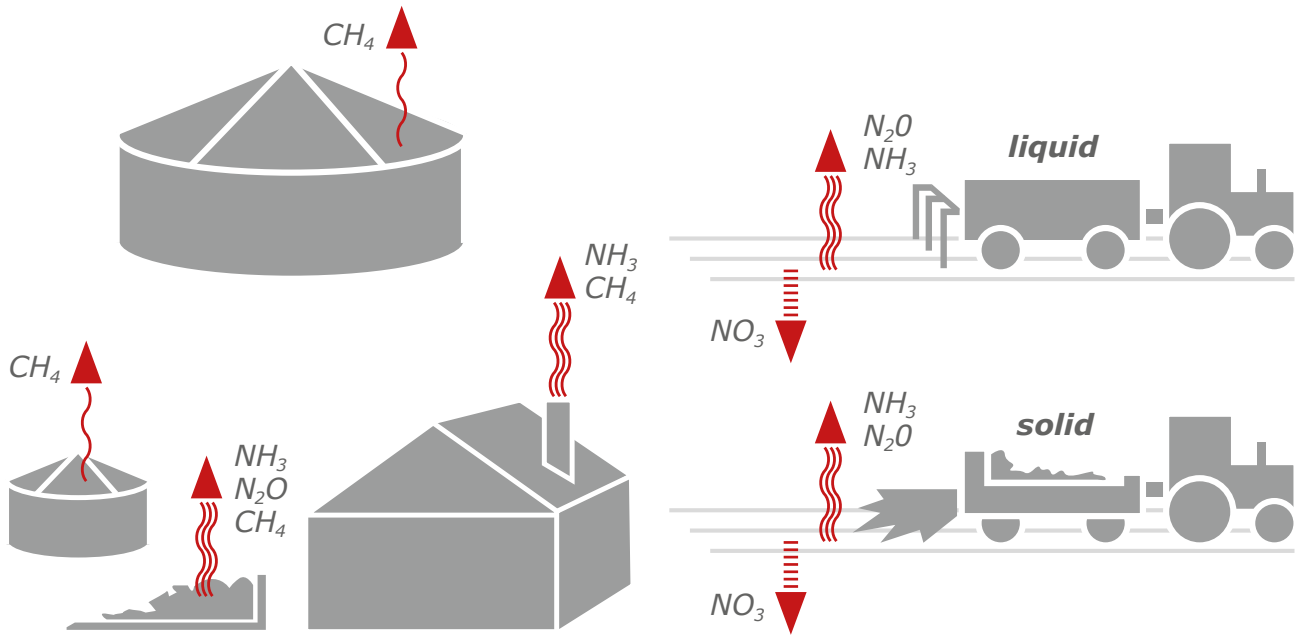
Manure is usually divided into the following three groups depending on its consistency and dry matter content: liquid (slurry), semi-solid, or solid manure.

The most important additives into manure are water and bedding materials. E.g. in slurry-based animal houses manure is diluted deliberately with washing waters. The choice and amount of bedding also affects manure properties. Peat or sawdust results in completely different manure properties than addition of straw.



Whatever type of manure, it needs to be stored before application on fields. A sufficient storage volume is essential for being able to apply the manure on fields during the vegetative period when the growing crops take up the manure nutrients directly (spring, early summer). Obviously, the dose should be according to the crops need, the nutrients spread with high evenness, and N loss through ammonia (NH₃) volatilisation minimised with





Storing and spreading of manure in liquid or in solid form. Red arrows point out the risks of N losses either as gaseous emissions like ammonia contributing to eutrophication and acidification and nitrous oxide contributing to climate change or as leakage to water as nitrate. There is also a risk of methane (CH_4) emissions from stored liquid manure.



incorporation/injection of manure into soil. Since NH_3 can also volatilise during housing and storage, it is important to minimise NH_3 losses in those handling steps as well. This can be achieved e.g. by quick collection of manure from animal houses to covered storages.

The choice of technology for handling manure is decided by the consistency of the manure, starting with the mucking out technology in housing and ending with the spreading technology.

In Baltic Manure the contemporary handling chains were studied on 31 case study farms with large-scale dairy, pig and poultry production in the BSR.

The manure was handled as slurry on most pig farms, while on poultry farms manure was mainly handled in solid form. On dairy farms, 62% of the total amount of manure was handled as slurry and the remaining 38% as solid manure.

Find more details on www.balticmanure.eu



Animal housing systems

Animal housing should make an effective environment for production and meet the animal's basic needs for space, air, food, water and social behaviour. Animal welfare and environmental considerations regulate the housing systems.



How the farmer handles the manure in the animal housing will have an impact on the physical and chemical properties of the manure. This will in turn affect how well the nutrients can be utilised in the plant production.

Daily manure removal with scrapers into primary slurry channels is the most common practice on the slurry-based case study farms with large-scale dairy and pig production in the BSR. Further on, the manure usually flows in cross-channels to storage in tanks made of concrete panels outside the farm building.

For the solid manure either mobile manure removal technology as a tractor, a four wheeler with scraper or mechanical scrapers/conveyors are used and the manure mostly stored on concrete pads or in field heaps.

