BEST AVAILABLE TECHNOLOGIES FOR MANURE TREATMENT

– FOR INTENSIVE REARING OF PIGS IN BALTIC SEA REGION EU MEMBER STATES

BALTIC SEA 2020

ACKNOWLEDGEMENTS

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We've had valuable input from participants in the digital survey and the workshop in Stockholm in October (see Annex I) as well as during meetings and interviews in Belgium, Denmark, Holland, Poland, Sweden and USA.

We appreciate the time devoted and comments given by authorities and expert in the review of the final draft of this report; including the European IPPC Bureau, the Lithuanian Environmental Protection Agency, the Department of Agricultural Engineering at Aarhus University, the Danish Society for Nature Protection, MTT Agrifood Research in Finland, the Federation of Swedish Farmers, the Danish Plant Directorate, the Dutch Ministry of Housing, Spatial Planning and Environment, the Estonian Environmental Department and the Finnish Environment Institute. Their specific comments and our considerations can be viewed at the Baltic Sea 2020 webpage.

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BALTIC SEA 2020

Front page pictures: a farm-scale nitrification-denitrification plant (upper left), screw pressers (upper right), a conveyor transporting the solid fraction from a drum filter press with flocculation to a store (lower left), and a propeller mixer mounted on an anaerobic digestion tank (lower right). All pictures are taken by Henning L. Foged in Holland.

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FOREWORD

One main objective for Baltic Sea 2020 is to reduce the eutrophication of the Baltic Sea. The reduction of nutrient leakage from intensive livestock farms to the Baltic Sea, through technical development and spreading information on "Best Available Technologies" is one important activity to reach this objective.

This report with findings and recommendations concerning "Best Available Technologies for Manure Treatment" is produced by Henning Lyngsø Foged and his colleagues at the Innovation Centre for Bioenergy and Environmental Technology (CBMI), commissioned by Baltic Sea 2020.

The report focuses on leaching of nutrients from the huge amounts of manure produced by intensive rearing of pigs in the EU Member States of the Baltic Sea catchment area, and evaluates the technological solutions to reduce this leaching. The report does not evaluate the leaching reduction potential of agricultural practices, such as spreading techniques, timing of spreading, buffer areas, wetlands etc. These important measures are discussed by many other actors involved in reducing eutrophication in the Baltic Sea.

Baltic Sea 2020 will promote the recommended technologies within the Baltic Sea catchment area. We hope that other organisations, institutes and authorities will find the report useful and apply its findings, for example in the review process of the IPPC Directive and its reference documents, in agricultural advisory services, within the Baltic Sea Strategy and within the multiple ongoing projects aiming to develop intensive animal production within the Baltic Sea region in an environmentally sustainable way.

Stockholm January 2010

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INTRODUCTION AND BACKGROUND DESCRIPTION

Leaching of nutrients from sites with intensive rearing of livestock, also known as agricultural hot spots, has been identified by the Helsinki Commission as a prioritized area. Data shows that the amount of Phosphorous (P) and Nitrogen (N) in livestock manure spread on agricultural land by EU Member States in the Baltic Sea catchment area is 3–4 times higher than the amounts discharged from all households in the same area.

The objective of this report is to identify the most effective technologies to reduce leaching of nutrients from farms with intensive rearing of pigs. Technologies which reduce airborne emissions or for storage and spreading of livestock manure are not considered. Technologies have been evaluated based on their potential to reduce nutrient leaching in a cost effective way.

Nitrogen (N) leaching from livestock manures happens especially as percolation through soil layers when it is applied on fields in an imprecise way, not being based on norms and fertiliser planning, or when it is distributed to bare soils or in any case at periods, ways and situations where the nutrients are not taken up by the crops.

Phosphorus (P) is lost to the environment via run-off and leaching, largely for the same reasons as mentioned for N, but closely connected to soil erosion mechanisms and the P content of the soils.

It is on basis of data in Table 1 and Table 2 (Chapter 1), concerning fertiliser norms (norms have a certain correlation to the removal by the crops) and the livestock density in the target countries, suggested that the minimising of P leaching from livestock manure first of all is ensured via distribution on a sufficiently large agricultural area. There is in the BSR averagely 37 kg N and 9 kg P per ha in the produced livestock manure (Table 2) – it would in relation to the Nitrates Directive and the HELCOM Convention be possible to expand the livestock production (170 kg N/ha / 37 kg N/ha =) 4,6 times, and in relation to the need of P as nutrient for typical crop rotations (Table 1) be possible to expand the livestock production (25 kg P/ha / 9 kg P/ha =) 2,8 times

The listed EU legislation would, if fully implemented and enforced, hinder point source hot spot pollution from installations for intensive rearing of pigs, caused by leaching of N and P from the production site – hotspot pollution is especially related to lack of or insufficient livestock manure storages and/or keeping livestock in stables without floors or without watertight floors. However, only four of the eight target EU Member State countries have designated the whole territory as Nitrate Vulnerable Zones (NVZ's), despite being part of the Baltic Sea Region (BSR). Farms that are not under the IPPC regulation in the non-NVZ parts of those Member States may escape requirements for manure storages and other leaching prevention measures.

The Integrated Pollution Prevention Control (IPPC) Directive is identified as having potential to promote the most efficient technologies for manure treatment, for the intensive rearing of poultry and pigs.

METHODOLOGIES AND ORGANISATION

It is anticipated in this report that there is a correlation between leaching and field effect (also called bio / plant availability) for N, except in cases where the N is converted to free N – N2 or other airborne N.

The word "technologies" shall in this report be understood in a broad sense, for instance according this definition: "Technologies is the application of scientific or other organized knowledge - including any tool, technique, product, process, method or system - to practical tasks".

It is also emphasized, that this report does not consider various trade marks, brands, solutions or concepts offered by individual producers – behind those are typically a clone of the technologies mentioned in this report, or/and one or more technologies that are optimised for specific purposes.

The term "leaching" is consistently used to describe all N and P reaching the Baltic Sea, either through leaching or run-off.

The complete list of manure treatment technologies requires an estimation of the cost efficiency of the leaching reduction. It is for this purpose necessary to make a few assumptions. In order to rationalise this as well as to make the comparison and competitiveness of the various technologies more clear, we have developed five farm scenarios.

A questionnaire was elaborated and transformed into a digital survey, see Annex F. Members of the IPPC Technical Working group (Annex G) and IPPC Information Exchange Group (Annex H) were invited to participate in the survey. Ten persons responded, most of them from the Technical Working Group.

Interviews were performed with staff at the IPPC Department at DG Environment, the European IPPC Bureau and with national responsible authorities for implementation of the IPPC Directive in Denmark, Poland and Sweden (list of people met in Annex C). Additional information has been sought at DG Environment and IPPC Bureau web pages.

INFORMATION GATHERED

We have established a list of more than 40 technologies for livestock manure treatment.

The list of livestock manure treatment technologies indicates whether the technologies can stand alone or they can be pre- or post-treatments to other treatments. For livestock manure treatment, several technologies are often built together to improve the technical and economic efficiency of the treatment.

The total number of "IPPC farms" (pigs; sows and poultry) in the EU-25 is around 16.000. This is less than 0,1% of the total number of farms in the EU-25. On these farms, 16% of the total number of production pigs, 22% of the total number of sows, and around 60% of the total number of poultry are kept (2008). There are 1.328 IPPC installations for the intensive rearing of pigs in the Member States surrounding the Baltic Sea (Table 7).

The IPPC directive sets no limits regarding emissions of nutrients from installations for the intensive rearing of pigs, but refers to other Community legislation to be applied as maximum emission limit vales. The Nitrate Directive limits the annual amount of N from livestock manure in designated N vulnerable zones to be maximum 170 kg/ha.

OVERALL RECOMMENDATIONS

The complete list of identified livestock manure treatment technologies has been reduced in different ways in relation to the specific needs and purposes of this project. Priority was given to technologies with proven leaching reduction effect that are commercially implemented, with no apparent negative impacts on the environment or ethical considerations and with proven and acceptable economic performance.

The Project Leader has on basis of reviews, study tours meetings and discussions formulated the following recommendations:

Recommended best available technology for manure treatment for intensive rearing of pigs, to reduce leaching of nutrients cost effectively

Anaerobic digestion is the best technology for the reduction of N leaching. Digested pig slurry has a well validated higher field effect, whereby more N is re-circulated in the agricultural production, and less is leaching, ultimately to the Baltic Sea. Each cubic metre of pig slurry that is anaerobic digested would result in around ½ kg less leached N, provided the digestate is used according a fertiliser plan. The estimate of ½ kg less leaching is based on a field effect of digested slurry, which is reported to be 17–30% higher than non-digested slurry (Birkmose et al., 2007), but considering as well that the increase in field effect is in the lower range for pig slurry, a conservative estimate of 10% increase in field effect is used (10% x 5 kg N per m3 slurry = ½ kg N/m3). Digested slurry is furthermore much more homogenous and can be spread on the fields with higher accuracy as fertiliser, and it better incorporates and binds to the soil. Break-even for the economic performance of an anaerobic digestion plant is calculated to be around € 0,1 per kWh electricity that can be sold, with a reasonable use of the heat. Anaerobic digestion plants are found in all target countries, except Latvia (Birkmose et al., 2007), although two third of the around 100 plants in the target countries are found in Denmark. On EU level the target countries are currently only holding around 2% of the total number of anaerobic digestion plants. Anaerobic digestion is internationally a well known technology, which is seen as a way to meet waste, environmental, climate and renewable energy targets. The main promoters to spread the use of anaerobic digestion are financial support for their installation and running costs, ensuring the market (sale of electricity, biogas and/or heat, grid connection, guaranteed prices for a number of years), designation of places to situate the plants, and incentives for the cooperation to establish and run the plants.

The mandatory use of official P fertiliser norms is a way to ensure that livestock manure is not overdosed, as it easily happen when only the limits for N fertilisation is respected (Scenarios II and III). The HELCOM Convention decides that official P norms should be taken into use in all target countries, but this has so far only happened in four of the target countries.