Dilution of manure with water is a major challenge on the studied farms. Phosphorus concentrations in slurry leaving the animal house (Ex-housing) was about half of the concentrations excreted from animals (faeces + urine; Ex-animal) on slurry-based Swedish and Estonian dairy farms (See figure below and table page 9).

This reflects nearly 100% dilution of the manure in the housing system. Water dilution increases the amount of manure and gives a significant decrease in its fertiliser value, not to mention increased costs for manure storage and handling.

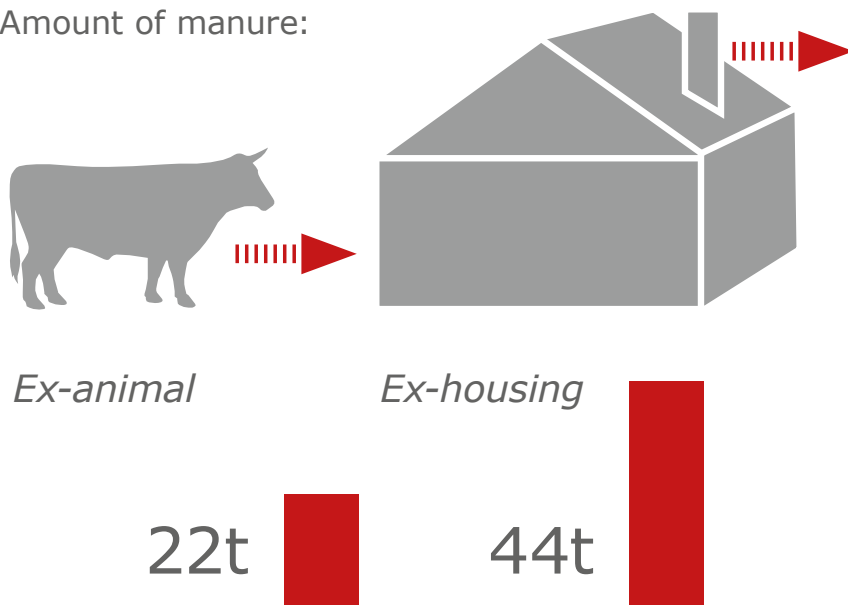
On pig farms some dilution in the housing system was apparent as well, although less significant than on dairy farms, whereas there were little changes in manure quality in the poultry housing system.

Manure properties did not change significantly during storage on the case farms. Thus, manure handling in the housing system has a greater effect on manure properties than storage, even though many of the storage facilities were not covered resulting in addition of rain water and in evaporation.

There was a large variation in the P concentrations and other characteristics of manure Ex-housing and Ex-storage among all case study farms and also within one farm during one year. This indicates that the spreading dosage should ideally be based upon actual manure nutrient analysis.

Read more details in the manure sampling manual at www.balticmanure.eu.

Amount of manure:



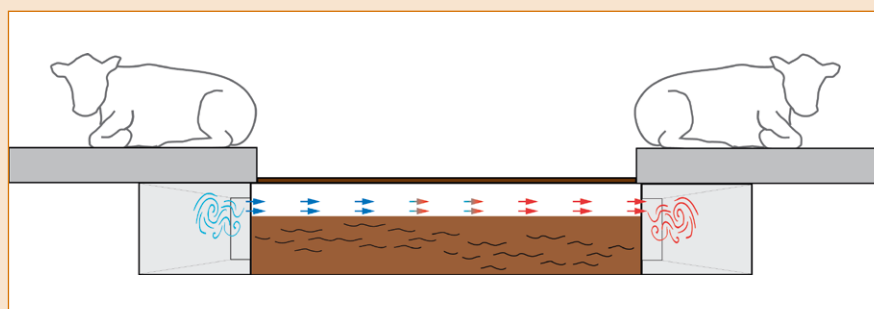
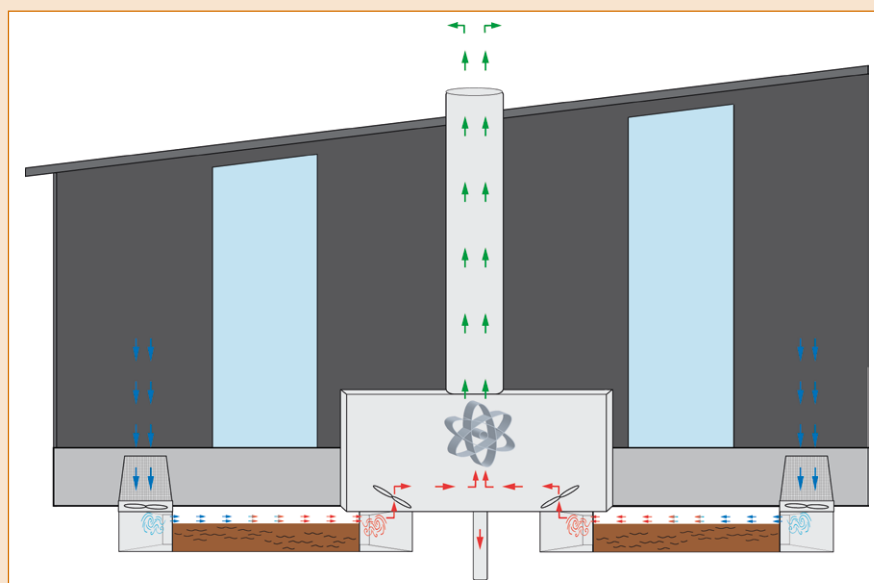
Example of increased amount of manure (tonnes per year) from one dairy cow with annually excreted faeces and urine Ex-animal to the increased amount as slurry Ex-housing. The increase is mainly due to water addition during housing.