P-index is a technology that supplements the P norms in the way that it further indicates, where there are high risks of P leaching despite the dosing is kept under the P norms. P-indexes are compulsory for installations for the intensive rearing of pigs in Iowa, USA, and have in Denmark been tested on pilot basis in a restricted area in connection to a LIFE project. Heckrath et al. (2007) made a review on P indexing tools for the Nordic countries, and concludes e.g. that:

- "Without addressing the role of critical source areas for P loss, policy measures to abate diffuse P losses are likely to be ineffective";
- "A common feature is that they are empirical, risk-based, user-friendly decision tools with low data requirements."; and
- "Phosphorus indices vary between the four Nordic countries in response to different agriculture, soil and climate."

Development of both P norms and a P-index would largely require cooperation among the relevant strategic and development research institutes around the Baltic Sea, as well as policy decisions, information campaigns and other measures for the implementation.

Separation technologies can for many installations for the intensive rearing of pigs (Scenarios II to V) be a really good technology for ensuring a balanced fertilisation on own agricultural lands and export of the P rich fibre fraction to regions where it can be used in an environmentally safe way. Storage and transport of the fibre fraction must happen in a way that avoids seepage and evaporation of ammonia and laughter gas. Alternatives to export of the fibre fraction might be to combust or thermally gasify it, possibly after further drying and maybe pelletizing, in which case the charcoal or ash can be used as fertilisers at other farms – however, these technologies needs further research to verify their environmental and economic performance when used for fibre fraction from pig slurry. Separation would typically be an integrated part of an anaerobic digestion plant, but it can also be a stand-alone technology. It is relatively easy to implement on a farm basis, but solutions have been seen with mobile separators, that can go from farm to farm and separate a batch of slurry, and in this way ensure a high utilisation of the investment. Separation technologies are well known in the BSR and internationally, and 3% of slurries in Denmark were separated in 2007 (Hjorth, 2009).

Certification of persons that transport and/or spread slurry would be a precaution against accidental spills, leading to both N and P leaching. The certification would be a very cost-efficient way to ensure that persons who deal with slurry are aware of its potential harmful effect on the environment, and of all regulations related with the transport and disposal of slurry. Certification requirements are compulsory in Iowa, USA, and are internationally comparable with the required certification of personnel that deal with pesticides.

Evaluation of the IPPC directive efficiency to promote the recommended technologies

The Integrated Pollution Prevention Control (IPPC) directive regulates that Best Available Techniques shall be used to minimize pollution of nutrients to water from farms with intensive rearing of pigs. It has therefore the potential to promote the technologies recommended above. The Directive has been in force since 1996, and has functional procedures for communication, implementation and evaluation of Best Available Techniques. Manure treatment is used more and more as a response to legislation and policies related with waste handling, environmental loads, climate gas emissions and renewable energy production. Livestock manure treatment technologies have impacts on the leaching of N and P, and they should have high priority in the coming revision of the BREF document.

Regarding BATs to prevent leaching of nutrients from intensive rearing of pigs to water, the report identifies the following areas for improvements:

1. The Technical Working group members should in the ongoing review of the BREF document consider to

- update the current BREF document with the latest technologies for manure treatment and expand their presentation, especially with information about their cost-efficiency in relation to minimizing leaching of nitrogen and phosphorous to water
- specify criteria for what is to be considered as a BAT in the revision process, and communicate them in the guiding documents to prepare the BREF documents.

2. Off farm treatment of manure is currently not regulated by the IPPC directive. As off farm treatment is likely to be more and more widespread, these installations should be considered during the revision of the IPPC Directive to be listed in Annex 1, to ensure that cost effective treatment of large amounts of manure off farm does not pollute water and air.

1: INTRODUCTION AND BACKGROUND DESCRIPTION

1.1: BACKGROUND

Leaching of nutrients from sites with intensive rearing of livestock, also known as agricultural hot spots, has been identified by the Helsinki Commission as a prioritized area. Data shows that the amount of Phosphorous (P) and Nitrogen (N) in livestock manure spread on agricultural land by EU Member States in the Baltic Sea catchment area is 3–4 times higher than the amounts discharged from all households in the same area.

Consultations have been done on the value and potential for Baltic Sea 2020 to address manure handling at intensive livestock farming with e.g. HELCOM, Swedish Institute of Agricultural and Environmental Engineering (JTI), Swedish University of Agricultural Sciences (SLU), Swedish Environmental Research Institute (IVL) and the Federation for Swedish Farmers (LRF). There is concordance on the importance to reduce nutrient leakage from intensive livestock farms to the Baltic Sea, through technical development and spreading of "Best Practices".

Baltic Sea 2020 has initiated a project to identify Best Available Technologies to reduce leaching of nutrients from farms with intensive rearing of pigs. The target area of the project is EU Member States of the Baltic Sea area: Sweden, Denmark, Poland, Germany, Finland, Estonia, Latvia, and Lithuania.

Based on analyses of current projects and activities, existing EU legislation and with consideration to the sources of origin of N and P leaching to the Baltic Sea, the report focuses on:

- Pig production in herds of more than 2.000 pigs
- Technologies for manure treatment rather than practices for manure storage and spreading
- Denmark and Poland's parts of the Baltic Sea river basin area

1.2: TURNOVER OF N AND P IN THE AGRICULTURAL ENVIRONMENT

When focusing on the N and P in livestock manure it is important to clarify the process stage from animal to final disposal. Figure 1 indicates via indexes the typical retention of N and P in agricultural production systems that respect good agricultural practices – the rest is generally lost to the environment.

N is lost to the environment both via emissions, leaching and run-off. Typically the emissions are relatively high in pig stables, but emissions can also happen from manure storages and in connection with spreading. Run-off happens if manure is spilled on the ground, if the floors in stables and the walls and floors of the manures stores are not water tight, if there is a long time span between spreading of manure on the fields and the incorporation into the soil, or if livestock manure is spread on steep, frozen or water saturated soils.

Nitrogen (N) leaching from livestock manures happens especially as percolation through soil layers when it is applied on fields in an imprecise way, not being based on norms and fertiliser planning, or when it is distributed to bare soils or in any case at periods, ways and situations where the nutrients are

Index of N amount:	100	80	75	50
Phase:	Manure leaving animal	Manure leaving stable	Manure leaving storage	Re-circulated in the crop
Index of P amount:	100	95	90	85

Figure 1: Recirculation of N and P in the agricultural production, based on Poulsen & Kristensen (1998) and Birkmose et al. (2007) as concerns manure leaving animal, stable and storage, while indications for P as well as amounts re-circulated in the crop largely are own estimates in situations, where good agricultural practices are applied.

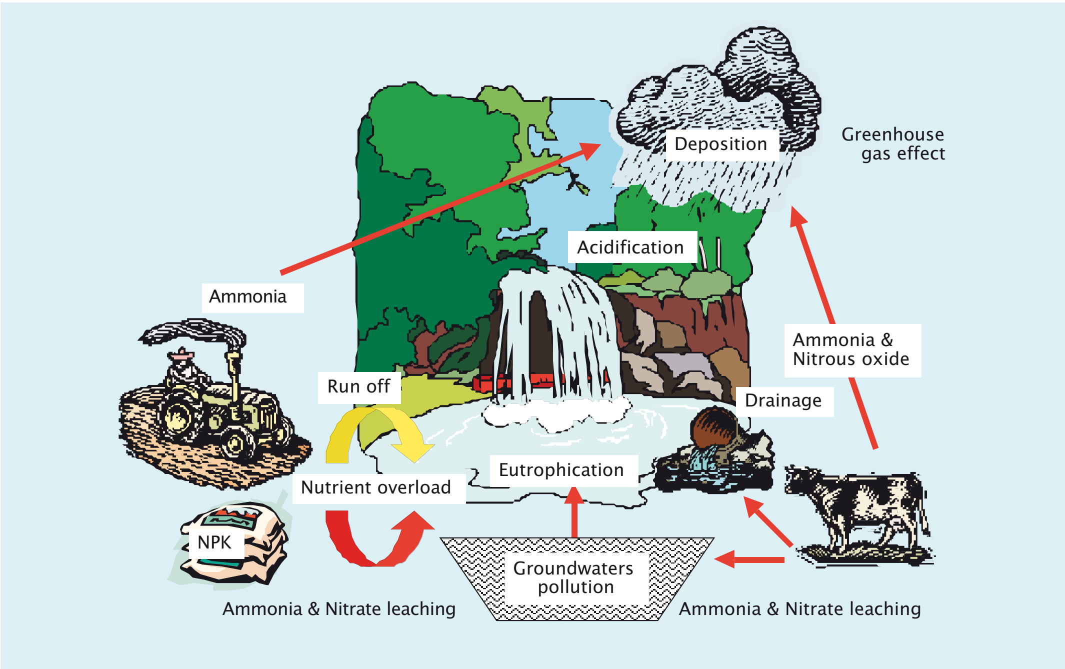

Figure 2: The agricultural N air/soil/water exchanges and possible impacts (European Communities, 2002: http://ec.europa.eu/environment/water/water-nitrates/pdf/91_676_eec_en.pdf).