AgriFarm – housing system for dairy cattle.

AgriFarm has developed a new housing system for dairy cows with a newly developed ventilation system, Environment Defender. In this system a controlled air stream is flowing across the manure in the slurry channels, thereby capturing ammonia, odour gasses, methane and other emissions at the source. The polluted air stream is transferred to a central chimney in which it is cleaned by a special filter addressing various pollutants.

The housing system is partially closed due to the window panels which are opened and closed automatically according to the temperature and climate inside and outside the building. The patented system is awarded nationally and internationally.

AgriFarm has also developed environmentally friendly housing systems for pig production. For further information please visit www.agrifarm.dk.



Recommendations

- Control water additions to slurry as an integral part of manure management.
- Separate and re-use cleaning water when possible.
- Collect manure frequently from housing to outdoor storage.

Percentages of nitrogen and phosphorus in the manure in three steps as based on Swedish and Estonian dairy case farms. Ex-animal is 100% for N and P with significant dilution after housing and storage. Some variation between farms was found (number of animal houses studied were 7):

	Ex-animal	Ex-housing	Ex-storage*
Average Total N	100%	52%	62%
Average Total P	100%	52%	61%

*Sampling made mainly in spring, not including slurry produced in summer (often more diluted)

Choice of manure processing technology

There are several reasons for processing manure and a wide range of different processing techniques available. Still, few are implemented on farm level during the time of writing (2013).

Some of the reasons for processing manure are:

- Reduce the amount of manure to be stored, transported and spread.
- Increase the nutrient utilisation of the manure.
- Utilise the energy potential of the manure.
- Improve the handling properties.
- Reduce odour.
- Improve the economy of manure handling, e.g. by producing commercial fertiliser products.

Some examples of manure processing technologies were found on the case study farms, including technologies for nutrient concentration, slurry acidification, mechanical separation, slurry cooling in manure channels and anaerobic digestion.

The technologies implemented were mainly for processing slurry, and only one technology (drum composting) was for processing of solid manure. The processing technologies had a capacity ranging from 1200 to 20 000 m³ slurry per year, Table p. 13.

Information on nutrient flows and balances was unavailable for the processing technologies under varying conditions. Such information, however, is needed in order to analyse whether the manure processing technologies are actually reducing the environmental impact of livestock production. The technologies for concentrating manure nutrients on the case study farms are not yet commercially available for farm use, while the other processing technologies are



on the market. For instance, mechanical separation has been commercially available for a long time. Slurry acidification (in-house or during field application) has been increasingly implemented on farms in Denmark during recent years. The estimated processing costs were 1-7 EUR per m³ slurry and year, Table p. 13. The profitability of the investment depended very much on the income derived from selling fertiliser products.

An accurate and realistic farm-specific business plan for investment is strongly recommended, as external income could be the driver of good financial returns. It is also important to consider the entire manure handling chain, so that all components are resolved (e.g. how to spread new fertiliser products, nutrient plant availability, etc.) before investment.

Find more details on www.balticmanure.eu

Farm business plan for technology investments

For each farm, a calculation of the investments and consequences for choosing manure handling technologies should be undertaken. What is profitable for one farm in one location might not be profitable for another farm.

The analysis should balance the investment and environmental benefits in the entire manure chain, point out the barriers and support opportunities for the farmer.

Drum composting of manure

European Composting System AB (ECSAB) has developed a drum composting system, Quantor® XL, for processing manure.

The system fulfils EU-regulations for animal by-products and is validated by the Swedish Board of Agriculture. With the closed composting system the farmers can get incomes both from selling high quality fertilizer products and by getting acceptance fees for example from horse owners delivering horse manure.

The treatment capacity for one drum system is 10.000 m³ of manure per year and the optimal temperature range is 52 – 70 °C. The electricity consumption for one drum system per year is 20,000 kWh with continuous operation, but the composting process itself generates excess heat which may be re-used in the process or potentially for heating adjacent buildings. For further information please visit www.ecsab.com.





Most common manure processing technologies on studied farms, including processing capacities, motives for investment and estimated costs. Annuity method used for calculating depreciation, investment lifetime 10 yrs and interest rate 5%.

Method, (country)	Type of farm and processing capacity	Main motives for use by farmer	Costs, € m ⁻³ yr ⁻¹	Incomes and savings not included
Nutrient concentration technologies				
Split-Box (SE), prototype	Dairy farm. Targeted capacity 15000 m ³ yr ⁻¹ .	Reduce volume to store and spread.	4.92	Less costs for storage, transport and spreading; possible fertiliser sale.
Pellon (FI), prototype	Pig farm. Targeted capacity 6000 m ³ yr ⁻¹ , test farm produced 2200 m ³ yr ⁻¹ .	Reduce volume to store and spread.	3.81	Less costs for storage, transport and spreading; possible fertiliser sale.
Reverse osmosis (NL)	Pig farm with 1050 sows. 10 000 m ³ yr ⁻¹ .	Reduce volume, export solids and concentrate off-farm.	6.49	Reduced costs for exporting manure off farm, income for liquid fertiliser.
Acidification of slurry				
InFarm A/S (DK)	Pig farm, produces 6500 fatteners yr ⁻¹ . Max capacity unknown. Farm produced 3250 m ³ yr ⁻¹ .	Ammonia abatement demanded by legalisations.	6.68	Saved N; S fertilisation unnecessary.
BioCover (DK)	Fictive farm with 3800 pig places, typical for Denmark. Max capacity unknown. Farm produced 6000 m ³ yr ⁻¹ .	Ammonia abatement demanded by legalisations.	1.04	Saved N; S fertilisation unnecessary.
Composting				
Drum composting 1 (SE)	Beef animals, import horse manure. Mainly 10 000 m ³ yr ⁻¹ horse manure, minor deep, organic residues.	Produce commercial soil and fertiliser products.	5.55	Income from tipping fees, sold commercial soil and fertiliser products.
Drum composting 2 (SE)	640 sows, 5500 places for finishers, beef cattle (150 nursing cows). 13500 m ³ yr ⁻¹ solid manure from horses, beef, separated solids from pig slurry.	Less manure to handle, income from compost sold to a company that produce soil improvers.	3.96	Income from reduced volumes to store and spread and sold commercial soil and fertiliser products.
Mechanical separation of slurry into two phases				
Separation, screw press (FI)	600 sows, 2300 finishers yr ⁻¹ . Max capacity 20 m ³ hr ⁻¹ cattle slurry, 25 m ³ hr ⁻¹ pig slurry. Farm produced 1700 m ³ yr ⁻¹ .	Allocating of manure nutrients on farm, reduce odour, improved properties.	2.11	Saved logistic costs, better allocation of nutrients on farm.
Separation, centrifuge (SE)	450 milking cows plus recruitment animals. Dairy farm produced approx. 20 000 m ³ digestate yr ⁻¹ .	Reduce volume of liquid digestate, lower P concentration in the liquid fraction.	1.62	Less costs for liquid manure handling (but costs for solids).
Cooling and heat recovery				
Pellon (FI)	1000 fattening pig places. 1200 m ³ yr ⁻¹ (out of 2000).	Save energy, decrease emissions.	2.99	Saved N and energy.

Biogas in the Baltic Sea Region

Manure is usually utilised as an organic fertiliser with the focus on its nutrients.

However, manure also contains organic matter (carbon) and thus energy. Baltic Manure studied different technologies for energy recovery from manure, with the focus on biogas production.

Biogas is the most mature technology for recovering manure energy and it offers multiple benefits as a renewable energy source, by improving the nutrient utilisation of especially manure nitrogen and by offering means for emission mitigation.

The energy content of manure is relatively modest, but as the amounts of manure produced are significant, the energy content is appealing for energy production.

Agricultural production is energy-intensive at the farms and in the production of mineral fertilisers and the replacement of this fossil energy consumption with renewable energy is attractive from a societal perspective.

According to estimations made in the Baltic Manure project, the realistic energy potential of manure in the BSR is 17-35 TWh (61-126 PetaJoule) as biogas. This includes manure from farms with more than 100 animals annually.

An important thing to consider for harnessing this energy potential

What is biogas?

When manure is kept in a digester without oxygen, the organic matter in manure is degraded into biogas by specialised bacteria. Biogas is partly methane (CH₄) and partly CO₂, and the methane can be used for various energy purposes (heat and electricity, and after removal of CO₂ also for transport).

The residual mass from the digester, the digestate, contains all the manure nutrients and a higher share of directly plant-available ammonium nitrogen than raw manure – it is an improved fertiliser.



as biogas is the share of slurry and solid manure which differs from country to country. The manure types are related to available technologies for manure digestion.

The technology (continuously stirred tank reactors) for slurry digestion is mature and widely used, whereas the digestion of different solid manures requires further development. Rather, some of the solid manures should be co-digested with slurry directly or after pre-treatment.

Different mechanical pre-treatments, such as extrusion and milling for reducing the particle size

and increasing degradability in the digester, can be recommended. Still, the share of solid manure for slurry-based biogas plants is limited as the dry matter content in the digester should remain below approximately 15%.

Baltic Manure concludes that biogas is the best solution for manure energy use today. Despite its potential, it is calculated that only around 2% of all cattle, pig and poultry manure in the BSR (excluding the German states on the shore) is presently used for biogas – with a large variation between countries. The unutilised



Biogas digestate fertilisers

Biovakka Finland Ltd produces commercial fertilisers and biogas based on pig slurry and co-substrates, such as industrial by-products. The company was founded in 2002 by 21 farmers.

Biovakka has seen a business opportunity in producing commercial digestate-based fertilisers. The plant operates in accordance with the animal by-product regulation and the raw materials for the fertiliser products go through a hygienisation process. Different post-processing steps allow Biovakka to produce a wide range of different fertiliser products.

The produced fertiliser products are a relevant alternative to mineral fertilisers and the nutrients are readily available for the crops.

For more information please visit www.biovakka.fi.



potential for manure based biogas is immense.

In order to take full advantage of the benefits of manure based biogas, few essential actions need to be considered.