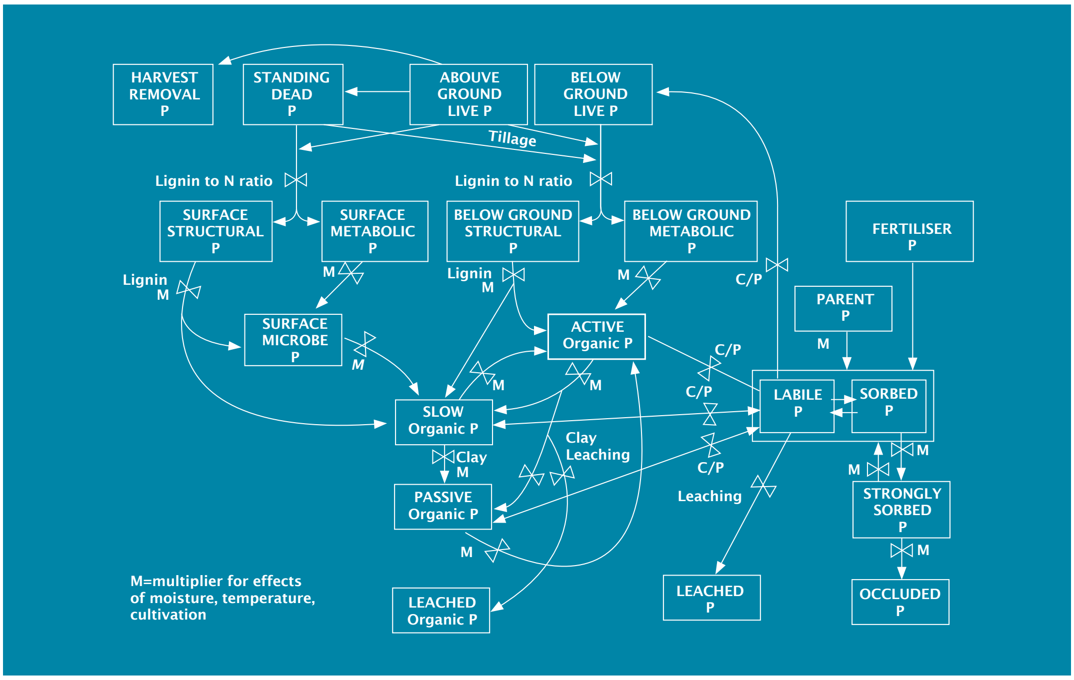

Figure 3: The agricultural P soil/water exchanges and possible impacts (after Parton et al., 1988).

	Yield	N	P	K
Winter wheat	8,6 t	175	20	70
Clover grass with less than 50% clover, in rotation	43,4 t	238	29	210
Winter rape seed	3,8 t	181	27	90

Table 1: Extracts from Danish fertiliser norms (2008). Figures per 1 ha of the best soil quality (clay soils)

not taken up by the crops.

Phosphorus (P) is lost to the environment via run-off and leaching, largely for the same reasons as mentioned for N, but closely connected to soil erosion mechanisms.

N and P have completely different turnover in the agricultural environment, as seen from figure 2 and 3.

Excess fertilisation with P is not necessarily leached like the case is for nitrogen, but can go into the turnover of the various phosphorus types/ compounds in the soil layers, whereof some are passive and/or only slowly converted to other forms. Agricultural soils can bind varying amounts of P but accumulation increases the amount of labile P and the risk for P leaching.

1.3: RELATION BETWEEN CULTIVATED LAND AND LIVESTOCK PRODUCTION IN BALTIC SEA AREA

Manure is according to EU policies considered as a waste, which must be accounted for by the owner of the livestock production, and disposed of as crop fertiliser in a sustainable way. In order to implement these policies the Member States must basically

- introduce official N fertilisation norms;
- introduce official manure standards; and
- set requirements to the field effect[1] of the livestock manures.

Table 1 shows examples of fertiliser norms in Denmark. The norms are largely correlated to the amount of N, P and K that is removed with the crop. They are determined according fertiliser trials. The N norms are in Denmark re-calculated into economic optimal norms (typically 15–20% lower than absolute optimums), and politically reduced further with 10% - see Figure 4.

The Danish N fertiliser norms are therefore low in comparison to countries without a politically determined maximal use of N fertiliser. It is often seen in the new EU Member States, where farm advisory services are relatively weak and farmers generally poor, that farmers either do not use economic optimal fertiliser amounts, or - if they can afford to buy fertilisers - fertilise after optimal productivity levels.

The Danish authorities have in an app. 100 pages publication informed about the official N fertiliser norms, manure standards and field effects, which all farms have to respect and use, and there is a new and updated publication every year (Danish Ministry of Food, Agriculture and Fisheries, 2008).

1 The field effect, also called bio-availability, express the amount of N in mineral fertiliser that gives the same crop yield as 100 kg N in livestock manure.

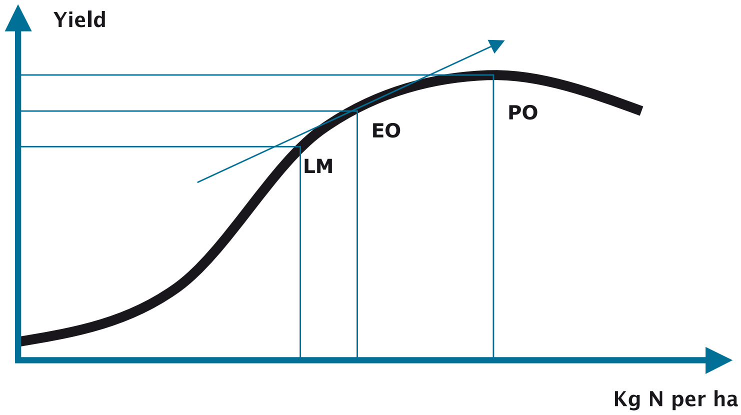

Figure 4: Typical s-formed fertiliser response-curve, indicating the productivity optimum (PO), the production economy optimum (EO), determined by the price vector (N and crop), and the legislative maximum (LM).

Country	From livestock manure, 1.000 tonnes		Agricultural land, 1.000 ha	In livestock manure, kg per ha agricultural land	
	N	P		N	P
DE	89.445	15.787	2.051	44	8
DK	166.063	34.758	2.077	80[2]	17
EE	23.514	7.634	1.160	20	7
FI	84.685	22.076	2.387	35	9
LT	72.255	27.332	3.527	20	8
LV	60.956	21.960	2.826	22	8
PL	347.278	128.938	14.247	24	9
SE	136.585	22.389	2.698	51	8
SUM /AVERAGE	980.781	280.874	30.973	37	9

Table 2: Estimates of N and P in produced livestock manure in relation to the agricultural land in the Baltic Sea catchment area of the target countries. The agricultural land is according to Granstedt et al. (2004), and the production of N and P is according EU's Joint Research Centre.

2 It is emphasized, that the figures are for the BSR part of Denmark, only. The average N amount in livestock density for the entire Denmark is around 110 kg.

#	Animal type	Kg plant nutrients in the livestock manure	
		N	P
1	1 sow in one year, with a production of 26 piglets till 7.3 kg, contribution from mating and farrowing stable, fully slotted floors	15,6	4
2	Same as above, contribution from farrowing stable	6,3	1,7
3	10 piglets produced, 7.3 to 32 kg, fully slotted floors	4,5	1,4
4	Total for a sow in one year with production of 26 piglets of 32 kg (1 + 2 + 2.6 x 3)	33,6	9,3
5	10 production pigs produced, 32 to 107 kg, drained floor + slots (33/67)	26,4	5,3
6	Total for a pig production, per 1 sows and 26 pigs produced (4 + 2.6 x 5)	102,2	23,1

Table 3: Examples of content of N and P in pig slurry (Ministeriet for Fødevarer, Landbrug og Fiskeri, 2008).

The Baltic Sea area covers 2.3 million square kilometres, with a population of 90 million. The land use of the area is unique, with 50% afforested and 20% arable land. Approximately 30% of the Baltic population lives in the countryside. The Baltic Sea covers an area of around one fourth of the total catchment area.

Table 2 shows a calculation of the load of N and P in livestock manure in all the target countries.

It is by comparison of Table 1 and Table 2 seen, that the average level of N and P in the produced livestock manure is far below the needs of the crops, as defined by the Danish fertiliser norms in Table 1 (economic optimal norms, politically reduced with 10% in case of N) as well indicated by the Nitrates Directive, setting a limit of 170 kg N in livestock manure per ha. The highest production of plant nutrients in livestock manure, i.e. the livestock density, is seen in the Danish part of the Baltic Sea catchment area, followed by Sweden.

It is on basis of data in Table 1 and Table 2 concerning fertiliser norms (norms have a certain correlation to the removal by the crops) and the livestock density in the target countries, suggested that the minimising of P leaching from livestock manure first of all is ensured via distribution on a sufficiently large agricultural area. There is in the BSR averagely 37 kg N and 9 kg P per ha in the produced livestock manure (Table 2) – it would in relation to the Nitrates Directive be possible to expand the livestock production (170 kg N/ha / 37 kg N/ha =) 4,6 times, and in relation to the need of P as nutrient for typical crop rotations (Table 1) be possible to expand the livestock production (25 kg P/ha / 9 kg P/ha =) 2,8 times[3].

By comparing Table 1 and Table 3 is seen, that P typically would be the most limiting factor in a balanced fertilising with livestock manure according the needs of the crops - see Table 4. It is seen, that the

[3] 25 kg P/ha is recommended by HELCOM as fertilising norm.

plant nutrients in slurry from production pigs is a bit better in balance with the needs of the crops than the case is for slurry from sow production. However, in all cases, whether a limit of 170 or 140 kg N per ha is used as a limit for fertilising with livestock manure, the spreading of P on the fields is above the P norms for a typical crop rotation on a pig farm.

It should be noted in connection to the Table 1 and Table 4 that winter wheat is the most commonly grown crop on pig production farms in Denmark (Weznæs et al., 2009) and probably in the entire Baltic Sea Region (BSR). Fertiliser norms for grass is also shown in Table 1, although this is not a common crop on pig production farms – however, grass is basically a protein crop, therefore requiring a high N fertilisation, and being the reason for derogations admitted cattle farms in Denmark and Holland to the general rule of maximally 170 kg N per ha from livestock manure.

According HELCOM Convention, Annex III section 2.1, "The maximum number of animals should be determined with consideration taken to the need to balance between the amount of P and N in manure and the crops' requirements for plant nutrients." It decides for Contracting Parties that "The amount of livestock manure applied to the land each year including by the animals themselves should not exceed the amount of manure containing 170 kg/ha nitrogen and 25 kg/ha phosphorus with a view to avoiding nutrient surplus, taking soil characteristics, agricultural practices and crop types into account."