The energy yield of manure (slurry) based biogas can be increased with co-substrates.

The co-substrates to be promoted are manure-derived materials (solid manure, separated solid fraction of slurry) or other societal and agricultural waste materials with no uses as food or feed. The

environmental impacts of annual energy crops, such as maize, are significant. Thus, their use should be minimised.

The digestate directly out of the digester is still biologically active and contains degradable organic matter. It should not be stored in open tanks, but directed into a gas-tight post-digestion tank with biogas collection.

The post-digester biogas production is significant for the total energy yield from the plant and if emitted into the atmosphere, a significant source for greenhouse gas emissions.

The digestate also contains more ammonium nitrogen than raw manure. It is easily volatilised and lost as ammonia if the digestate is not stored properly. Covered storages are recommended.

When applying the digestate on fields, ammonia is also easily lost via volatilisation and/or leaching. It is recommended to inject/incorporate the digestate into the soil.

Find more details on www.balticmanure.eu



Storage and field application of manure products

On the slurry-based case study farms with large-scale dairy and pig production, the slurry was mainly stored in concrete tanks. More than half of these were covered, in most cases with an undisturbed crust. Appropriate application rates and timing are important for achieving high nutrient uptake by plants and low leakage to water together with measures to minimize ammonia emissions.

Mean slurry storage capacity was seven months for dairy farms and almost ten months for pig farms. Several poultry and pig farms operated without any arable land and instead exported the manure to other farms.

The slurry was mainly band-spread (84%) on grassland (dairy farms) or before sowing of a cereal crop in spring or early autumn (pig and poultry farms). About 7% of the slurry was spread with soil injectors, either with shallow disc



tines in grassland or with cultivator tines in open soil before sowing a crop, often maize.

Application rates of 20 to 30 tonnes manure per ha dominated, but rates as high as 80 tonnes per ha were reported. However, poultry manure was applied at rates of 2.5 to 10 tonnes per ha but with low spreading accuracy, as existing spreaders cannot cope with such low doses.

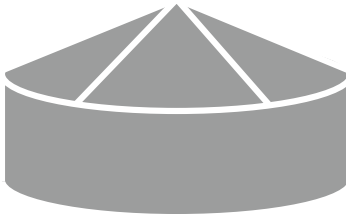
Slurry designer fertiliser

The SyreN system from BioCover, where sulphuric acid is added directly to the slurry during field application with trailer hoses, has won 8 national and international awards. With 87 SyreN systems in operation, the system currently treats >5 mill. m³ slurry per year. The system was awarded the Baltic Manure Handling award in 2012.

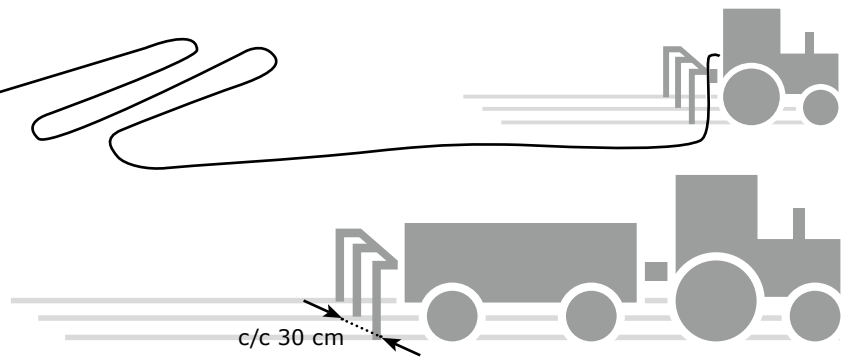
SyreN+ system is a further development to adjust the nutrient values of slurry during application. With an integrated ammonia pressure tank in the slurry tanker, the system can add liquid N (ammonia) to the slurry during field application and the slurry is thereby 'designed' according to crop needs in one field operation.

For more information please visit www.biocover.dk.





Slurry application by tanker or umbilical hose spreader



Solid manure was most often stored on concrete pads, but also in field heaps. In most cases solid manure was stored without a cover, although on two poultry farms manure was covered with either peat or straw.

In general, manure handling after storage is the least well-described part of the manure handling chain. Therefore, emphasis should be given to the responsibility of livestock farmers for the end-use of manure. This means more focus on the timing, dosage and spreading evenness of manure application in the field.

The farmers interviewed pointed out a range of bottlenecks that

make it difficult for them to fully utilise the resource potential in manure. Four categories of bottlenecks were identified:

- 1) Costs/economic factors,
- 2) Technological limitations,
- 3) Lack of knowledge on solutions, and
- 4) Regulation or lack of incentives and support mechanisms for adopting best available technology (BAT).

The importance of appropriate application rates and timing for achieving high nutrient uptake by plants and low leakage to water together with measures to minimise ammonia emissions should be stressed.

Recommendations

- Place more focus on the timing, dosage and spreading evenness of manure application in the field.
- Ensure sufficient covered storage capacity.
- Minimise the losses of ammonia after spreading by harrowing directly after spreading, use of injectors or acidification
- Use precision agriculture for field application including manure analysis, dosage, high spreading evenness according to spatial field data.
- Use upper limits for P-dosage in the fields.