Four of the eight target countries have consequently introduced official P norms for fertilising: In Sweden and in Lithuania the norms have been set as a general limit without respect to the actual crop grown. The limit in Sweden is 22 kg P per ha, and similarly 40 kg P2O5 in Lithuania. German farmers are restricted by a P balance of 20 kg P2O5 per ha (Foged, 2008). Denmark has introduced a maximal allowed spreading of 140 kg N in livestock manure per ha, but as seen from Table 4, this is not a sufficiently low rate to avoid over-fertilisation with P; Danish installations for the intensive rearing of pigs typically maximise their production up to the 140 kg N per ha limit. In Finland the P limits are based on crops grown and the soil P content. If only manure is used as P-fertilizer about 18 kg of manure total P can be spread for grain crops (if the soil P content is not very high).

Annex L includes statistics about the pig production in Denmark, Poland and Sweden, as well as maps with the geographical placement of pig farms in Denmark and the installations for the intensive rearing of pigs in Poland.

Animal type	Number of animals that can be contained within 1 ha of winter wheat according norms in Table 1		Kg P spread per ha per year, if the limit for N fertilisation in livestock manure is fully utilised	
	N	P	170 kg N per as limit	140 kg N per ha as limit
Total for a sow in one year with production of 26 piglets of 32 kg	5,1	2,2	47,43	38,75
10 production pigs produced, 32 to 107 kg, fully slotted floors	64,4	37,7	34,12	28,11

Table 4: Number of sows or production pigs that produces N and P equivalent to the consumption of one ha winter wheat – by comparison of Table 1 and Table 3, and amount of P spread if the allowed spreading of N is the limiting factor.

1.4: EU LEGISLATION IN RELATION TO THE PROJECT

EU has already taken steps to generally reduce the pollution with N and P from livestock production, especially addressing the hot spot point sources and the pollution from intensive installations for the intensive rearing of pigs, via the following legislation:

- EU's Nitrates Directive (91/676/EEC) introduce the voluntary Codes of Good Agricultural Practices, the designation of Nitrate Vulnerable Zones (NVZ's) for areas with high nitrate levels in the waters or risks of this, and a mandatory Action Programme for farms within the NVZ's. The Action Programme require farms to fertilise according the needs of the crops and not spread livestock manure in periods where lands are water saturated or frozen – indirectly this is a requirement for sufficient manure storage capacity.
- Council Regulation 1257/1999 on rural development support requires Member States to set up Rural Development Programmes, which shall "provide for agri-environment measures throughout their territories, and in accordance with their specific needs". These programmes shall be approved by the EU Commission.
- Regulation 1698/2005 provides the basis for Member States' support to farms' investments in manure storages etc.
- Regulation 1782/2003 sets the frames and conditions for farms' receive of financial support, the so-called Cross Compliance (CC). The Nitrates Directive as well as other environmental EU legislation is part of the CC criteria. This means that the sanction for violating the Nitrates Directive is strengthened.
- The IPPC Directive (2008/1) determines that intensive pig and poultry farms must have an environmental approval. The installations for the intensive rearing of pigs are defined as those having more than 750 sows or 2.000 places for production pigs (over 30 kg). The environmental approval is conditioned compliance with all agro-environmental legislation, use of Best Available Techniques (BAT's) to minimise pollution of water, air and land, and compliance with specified emission limits.
- The Animal By-products Regulation (1774/2002) regulates the disposal of fallen stock (dead livestock) and other animal by-products.

Annex J gives, as an example from a Member State, Poland, a more detailed description of the way the Nitrates Directive is implemented in Polish legislation and Annex K the same for Denmark.

The listed EU legislation would, if fully implemented and enforced, hinder point source hot spot pollution from installations for intensive rearing of pigs, caused by leaching of N and P from the production site – hotspot pollution is especially related to lack of or insufficient livestock manure storages and/or keeping livestock in stables without floors or without watertight floors. However, only four of the eight target EU Member State countries have designated the whole territory as Nitrate Vulnerable Zones (NVZ's), despite being part of the Baltic Sea Region (BSR). Farms that are not under the IPPC regulation in the non-NVZ parts of those Member States may escape requirements for manure storages and other leaching prevention measures.

The EU legislation had to be enforced in the new EU Member States by year 2008 as concerns the Nitrates Directive, by year 2009 concerning the Cross Compliance and by October 2008 concerning the IPPC Directive. The European Commission's monitoring of the implementation process, combined with the duration of the infringement procedures makes it unclear whether the legislation in fact is enforced. However, the general impression is that the enforcement lacks behind the schedule in the new EU Member States.

1.5: OTHER PROJECTS IN THE AREA OF MANURE PROCESSING/TREATMENT

The projects listed in sections 1.5.1 to 1.5.5 below have related objectives with "Best Practise Manure Handling". The results in this report will be essential knowledge for projects in the area of manure processing/treatment in order for them to proceed effectively.

1.5.1: HELCOM agricultural hotspots project

According to Helsinki Convention, and the revised Annex III, special measures and Best Environment Practice and Best Available Techniques in agriculture should be applied by the contracting states in the entire territory of the catchment area of the Baltic Sea. Unlike the IPPC directive, environmental permits should also be applied also to cattle farms >400 units. There are three ongoing processes dealing with agricultural hot spots:

1) To develop a prioritized list of single installations of intensive rearing of poultry, pigs and cattle. This list will be bases for decision on internationally financed investment projects for farm infrastructure improvements. The objective is to collect information on nutrient load potential, taking into account simple production criteria and manure handling measures, as stipulated in the convention. This should be done by collecting existing information readily available (statistics, IPPC permits, EU EPER/PRTR, etc) and rely on voluntary reporting by countries for additional, more specific information on individual agricultural installations. The easily accessible background information has been gathered and summarized. Specific information on pollution potential and pollution loads for individual installations is being collected.
2) Development of criteria for agricultural point source hot spots. This is an ongoing process within HELCOM to revise the HELCOM Hot Spot system to be more precise and to show specific information per each installation. The exact criteria for designation as an agricultural point source hot spot will be discussed among the contracting states in the upcoming HELCOM LAND workshops and meetings in November 2009 and January 2010.
3) BALTHAZAR -project, financed by EU. The objective is to facilitate the implementation of the HELCOM Baltic Sea Action Plan in Russia, with respect to the objectives of the eutrophication and hazardous substances segments of the BSAP. The specific goal of the project in the agricultural sector is to develop pilot projects on the prioritized installations of intensive animal rearing, with a focus on mitigating the environmental risk posed by these installations to the Baltic Sea. A final report with a prioritized list of the selected installations and proposals for pilot projects is expected to be finalized in February 2010.

1.5.2: Manual for start of new biogas plants in Denmark

The Danish government has launched a 'Green Growth' plan to increase the biogas treatment (and other treatment for energy purposes) of slurry from presently 5% to 50% before 2020. Today Denmark has 22 larger centralised biogas plants in addition to some 50 farm scale plants. The new plan will require 40–50 new larger centralised plants, seriously challenging the planning system in Denmark. The coming biogas plants should be located where animal husbandry is dense to reduce transportation costs, and they should be located where the produced heat and power can be sold. Alternative locations could be where the natural gas-grid is for upgrading of the biogas and selling to the gas-grid.

The system for environmental approval of new biogas plants is complicated, and the newly formed municipalities have few experiences. In addition, there is a classic 'Not in My Back Yard' challenge (the so-called NIMB syndrome) and numerous neighbour complaints can be expected.

Therefore, a group of experts, led by CBMI, has been given the task to develop a detailed manual on how to start new biogas plants. The manual is aimed at farmers, authorities, neighbours and energy companies, thereby trying to encompass all aspects (positive and negative) of biogas. The working group is followed by a group of stakeholders, ensuring the right balance of the manual. The manual will be published in a light version, a thorough reading version and numerous very detailed fact sheets on cbmi.dk.

The work is to be coordinated and adapted to the initiatives in 'Green Growth' as they become approved and in place during 2009–2010, including legislative changes, new expert panels being established etc.

The work is financed partly by Central Denmark Region, The Rural Development Programme and the

Biogas Branch Association. It is planned to publish a version ultimo 2009, and a 'final' version October 2010.

1.5.3: balticCOMPASS

balticCOMPASS is a new project with a budget of M€ 6.5 that recently was approved for financing by the EU Baltic Sea Region Programme 2007–2013 / Interreg IIIB. The project is led by Swedish Agricultural University and has some 25 partners in the countries around the Baltic Sea. The overall objective is defined as "To contribute to securing a good ecological status of the Baltic Sea as a means to contribute to economic growth and integration in the Baltic Sea Region", and livestock manure treatment technologies are a key focus of the project. The project includes the following six work packages (work package leaders in brackets):

i. Management and Administration (SLU)
ii. Communication and information (BSAG)
iii. Best Practice - utilisation and transfer (JTI)
iv. Investment preparation (ABP/CBMI)
v. Comprehensive assessment and scenarios (SYKE)
vi. Governance and policy adaptation (SEI)

The work packages contains measures to reach the overall objective, here under information and dissemination measures, development on utilisation and transfer of best practices, support to speed up investments in the best manure treatment technologies, monitoring and modelling measures, and policy adaptation. The project will run for 4 years.

1.5.4: Forum for Inventive and Sustainable Manure Processing, a Baltic Sea Strategy Flagship Project

There is a long term need to co-ordinate basic and applied research, model development, develop and discuss scenarios, transfer of knowledge, and business innovation and development initiatives within the field of Sustainable Manure Processing.

The Baltic Forum for Inventive and Sustainable Manure Processing will contribute to rural development by reinforcing sustainability of agriculture in the Baltic region. This will be done through an improved exchange of information on how to process manure (pig, cattle, poultry) in sustainable ways in the Baltic Sea Region to minimize the environmental impact, and to reach benefits such as renewable energy, job creation and business development.

The forum considers manure a serious problem, but also a part of the solution. Manure should become an attractive and profitable resource in the future. Processing manure can and should lead to production of 'designer fertilisers' (pellets, liquid, etc.) improving agricultural production and bio-energy (biogas, fibre combustion, etc.) reducing the CO_2 emissions in the region.

The Forum is included as a 'Fast track Flagship project' (i.e. highly prioritised) in the EU Baltic Sea Action Plan. CBMI (Denmark) and Agrifood Research, MTT (Finland) are nominated as lead partners.

The process of project establishment is ongoing and specific objectives of the project are to be defined. So far there has been held consultations between the key actors; MTT and CBMI as well as a contact committee under the Danish Ministry of Foreign Affairs, and a coordination meeting organised by the Finnish Ministry of Agriculture.

1.5.5: Baltic DEAL – Putting Best Practices in agriculture into work, a Baltic Sea Strategy Flagship Project

The overall aim of Baltic DEAL is to improve the environmental status of the Baltic Sea through reductions in nutrient losses from the agricultural sector without impairing competitiveness or production. The project aims to create a sector-driven and voluntary approach to raise awareness and increase expertise among farmers in order to reduce negative environmental impact while at the same time maintaining or increasing competitiveness, thus creating a win-win situation.

The specific objective of the project is to develop a nationally adapted, yet common, Baltic Sea region approach to advance and strengthen agricultural advisory services and related demonstration and information activities using practices that focus upon good and improved environmental and agricultural practices.

The project is included as a "Flagship project" in the Baltic Sea Action Plan. The Federation of Swedish Farmers, Danish Agricultural Advisory Service, Central Union for Farmers and Forest Owners, Central Union of Swedish-speaking Agricultural Producers in Finland, Agricultural Organisations of Finland, and Deutscher Bauernverband are nominated as lead partners. The process of project establishment is ongoing and finance is not yet secured.

2: METHODOLOGIES AND ORGANISATION

2.1: METHODOLOGY

2.1.1: General approach

The project, here under the data compilation and creation of a complete list of manure treatment technologies from source to disposal of the livestock manures, and a reduced list, i.e. the recommended technologies in relation to the objectives of this project, has been done via

- Compiling and structuring already known knowledge and searches for newest scientific literature, relevant reports and document etc. – see list of references in Annex B.
- Performing a survey among network partners in the project target area and in other relevant countries – the content of the survey was largely formulated by the Baltic Sea 2020 secretariat, while the Project Leader organised the programming of an Internet based version of it.
- Study visits to Holland and USA, especially to get on-hands impressions, to be acquainted with on-going and not yet published research, and for reviewing current manure management technology practices.
- The identified technologies are on basis of well documented effects (in some cases on basis of researchers personal information or qualified estimates), concrete prices and other facts analysed/evaluated with respect to environmental effects (total/ammonia/nitrate N and P, other environmental effects), economy/profitability (income/savings – for instance from improved fertilising value of the livestock manure, investment price, running/operational costs, pre-requisites/enablers (herd size/scale of economy, available land, distance to available land, price of energy, available subsidies, etc.)
- Stakeholder consultations via a roundtable discussion in Stockholm on 29 September 2009.
- Consultations with Researchers/experts, who represent the countries in the target area in the Technical Working Group connected to the European IPPC Bureau. Some of those, who could not participate in the Roundtable discussion, have been consulted at individual meetings about for instance the efficiency of the implementation of the IPPC Directive.
- Data analysis to make a reduced list of most interesting technologies.
- Formulation of recommendations for Best Available Technology for manure treatment to reduce leaching of N and P.
- Policy recommendations, here under formulation of final recommendations on basis of analyses and evaluations.

2.1.2: Principle concerning leaching, and its connection to the field effect

It is anticipated in this report that there is a correlation between leaching and field effect (also called bio / plant availability) for N, except in cases where the N is converted to free N – N2 or other airborne N.

The field effect is in Denmark defined as the amount of N in mineral fertiliser that gives the same yield as 100 kg N in livestock manure in field trials.

If the field effect is 60%, for instance, then we anticipate that 40% is lost to the environment, mainly via percolation to the soil layers, whereof a big part is further leached to the aquatic environment, while some is immobilised in the soils.

This report will thus use the field effect as one of the evaluation parameters for the leaching reduction effect of livestock manure treatment technologies.

2.1.3: Broad meaning of technologies

This report deals with livestock manure treatment technologies for installations for the intensive rearing of pigs.

The word "technologies" shall be understood in a broad sense, for instance according this definition: "Technologies is the application of scientific or other organized knowledge - including any tool, technique, product, process, method or system - to practical tasks".

The following few words are further creating the basis for a common understanding of the type of technologies the project focuses on:

- Dealing widely with manure handling, processing and treating, comprising mechanical, thermal, chemical, biological and probably other
- Focusing on technologies that are relevant for industrial pig farming in the Baltic Sea Region
- Focusing on technologies, which in a cost efficient way minimize N and P leaching from manure
- Excluding conventional technologies for manure storing and spreading, which have (or should have) been enforced several years ago according existing legislation
- Excluding technologies focused on reduction of smell and airborne emissions
- Focusing on technologies which have become more widespread since the introduction of the IPPC directive, for instance separation, aerobic treatment, anaerobic treatment, incineration, flocculation, flotation, reverse osmosis, etc.

It is also emphasized, that this report does not consider various trademarks, brands, solutions or concepts offered by individual producers – behind those are typically a clone of the technologies mentioned, and/or one or more technologies that are optimised for specific purposes.

2.1.4: Definition of leaching

Understanding of the word "leaching" varies in different countries.

Native English speaking countries normally understand

- leaching as percolation to the soil layers; and
- run-off as washing away along the soil surface, closely associated with erosion.

There are in the native languages in the Baltic Sea Region (BSR) countries normally no linguistic distinguishing between leaching and run-off.

The term "leaching" is consistently used to describe all N and P reaching the Baltic Sea, either through leaching or run-off.

2.1.5: Building on the Reference Document on Best Available Techniques for Intensive Rearing of Poultry and Pigs (BREF) concerning pigs

The current BREF document (European Commission, 2003) contains about 1 page summary (page xvi and xvii) and 5 pages detailed description (from page 77 to 82) about "on-farm manure treatment" of manure from pigs and poultry, and lists up technologies, which can be used of the following reasons - citation:

1. To recover the residual energy (biogas) in the manure;
2. To reduce odour emissions during storage and/or land spreading;
3. To decrease the N content of the manure, with the aim of preventing possible ground and surface water pollution as a result of land spreading and to reduce odour; and
4. To allow easy and safe transportation.

The listing of technologies in this report comprises the listing in the BREF document, excluding technologies that are not in focus for this project, such as those related with chicken manure or odour emissions. We furthermore find it relevant to structure the technologies according their logistic route from the source (pigs) to the end disposal (mainly field application), and to estimate the leaching reduction potential conditional in relation to a given situation on the farm.

2.1.6: Model farm for scenario calculations

The complete list of manure treatment technologies requires an estimation of the cost efficiency of the leaching reduction. It is for this purpose necessary to make a few assumptions. In order to rationalise this as well as to make the comparison and competitiveness of the various technologies more clear, we have developed five farm scenarios.

- Scenario I describe a model farm, where spreading of N and P is done in an environmentally safe way, meaning according to the EU and HELCOM regulations on the agricultural land of the farm.

Scenario	I	II	III	IV	V
Ha land on the farm	1.150	893	735	625	0
Kg N per ha on the farm	109	140	170	200	-
Kg P per ha on the farm	25	32	39	46	-
Land for spreading available in the region	No	No	No	Yes	Yes
Average distance to sustainable disposal of the slurry or its plant nutrients	4 km	4 km	4 km	24 km	144 km

Table 5: Five scenarios for installations for the intensive rearing of pigs, all with a size equal to an annual production of 25.000[3] ton of slurry, containing 5% dry matter, and 5 kg total N and 1,15 kg P per ton, but with different availability of land / livestock density.

- Scenario II is much comparable to the Danish situation, allowing pig farm to produce 140 kg N in livestock manure per ha.
- Scenario III is equal to the maximally livestock density according the Nitrates Directive.
- Scenario IV and V describe situations, where livestock farms have insufficient or no land for spreading livestock manure, and where there is a possibility to dispose of it within the region, or outside the region, respectively. These scenarios are often seen at the large livestock farms in the new EU Member States.

2.1.7: Data analysis

The complete list of livestock manure treatment technologies was analysed and reduced on basis of the following criteria:

1. Non-project relevant technologies
2. Technologies that are not commercially implemented
3. Technologies without leaching reduction effect
4. Technologies with apparent negative environment or climate impacts
5. Technologies without proven or unacceptable economic performance for general use
6. Technologies with ethical considerations

We have for the livestock manure treatment technologies especially focused on the following parameters:

- Total leaching reduction capability (N & P)
- Kg saved N or P per €
- Implementation and maintenance complexity assessment
- Cost of implementation
- Cost of maintenance
- Legal, structural, cultural and ethical obstacles for implementation of proposed technologies

2.1.8: Efficiency of the IPPC directive

The Integrated Pollution Prevention Control (IPPC) directive was identified during background research

[4] 25.000 ton of pig slurry equals for instance the production from 1.075 sows + production of the piglets and production pigs from them (around 29.000 production pigs produced per year)

of the project to be a potential tool to implement best practices for manure treatment in the Baltic Sea catchment area. Hence, one objective of this report is to evaluate the efficiency of the directive to communicate and implement "Best Available Techniques" (BATs) to reduce leaching of nutrients from installations for the intensive rearing of pigs.

A questionnaire was elaborated and transformed into a digital survey, se Annex F. Members of the IPPC Technical Working group (Annex G) and IPPC Information Exchange Group (Annex H) were invited to participate in the survey. Ten persons responded, most of them from the Technical Working Group.