Soil phosphorus status

Fertile soils are a prerequisite for the production of high-quality food and feedstock. Sustainable phosphorus (P) fertilisation provides the essential nutrient at rates, which meet the demand of the crop and equally avoid excessive supply.

Focus should be directed to higher P utilisation efficiency. Only then crop productivity is maintained and negative impacts on the environment by erosion and surface run-off of P are reduced to a minimum.

However, improved P regulation requires common understanding of the problem and common approaches for the solutions. For instance, the BSR member states use different official standard methods for the determination of the soil P status.

To improve P regulation, the methodologies should be compared and the most suitable should be chosen to be used in all countries. The investigations in Baltic Manure showed that four standard soil extraction methods for P were highly interrelated while two other procedures were less comparable with the other four methods.

Consequently, the classification system for the results of soil P analyses show distinct differences between countries and recommendations for P fertiliser input may vary considerably. The classification system comprises in all countries of five categories from strong P deficit to excess P supply. More than 1000 soil samples were taken in different BSR countries and analysed for the P status.

Differences proved to be strongest between Germany, Estonia and Sweden. For instance, in more than 85% of the tested soil samples the Swedish soil analysis

showed a higher P supply by one or two categories when compared to the German system. For Estonian soil samples the share of higher P samples was 38%. In practice these deviations imply for instance that the P supply can be rated as deficient in one country and sufficient in the other despite being from the same soil.

Agricultural research locations are limited in number and results from different sites have been averaged. However, the variability within one field can be as high as in the whole surrounding landscape.

The results from Baltic Manure show that we need to implement modern technologies which allow for precise positioning and mapping of analytical data. Addressing variability over time and landscape is the first step before merging it with land management systems.

The following rule for calculating P fertiliser rates should consequently be applied: on soils where the P supply is sufficiently high to realise the site-specific maximum yield, fertiliser rates should simply balance the off-take by harvest products.

Basically manure is an ideal fertiliser product as it provides not only the essential plant nutrients, but also organic matter. So far upper manure rates may not exceed a maximum of 170 kg/ha N. With a view to P such practice causes an excessive oversupply of P when pig and poultry manure are applied.

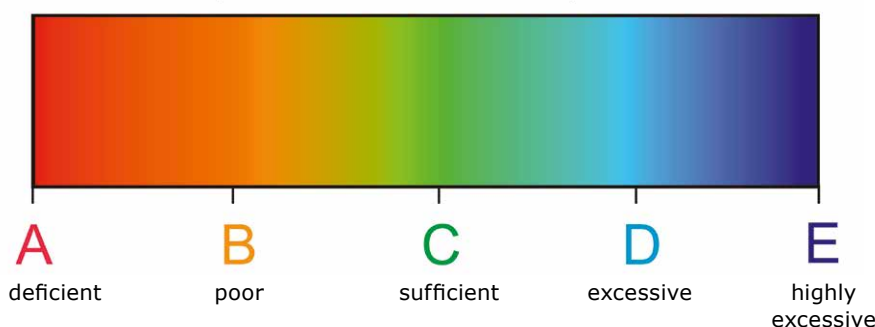
The solution to the problem could be to allocate manure to fields with low P status, and dose the manure according to manure P content and crop need without exceeding maximum N rates. If a surplus of manure P exists on farm level, a solution could be to separate the slurry into a liquid and solid phase, where the solid containing high rate of P could be exported from the farm. This solution calls for markets for the P-rich solids.

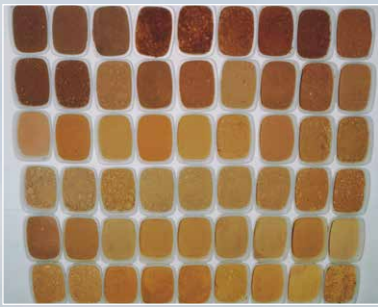


Recommendations

- Agree on a common soil P method in the BSR.
- Use modern technologies which allow for precise positioning and mapping.
- P fertiliser rates should simply balance the off-take by harvest products on soils where the P supply is sufficiently high to realise the site-specific maximum yield.
- Allocate manure to fields with low P status, and dose the manure according to manure P content and crop need without exceeding maximum N rates.
- If a surplus of manure P exists on farm level, separate the slurry and export the solid fraction from the farm.

Interpretation of soil analytical data. Categories denoting the P-supply.





Geo-coded soil samples



Soil transects describe the variability of soil P-status with geo-coded soil samples



Life Cycle Assessments (LCA)

– why do we need LCA?

Both scientists and decision makers within policymaking are aware of the necessity of a whole-system approach as a basis for decision making. No one is interested in implementing and investing in a manure management technique, if unforeseen environmental side-effects later emerge.

This especially applies if the technique is part of a larger scale and longer term system integration (e.g. biogas, when integrated with the energy and waste management systems), involving longer life time and return on investment (like 30-40 years).