Interviews were performed with staff at the IPPC Department at DG Environment, the IPPC Bureau and with national responsible authorities for implementation of the IPPC Directive in Denmark, Poland and Sweden (list of people met in Annex C). Additional information has been sought at DG Environment and IPPC Bureau web pages.

2.2: ORGANISATION

The project is executed by Project Manager Henning Lyngsø Foged at the Danish Innovative Centre for Bioenergy and Environmental Technologies, (CBMI), being sparred and assisted by several of his colleagues, first of all Michael Støckler and Karl Martin Schelde.

The project has been implemented according to the time schedule, which was developed in connection to the initial kick-off meeting at Agro Business Park on 17 August 2009.

A close, effective, transparent and open cooperation has taken place between the Project Leader and Researcher Lotta Samuelson of the Baltic Sea 2020 secretariat, with who weekly scheduled telephone meetings took place. Lotta Samuelson took the lead on the formulation of the questionnaire for the survey as well as for the inviting of people to the roundtable discussion, and also took the lead in several meetings with stakeholders in Brussels, Poland and Denmark.

3: INFORMATION GATHERED

3.1: FULL LIST OF LIVESTOCK MANURE HANDLING TECHNOLOGIES

More than 40 technologies for livestock manure treatment have been identified with in the project. The technologies are grouped and numbered. The groups are inspired by the BREF document (2003), and extended with other technologies we have identified. The code numbers are incidental, but made with the purpose of linking the Table 6 with Annex D, Annex E and the reduced list in chapter 4 (Table 8).

Table 6 includes information about the way the technologies can be deployed, meaning whether they are stand alone, pre treatment or post treatment technologies:

- Stand alone technologies can be deployed as the sole treatment technology, and the manure does not have to be pre treated. We assume here that pig manure alone is on slurry form.
- Pre treatment technologies are marked as such because they typically are followed by other treatments. Several pre treatment technologies cannot stand alone.
- Post treatment technologies are typically found in the end of the logistically way of the livestock manure treatment route. These technologies can typically not stand alone, and they would normally have the purpose to refine the products for further use as fertilisers or other.

However, the marking of technologies as being stand alone, pre or post treatments shall only be seen as an indication. We see in practice that technologies are combined in many different ways on concrete livestock manure treatment plants.

The information provided in the complete list of technologies is provided with the intention to be objective, and refers to validated information where possible, both for Table 6 and the Annex D and Annex E.

There is not complete overlap between the technologies presented in Table 6, the figures in Annex D and the tables with description of the technologies in Annex E. Emphasis has been given to collect information in Annex E about technologies where validated data exist. The work with development of a knowledge base on livestock manure treatment technologies will continue in Work Package IV of the balticCOMPASS project under auspices of CBMI.

3.2: COMBINATION OF TECHNOLOGIES

The list of livestock manure treatment technologies indicates whether the technologies can stand alone or they can be pre or post-treatments to other treatments. Speaking about livestock manure treatment, it is in fact typical that several technologies are built together to improve the technical and economic efficiency of the treatment.

Examples of this are:

- Logically, adding a mechanically separated fibre fraction from pig slurry with a dry matter content of 32% would make an anaerobic digestion of pig slurry with a dry matter content of 6,1% (Landscentret, 2005) more cost efficient (anaerobic digestion can typically happen with dry matter contents up to 12,5%).
- Composting of a mechanically separated fibre fraction before thermal gasification or combustion would save other needed heating, as the fibre fraction typically reach temperatures of more than 70°C whereby considerable amounts of water evaporates. Patni and Kinsman (1997) report a composting trial, where “75% of the water initially present was lost during 60 days of composting”.
- Powers and Flatow (2002) reports a study which for instance for one type of diet improves the mechanical separation of total solids from 48,6% up to 82,9% by use of flocculants.
- There is obtained synergy in combining temperature and pressure treatment with anaerobic digestion, because the substrates for anaerobic digestion anyway have to be heated up to around 35°C (mesophile process) or 55°C (thermophile process).

Table 6: Complete list of livestock manure treatment technologies

#	Livestock Manure Treatment Technology	Stand alone technology	Pre-treatment	Post-treatment
00:	**Pre-storage and storage**			
01	Source separation	✓	✓	
02	Pre-storage and temporary storage	✓	✓	
03	Storage of deep litter	✓		✓
04	Storage of solid manure	✓		✓
05	Storage of urine	✓		✓
06	Storage of slurry	✓		✓
10:	**Separation**			
10A	Flocculation		✓	
11	Separation by grate		✓	✓
12	Separation by screw pressing		✓	✓
13	Separation by sieves		✓	✓
14	Separation by filter pressing		✓	✓
15	Separation by centrifuge		✓	✓
16	Flotation		✓	✓
17	Separation by drum filters		✓	✓
18	Sedimentation		✓	✓
20:	**Additives and other pre/1st treatments**			
21	Acidification of liquid livestock manures	✓	✓	
22	pH increasing, liming	✓	✓	
23	Temperature and pressure treatment	✓	✓	
24	Applying other additives to manure, here under enzymes	✓	✓	✓
30:	**Anaerobic treatment**			
31	Anaerobic digestion	✓	✓	✓
40:	**Treatment of the fibre fraction**			
41	Composting of solid livestock manure or fibre fractions of liquid livestock manure	✓		✓
41A	Composting of liquid livestock manure	✓		✓
42	Drying, possibly followed by pelletizing			✓
43	Combustion	✓	✓	

Table 6 continued.

#	Livestock Manure Treatment Technology	Stand alone technology	Pre-treatment	Post-treatment
44	Thermal gasification	✓	✓	
46	Composting of manure with larvae of the housefly	✓	✓	✓
46	BtL (biomass to liquid)	✓	✓	✓
50:	**Treatment of the liquid fraction**			
51	Ultra filtration			✓
52	Ammonia stripping		✓	
54	Reverse osmosis			✓
55A	Electrolysis			✓
55B	De-mineralisation			✓
56	Aeration	✓		
56A	Ozonizing	✓		
57	Nitrification-denitrification		✓	✓
58	Struvite (magnesium ammonium phosphate) precipitation	✓		✓
59	Algae production on liquid manure substrates			✓
90:	**Transport and disposal**			
91	Truck transport	✓	✓	✓
92	Pipeline transport	✓	✓	✓
93	Field application			✓
94	Constructed wetlands	✓		✓
95	Other disposal			✓
100:	**Air cleaning**			
101	Air washing	✓		
110:	**Management**			
111	Official P norms	✓		
112	P index	✓		
113	Certification of persons, who transport or spread livestock manure	✓		

3.3: COMMUNITY PLANTS FOR LIVESTOCK MANURE TREATMENT

Technologies that are not stand-alone technologies and/or have clear economies of scale would typically have an advantage of being implemented via farmer cooperations or a service provider as off-farm manure treatment plants.

- Technologies that cannot stand alone would often be part of rather complex and high-tech solutions that would be complicated for farmers to handle along with their key production.
- Technologies with a clear economy of scale, i.e. where treatment of a small amount per year is more costly than treatment of a large amount per year, see for instance Birkmose (2006), would often be too costly for farms of average sizes to invest in and to operate.

Examples of these cases are livestock manure treatment plants, where pig slurry is converted to purified water and different commercial/mineral fertilisers, for instance nitrification-denitrification plants as seen in Spain, Holland and Belgium, purification plants as seen in Holland, or centralised biogas plants as seen in Denmark.

Further, it is important for farms to handle risks associated with their business, and the larger investments they make in relation to their turnover, the more vulnerable are they to changes in the markets, regulations and other external factors.

Remarks given by participants at the Roundtable discussion on 29 September generally expressed the opinion, that the project could promote larger community livestock manure treatment plants for combined technologies. This would take away the structural development pressure on pig producers, which would be a result in itself in relation to the environmental load of pig production. The rationale behind the remarks is that the structural development in the livestock production is forced by the legislative burden on the producers, which more rationally can be dealt with by the large production units than the smaller ones. Furthermore, if the legislative burden enforces use of specific technologies, then the economy of scale of the technology would force the smallest producers to go out of the market. It is also of importance for many pig producers to develop their competences on animal husbandry, and to source out other activities, as for instance livestock manure treatment. Therefore, by encouraging the livestock manure treatment technologies as community plant solutions, would avoid an extra pressure for livestock farms for growing bigger in order to survive. The extra transport of slurry to and from a community plant would typically be balanced by advantages of a more rational slurry handling, increased value of the slurry etc. within a certain radius from the community plant.

Additionally it should also be kept in mind that a major challenge with an environmentally sound disposal of the livestock manure is to distribute it at sufficiently large areas of agricultural land, as visualised in tables 1 to 4. Therefore, a major advantage of community plants are actually, that they in reality functions as centres for regional re-distribution of livestock manures, meaning that the logistics around the collection of pig slurry and distribution of treated manure ensures the distribution to for instance specialised plant producers without livestock production in the region. See also www.biovakka.fi.

However, the off-farm livestock manure treatment plants are actually moving the livestock manure treatment from being a regulated issue to a non-regulated issue, at least in some cases. The IPPC directive does not, via the Annex 1 list of installations that needs environmental approvals, comprise off-farm livestock manure treatment.

Off-farm livestock manure treatment plants should be listed in Annex 1 of the IPPC Directive as installations that require environmental approval because the deployed technologies have environmental impacts in general, and on N and P leaching in specific.

3.4: EFFICIENCY OF BAT DISSEMINATION IN RELATION TO THE IPPC DIRECTIVE

The following sections give a presentation of the information gathered about the IPPC Directive, how the administration of it is organised, and of the BREF document.

Additionally, reference is given to the annexes C and J with lists of people met and memorandum from roundtable discussion.