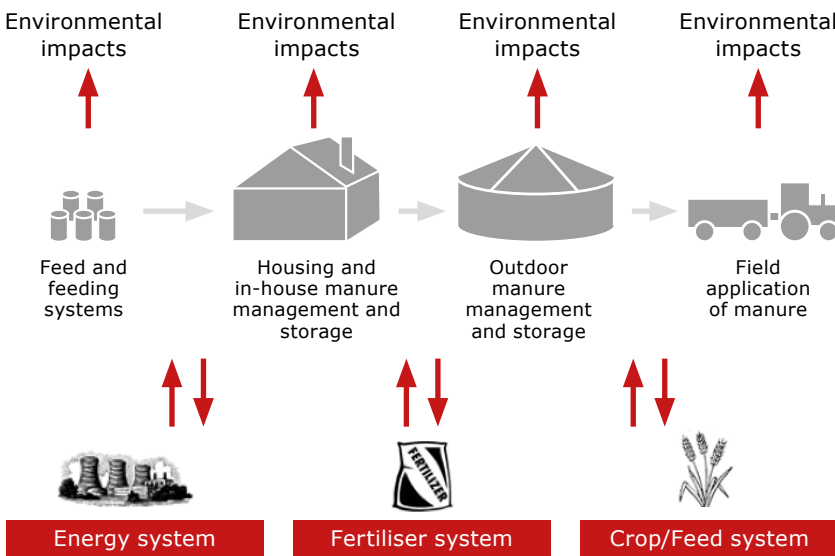
In the specific case of manure management systems, there are three main issues justifying why such whole system - or LCA-approach - is essential:

- the need to include the whole spectrum of substances affected;
- the need to consider the whole chain of production and;
- the need to consider relations with adjoining systems and related consequences.

However, it should be noted that LCA primarily has a focus on environmental aspects and do not include socio-economic factors in the conclusions. This is also the case for the LCAs carried out in Baltic Manure.



Whole system approach



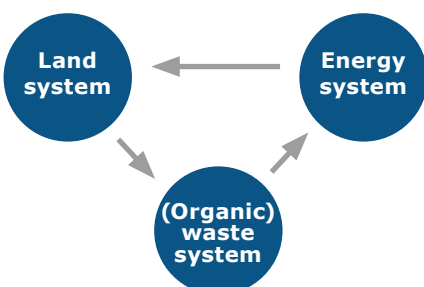
Include all substances affected

The microbial processes taking place in manure and soil are diverse and involve the transformation of substances in the spectrum from organic nitrogen to various inorganic forms like ammonia/ammonium ($\text{NH}_3/\text{NH}_4^+$), nitrous oxide (N_2O) and nitrate (NO_3^-) and from carbon to carbon dioxide (CO_2) and methane (CH_4).

As a result, acting on one targeted flow has simultaneous consequences on other flows, and could lead to induce unintended emissions of another flow. Such unintended impacts/benefits should be quantified to support an informed long-term decision making.

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System Integration



Any strategies allowing to minimize land use is likely to be of high interest for designing an environmentally ideal future. This could be achieved through system integration, for example by using manure-biogas as a key to wind power integration in future renewable energy systems.

Include the whole chain

Any change in the livestock production system by applying a new technique at any stage of the system may influence the environmental impacts downstream the manure chain.

Such effects appear rather obvious when dealing with manure management systems, where e.g. changing the diets, acidifying or digesting the manure, results in changed emissions flows downstream the manure handling chain. In few cases, a change may even influence environmental aspects upstream the point of application. This would for example apply when replacing the soy protein addition to the feed by synthetic amino acids. Partly avoiding soy production would, in this case, lead to very large reduction in upstream greenhouse gas (GHG) emissions.

Interactions with adjoining systems

The manure management system may also induce changes in other systems. The most significant environmental implications of a new technique are often found within such adjoining systems.

Adjoining systems typically affected by manure management techniques are the energy production system (e.g. avoided fossil energy use when biogas is produced), the fertiliser production system (e.g. avoided mineral fertilisers production as manure is applied on land) and the feed production system



(as a result of e.g. increased crop yield).

A reference system

One key pre-condition for assessing a manure management technique in an LCA-approach is to define a reference system against which this technique can be assessed. The main purpose of the reference is to serve as a measure-stick to compare and quantify all candidate techniques against.

This will ensure a common ground for the assessment and quantifica-

tion. The reference should ideally be a fair representation of a sound conventional livestock system, but as long as it is a well-known and common reference, it serves its function.

One major result of Baltic Manure work is the establishment of such reference systems, comprising eight different manure types and five Baltic Sea Regions, for a total of 15 reference systems. These are summarised in the table below and detailed in the LCA report for reference systems available at www.balticmanure.eu.

Reference systems established in Baltic Manure

Animal production	Manure type	DK	FI	SE	EE	PL	Total
Dairy cows	Slurry	X	X	X	X		4
	Solid manure					X	1
Bulls (> 6 months)	Deep litter	X					1
Fattening pigs	Slurry	X	X	X	X		4
	Solid manure					X	1
Broilers	Litter		X	X			2
Laying hens	Solid	X					1
Horses	Solid			X			1
Total		4	3	4	2	2	15

Key LCA conclusions and recommendations

LCA results are briefly summarised below and more details can be found at www.balticmanure.eu.

Three main categories of techniques were investigated:

- separation technologies;
- technologies involving energy production; and
- housing technologies.

All these techniques were compared with their corresponding reference manure management system. Four impacts categories were addressed:

- global warming,
- acidification (reflecting essentially ammonia emissions),
- eutrophication-N (where nitrogen is the limiting factor) and
- eutrophication-P (where phosphorus is the limiting factor).