	Sweden	Finland	Estonia	Latvia	Lithuania	Poland	Germany	Denmark	Total
Production pigs	102	14	34	22	24	116	395	378	1.085
Sows	15	10	-	2	4	6	206	-	243
Total	117	24	34	24	28	122	601	378	1.328

Table 7: Number of IPPC permitted installations for the intensive rearing of pigs in Baltic Sea Members States 2008 (European Commission, DG Environment, Monitoring of Permitting Progress for Existing IPPC Installations, Final Report, March 2009, Danmarks Statistiks Bibliotek og Information (personal communication)

3.4.1: The IPPC Directive

The purpose of the Integrated Pollution Prevention and Control (IPPC) Directive is to achieve integrated prevention and control of pollution arising from industrial activities. It lays down measures designed to prevent or, when that is not practicable, to reduce emissions in the air, water and land. It came into force in 1996, requiring full compliance by 30 October 2007.

Installations for the intensive rearing of pigs with > 2.000 places for production pigs (over 30 kg) or >750 places for sows are specified as industrial installations under regulation of the directive.

The total number of "IPPC farms" (pigs; sows and poultry) in the EU-25 is around 16.000. This is less than 0,1% of the total number of farms in the EU-25. On these farms, 16% of the total number of production pigs, 22% of the total number of sows, and around 60% of the total number of poultry are kept (2008). There are 1.328 IPPC installations for the intensive rearing of pigs in the Member States surrounding the Baltic Sea (Table 7).

The directive requires installations to operate according to permit conditions based on best available techniques (BAT), without prescribing the use of any technique or specific technology and taking into account the technical characteristics of the installation concerned, its geographical location and the local environmental conditions.

The IPPC directive sets no limits regarding emissions of nutrients from installations for the intensive rearing of pigs, but refers to other Community legislation to be applied as maximum emission limit vales. The Nitrate Directive limits the annual amount of N from livestock manure in designated N vulnerable zones to be maximum 170 kg/ha.

Member States are obliged to ensure that permits are issued, that they are properly determined and that operators comply with the conditions in those permits in order to comply with the legal requirements of the Directive.

3.4.2: Organisation

The Directorate General in charge of the Environment within the European Commission (DG ENV) is responsible for the IPPC Directive and its development.

The Information Exchange Group (IEG) is the DG ENV advisory group on legal issues related with the implementation of the IPPC Directive in the Member States.

The Information Exchange Forum (IEF) is the Consultative Committee established by the IPPC Directive to generally oversee the elaboration of BREFs and the information exchange process. It gives a final indication to the Commission of its degree of support for final draft BREFs.

The European Member States are responsible for implementing the Directive and for issuing operating permits to the installations concerned.

The Technical Working Group (TWG) is composed of European experts from industry, representatives from Member States authorities and environmental non-governmental organizations established for the purpose of elaborating or reviewing reference documents on best available techniques. A TWG generally consists of between 40 to 100 experts. TWG members are either nominated by their Member State, by a European industrial association (Business Europe) or by the environmental NGO EEB.

3.4.3 : Reference Documents on Best Available Techniques (BREFs)

The IPPC Bureau was set up by DG ENV to organize exchange of information between Member States and industry on Best Available Techniques (BAT), as well as associated monitoring and developments in them.

The European IPPC Bureau produces reference documents on Best Available Techniques, called BREFs. BREFs are the main reference documents used by competent authorities in Member States when issuing operating permits for IPPC installations. The European IPPC Bureau acts as a neutral, technically competent and permanent body to all TWGs.

The procedure used to elaborate or review a BREF includes a few plenary meetings of the TWG, subgroup meetings, visits to installations, and submission of draft BREFs for comments.

Once it has been finalized, each BREF is presented by the European IPPC Bureau to DG Environment at the Consultative Committee (Information Exchange Forum, IEF). The BREFs are then formally adopted by the college of commissioners and a notice of their adoption is published in the Official Journal of the European Communities.

4: RESULT OF DATA ANALYSIS

4.1: REDUCED LIST OF LIVESTOCK MANURE HANDLING TECHNOLOGIES

The complete list of identified livestock manure treatment technologies has been reduced in different ways in relation to the specific needs and purposes of this project. Technologies that are without leaching reduction effect, that are not commercially implemented, that are not in focus in this project, that have apparent other negative impacts on the environment, that have no proven or unacceptable economic performance, or have ethical considerations have been removed.

4.1.1: Non-project relevant technologies

It is for this project given on beforehand, that focus is not on technologies in relation to evaporation (emissions), storage or spreading of livestock manures.

4.1.2: Technologies that are not commercially implemented

A number of the technologies we have identified are still being researched or piloted, and we can of this reason not recommend them to be put into operation on a broad scale in the BSR.

4.1.3: Technologies without leaching reduction effect

Some of the technologies have neither directly or indirectly any leaching reduction effect.

4.1.4: Technologies with apparent negative environment or climate impacts

Especially the aeration technologies are reported to lead to smaller or larger evaporation of laughter gases and ammonia. Seepage is also seen in connection to composting, when material for composting with less than 30% dry matter is placed on the bare soil.

Therefore, of the aeration technologies we do alone recommend that the fibre fraction from separation is composted in order to make it

- stable in the storage, i.e. it will not start fermenting, moulding, leaching, evaporating or other during storage and transport; and
- with a high dry matter percentage, as we acknowledge that composting is an effective and cheap way to remove water from a substrate without consumption of external energy, because the temperatures normally raises to above 70°C during the composting process – a high dry matter percent is especially important if the fibre fraction shall be used in a later thermal gasification or combustion process.

If composting of the fibre fraction is done, then we recommend it happens in a way so that neither emissions of harmful gases nor seepage is possible, i.e. it should be in closed containers.

4.1.5: No proven or unacceptable economic performance for general use

Despite having been implemented in practice, meaning that we could not consider the technologies as being research or piloted, we are in doubt about their viability in commercial use without subsidisation. These technologies counts for instance those that are related with total purification of the liquid fraction, as well as the temperature and pressure treatment, which seems mainly to be relevant in case of a need to treat animal by-products.

4.1.6: Technologies with ethical considerations

We do not see any ethical considerations for any of the listed technologies in Table 6.

However, we remind that N is an expensive and limiting resource in the agricultural production, wherefore it seems uneconomic to convert it to free N (N_2), rather than using it for fertilising of crops instead of buying N fertilisers, that have been produced with high consumption of fossil fuels.

We also remind that P is a scarce resource, and that there is a risk that the P in the ash after combustion of livestock manure is converted to forms with low plant availability.

Table 8: Relation between technologies and selection criteria (4.1.1-4.1.6). Dots indicate technologies that are deselected in this project – open dots indicate technologies, that are indeed interesting, but which would require additional research and policy adaptation. Technologies without dots are the technologies recommended in the report.

#	Livestock Manure Treatment Technology	Not project relevant	Not commercially proven	No leaching effect	High risk for negative impacts on environment and climate	No proven economic performance for general use
00:	**Pre-storage and storage**					
01	Source separation	■				
02	Pre-storage and temporary storage	■				
03	Storage of deep litter	■				
04	Storage of solid manure	■				
05	Storage of urine	■				
06	Storage of slurry	■				
10:	**Separation**					
10A	Flocculation					
11	Separation by grate					
12	Separation by screw pressing					
13	Separation by sieves					
14	Separation by filter pressing					
15	Separation by centrifuge					
16	Flotation					
17	Separation by drum filters					
18	Sedimentation					
20:	**Additives and other pre/1st treatments**					
21	Acidification of liquid livestock manures	■				
22	pH increasing, liming					■
23	Temperature and pressure treatment					■
24	Applying other additives to manure, here under enzymes					■

Table 8 continued.

#	Livestock Manure Treatment Technology	Not project relevant	Not commercially proven	No leaching effect	High risk for negative impacts on environment and climate	No proven economic performance for general use
30:	**Anaerobic treatment**					
31	Anaerobic digestion					
40:	**Treatment of the fibre fraction**					
41	Composting of solid livestock manure or fibre fractions of liquid livestock manure				■	
41A	Composting of liquid livestock manure				■	
42	Drying, possibly followed by pelletizing					□
43	Combustion					□
44	Thermal gasification					□
46	Composting of manure with larvae of the housefly		■			
46	BT (biomass to liquid)		■			
50:	**Treatment of the liquid fraction**					
51	Ultra filtration					■
52	Ammonia stripping					■
54	Reverse osmosis					■
55A	Electrolysis					■
55B	De-mineralisation					■
56	Aeration				■	
56A	Ozonizing			■		
57	Nitrification-denitrification				■	
58	Struvite (magnesium ammonium phosphate) precipitation		■			
59	Algae production on liquid manure substrates		■			

Table 8 continued.

#	Livestock Manure Treatment Technology	Not project relevant	Not commercially proven	No leaching effect	High risk for negative impacts on environment and climate	No proven economic performance for general use
90:	**Transport and disposal**					
91	Truck transport	■				
92	Pipeline transport	■				
93	Field application	■				
94	Constructed wetlands	■				
95	Other disposal	■				
100:	**Air cleaning**					
101	Air washing	■				
110:	**Management**					
111	Official P norms					
112	P index					
113	Certification of persons, who transport or spread livestock manure					

4.1.7: Reduced list with the most cost-efficient livestock manure treatment technologies

Table 8 shows the relation between technologies and the above mentioned selection criteria.

4.1.8: Presentation and further justification of the preferred livestock manure treatment technologies

The recommended livestock manure treatment technologies in relation to the objectives of the project are the following:

- **Separation technologies (ref. group no. 10)** – the concrete principle is chosen according local prices and circumstances, both with respect to the type of mechanical separation technology, and whether it would be cost-efficient to enhance the separation with flocculation and/or flotation. The separation technologies are justified through their ability to provide the basis for an easy and cheap removal of excess P to areas with less intensive livestock productions, where the P can be used in an environmentally safe way, for instance as fertiliser for crops. Separation in a P rich fibre fraction and an N rich liquid fraction is a pre-condition for fertilising crops in a balanced way at farms with high livestock densities (Scenarios II to V). Mechanical separation can both be a pre-treatment and a post treatment. The technology should be a BAT for installations for the intensive rearing of pigs which have more P in the produced livestock manure than can be contained within the P norms and P-index at the fields, where they spread their livestock manure – see Table 8 It is important that both the liquid and the solid fractions are collected in ways that efficiently hinder seepage of effluents and evaporation of N compounds. It is likewise important to ensure, that possible use of floculation agents are made in compliance with EU legislation, and that used flocculation agents would not threaten human or animal health.