The main conclusions of the LCA work are as follows:

- The choice of a separation technology should be coupled with a nutrient optimisation strategy.
- Tightly covered storage of the separated solid fraction is essential to ensure the environmental benefits of separating manure and/or digestate. Similarly, the separated liquid fraction should be covered and ideally acidified.
- Anaerobic mono- and co-digestion of slurry with solid manure or residual products is recommended for the BSR. Co-digestion with energy crops or residual products with high feed quality is however not recommended, due to the extra land demand it generates. The solid fraction obtained from source-separation of manure is a particularly beneficial co-substrate.
- Slurry cooling was not highlighted as a suitable technique for manure management in the BSR in general, due to the important energy supply needed for the heat pump, the difficulty to fully use the recovered heat etc.

Read more at www.balticmanure.eu



Solid manure pre-treatment for biogas

WelTec Biopower GmbH has developed the MULTIMix system, which makes it possible to increase the amount of solid manure input for biogas production. With the MULTIMix pre-treatment system, the solid manure is macerated, opening up the biomass and increasing the surface area for the bacteria to digest.

During the mixing process liquid is added to the solid manure. The system can be integrated both in new and already existing biogas plants, which makes it possible for existing biogas plants dependent on a large share of maize silage to replace it with solid manure. The system was awarded the Baltic Manure Handling award in 2013.

For more information please visit: www.weltec-biopower.com.



More specific LCA results are:

Separation technologies

Separation of a pig slurry digestate with a decanter centrifuge revealed a potential for reduction of the P-eutrophication, in comparison to not separating the digestate.

The separated solid fraction contained ca. 70% of the digestate-P to be applied on a field with high P needs, providing a great potential for a controlled and optimised P management in the BSR.

A concentration technology applied on a digestate originating from dairy slurry and horse manure showed a medium decrease in N-eutrophication and global warming potential, but an increase in potential P-eutrophication.

Slurry cooling of fattening pig slurry was found to allow significant reduction of NH₃ emissions, in comparison to the reference slurry management. Still, slurry cooling was found to have a greater global warming potential than the reference pig slurry management, because of the electricity input required for the heat pump. Because of the increased N in the manure, this technology also involves an increased potential for eutrophication-N.

Source-separation of pig and dairy slurry was found to have a great potential for reducing ammonia and to some extent methane emissions in-house, but also showed an increased potential for nitrous oxide emissions.

For all separation scenarios, it was shown that the overall environmental performance was very much dependent upon a tightly covered storage of the solid fraction.

Coverage prevents both N and C losses (particularly as ammonia and CO₂). Such covering may be a simple polyethylene plastic sheet, kept tight to the heap; as long as it significantly limits the exposure of the heap to air, it serves its function.



Technologies involving energy production

For horse manure, it was shown that anaerobic co-digestion with dairy slurry yielded more environmental benefits than incineration. Thermal gasification of solid pig manure allowed improvements for all impact categories, in comparison to the reference solid pig manure management.

For this scenario, the possibility to produce highly available P mineral fertilisers from the ashes was investigated, and this resulted in important benefits for the eutrophication-P potential, besides contributing to recycle manure phosphorus.

Anaerobic digestion (and co-digestion), similarly allowed environmental benefits in comparison to the reference manure management. However, this does not apply when slurry is co-digested with energy crops such as maize silage or energy grass.

In that case, the overall environmental impacts were more important than the reference manure management, in particular for global warming as a result of indirect land use changes.

One advantage of anaerobic digestion (and co-digestion) over incineration and thermal gasification is that it allows to recycle manure nutrients (both N and P).

Moreover, the slowly degradable C can then be returned back to the soil.

Another advantage of biogas production that could not be highlighted in the LCAs lies in its versatility; being storable in the natural gas grid, it provides a key flexibility asset for future renewable energy systems involving a high share of wind power, such as those that are envisioned in many BSR.

This flexibility advantage also applies, of course, for thermal gasification.



Results, conclusions and recommendations from the project Baltic Manure



Baltic Sea Region
Programme 2007-2013

This magazine intends to communicate the major results, conclusions and recommendations from the flagship project Baltic Manure (Baltic Forum for Innovative Technologies for Sustainable Manure Management) for the interested layman, the advisor, the policy maker, business maker and the farmer, and to stimulate further reading on the project website: www.balticmanure.eu

Baltic Manure was via co-funding from Interreg Baltic Sea Region programme a Flagship project in the EU Strategy for the Baltic Sea Region from 2010-2013.

The project has involved 18 partners from 8 countries with MTT Agrifood Research Finland as the Lead Partner.

Recommendations

How to improve manure handling in the Baltic Sea Region

- Close the nutrient cycles
- Get the energy out
- Increase knowledge on manure quality
- Stimulate innovation
- Incentives for cooperation
- Communicate technologies for farmers and advisors

Project partners:



Part-financed by the European Union (European Regional Development Fund)



www.mtt.fi



www.agropark.dk



JTI – Swedish Institute of Agricultural and Environmental Engineering

www.jti.se



UNIVERSITY OF SOUTHERN DENMARK

www.sdu.dk



Julius Kühn-Institut
Federal Research Centre for Cultivated Plants

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BALTIC MANURE
BUSINESS OPPORTUNITIES

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