- **Anaerobic digestion (ref. no. 31)** is justified through its positive effect on the field effect (recirculation of N in the agricultural production), the positive physical properties of the digestate being more homogenous and easier to apply precisely on the fields and bound to the soil, and its overall economy influenced by a smaller or larger income/value of the biogas itself, as well as positive side effects such as minimised need for the farms to purchase N fertiliser, and positive effect on the climate accounts. Anaerobic digestion plants will, in case they are established as community plants, further serve as regional centres for an environmentally safe redistribution of livestock manure, so that the digestate can be used in a balanced way as fertiliser of crops. The technology is a stand-alone technology, but can be combined with any of the other selected technologies on the reduced list. The technology can be implemented as an on-farm as well as an off-farm technology. Due to the considerable positive effects of anaerobic digestion for the entire society, as well as due to the scale of economy in anaerobic digestion, society should be encouraged to take steps to establish community plants for anaerobic digestion of livestock manures.
- **Management measures (ref. group no. 110)**, including introduction (in all target countries) of official norms for P fertilisation, of a P-index, and of a demand for certification of persons dealing with transport and/or spreading of livestock manures. P fertiliser norms and the P-index will in combination directly avoid over-fertilisation with P in relation to the capacity of the field and the crop to consume the applied P. The certification of persons will ensure their familiarity with good practices as well as standards, norms and rules in relation to their work, and is expected to give less risk for spill of livestock manures in the environment due to un-awareness or accidents, as well as a more precise application on the fields according to plans. The relevance of certification is among other emphasized by the fact that a simple search of the Danish word "gylleudslip" (In English: slurry spill) on Google gives 32.800 hits.

It is emphasized,

1. that the list of the most relevant and cost-efficient livestock manure handling technologies well could change if other criteria were used for the drawing up of the reduced list of technologies, or if more information became available to validate their environmental impacts and cost-efficiency in relation to leaching reduction. It is also important, that the selection of technology principally shall be made on basis of the situation for the individual farm.
2. that the impact of manure treatment technologies on leaching often is dependent on the management of the technologies and on the way different technologies are combined. The leaching reduction effect of a technology should therefore not be seen in isolation – for instance the potential positive effects of separation should not be outweighed by run-off and evaporation due to in-responsible storing and transporting of the fibre fraction."

4.1.9: Interesting technologies that needs further research and policy adaptation

There are three technologies for treating of the separated fibre fraction that is suggested to be further researched and politically considered, namely drying, possibly followed by pelletizing, combustion and thermal gasification (technology reference numbers 42, 43 and 44). The technologies are to some extent proven, also on commercial scale, but it is with reference to Annex E suggested that their environmental and economic performances especially are researched in case of fibre fractions from pig slurry.

Such research would also clarify whether it politically could be made more feasible to implement thermal gasification and combustion.

4.1.10: Possible difficulties for the deployment of the recommended technologies

Considering the recommended technologies there are especially the following difficulties for their deployment:

- There is at policy level a need to spread information about the livestock manure treatment technologies and their beneficial influence on the leaching and other environmental parameters. Secondly it is a challenge to promote the required policy actions in form of legislation, standards, and support schemes.
- On the administrative level, the challenges are in relation to the administration of the IPPC Directive as well as the BREF document, both being in the beginning of a revision process, to
    - re-consider the Annex 1 list of installations to ensure as well that off-farm treatments of livestock manures are carried out in a regulated way;
    - give more emphasis to livestock manure treatment technologies in the BREF document, including being more specific about the condition for their deployment, to expand the description of them, and to add technologies that have emerged since the last revision of the BREF document;
    - introduce the use of N and P leaching as objective criteria for the inclusion of BAT's in the BREF document, both generally, but also specifically concerning livestock manure treatment technologies.
- Thermal gasification and combustion are technologies that are regulated under both waste handling and heating regulations. It is especially troublesome and expensive to deal with the waste combustion regulations for farm-scale plants, because they must be commissioned, registered, monitored, and have systems for cleaning of the flue gas. Changes in excise taxation of the heat produced at such plants could be implemented, or via spatial planning it could be forbidden to establish own heating plants or heating plants that do not use a prescribed fuel.
- Both plants for anaerobic digestion, thermal gasification, and combustion would, dependent on the specific target country as well as national definitions, require environmental permits, and it can be difficult and time consuming to find suitable locations for such a plants.
- Anaerobic digestion plants, and in general all "hardware" technologies, are expensive and require extra binding of capital in the production system of resources with a negative or a doubtful return. The binding of capital in the livestock manure treatment technologies poses an extra risk for a farm, because the alternative use of the investment might be low in case the farmer stops livestock production.
- Any technologies that result in products that are intended for sale/export out of the farm/region have the drawbacks that the markets do not exist or are not developed for the products. Marketing of such products requires, as enforced by the legislation, that the producers are registered, follow some Hazard Analysis Critical Control Point (HACCP) schemes, label their products, and guarantee the content of plant nutrients of them. These requirements are in themselves difficult and expensive to deal with, and are almost unrealistic for farm-scale installations.

4.2: EFFICIENCY OF THE IPPC DIRECTIVE TO PROMOTE BEST AVAILABLE TECHNOLOGY FOR MANURE TREATMENT

The questionnaire and interviews give a homogenous indication on stakeholders view on the efficiency of the IPPC Directive to promote best available treatment of manure. Generally, the respondents consider the implementation of the IPPC legislation to be effective, but that leaching of N and P to water and effective manure treatment technologies is not given high attention in the legislation.

The current Reference Document on Best Available Techniques for Intensive Rearing of Poultry and Pigs (BREF) was adopted in June 2003. It is a

338 page long document, describing several aspects of pollution from pig and poultry farming. Energy issues and emissions to the atmosphere are in focus of the document. The lower focus on manure treatment reflects the development in industrial pig farming since the document was adopted. At that time, the average Danish pig farm for example, had 550 pigs (including piglets, sows and production pigs) while the average herd size is 2.250 pigs today. The need to treat/process manure has vastly increased, and will most probably continue to increase as national economies in the new EU Member States increases.

Livestock manure treatment technologies have impacts on the leaching of N and P, and they need to be considered within the BREF.

Criteria for what is to be considered as a BAT for manure treatment in intensive rearing of poultry and pigs are not specified within the legislation or in the BREF.

A review process of the current BREF for intensive rearing of poultry and pigs was initiated in June 2008. The Technical Working Group members are asked to communicate recommended best available techniques to the IPPC Bureau by February 2010. The official guiding documents for the revision process of the BREF on the IPPC webpage (http://eippcb.jrc.ec.europa.eu/index.html), do not so far give special attention to leaching of nutrients to water.

Several respondents have shown interest in the "Best Practice Manure" project objectives and activities, especially the list of cost effective technologies to reduce leaching of nutrients from pig manure. **There seems to be a window of opportunity to develop a BREF who gives better attention to leaching of nutrients to water, and promote cost efficient manure treatment technologies that reduce this problem.** It is important to take this opportunity, as it will take several years before the next review.

ANNEX A: ABBREVIATIONS AND ACRONYMS

ABP	Agro Business Park
BAT	Best Available Technique, as defined in Directive 2008/1/EEC
BREF	Reference Document on Best Available Techniques for Intensive Rearing of Poultry and Pigs
BSAG	Baltic Sea Action Group
BSR	Baltic Sea Region
CBMI	Innovation Centre for Bioenergy and Environmental Technology
CC	Cross Compliance
CO2	Carbon Dioxide
DG ENV	The Directorate General in charge of the Environment within the European Commission
DM	Dry matter
EEB	European Environmental Bureau
EEC	European Economic Community
EIA	Environmental Impact Assessment
EU	European Union
HACCP	Hazard Analysis Critical Control Point
HELCOM	Helsinki Commission
IEF	The Information Exchange Forum
IEG	The Information Exchange Group
IPPC	Integrated Pollution Prevention and Control, as defined in Directive 2008/1/EEC
IVL	Swedish Environmental Research Institute
JTI	Swedish Institute of Agricultural and Environmental Engineering
K	Potassium
LCA	Life Cycle Analysis
LIFE	the EU's financial instrument supporting environmental and nature conservation projects throughout the EU
LRF	the Federation of Swedish Farmers
MTT	Agrifood Research Finland
N	Nitrogen
NGO	Non-governmental organisation
NVZ	Nitrate Vulnerable Zone, as defined in Directive 676/91/EEC
P	Phosphorus
SEI	Swedish Environmental Institute
SLU	Swedish Agricultural University
SYKE	Finnish Environment Institute
TS	Total Solids
TWG	Technical Working Group, in relation to Directive 2008/1/EEC

ANNEX B: REFERENCES

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ANNEX C: LIST OF PEOPLE MET

LIST OF PERSONS MET DURING STUDY TOUR TO HOLLAND

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Malgorzata Typko, Deputy Director, Department of Environmental Instruments, Ministry of the Environment, Poland.

Anna Poklewska-Koziell, Polish Institute for Building, Mechanization and Electrification of Agriculture (IBMAR), Branch in Poznan.

Mona Strandmark, Plant Nutrient Division, Swedish Board of Agriculture.

Poul Arne Iversen, Ministry of Food, Agriculture and Fisheries, Denmark.

Poul Pedersen, Danish Pig Housing & Production Systems, Denmark.

Karen-Marie Mortensen, Department of Environment, The Danish Plant Directorate, Ministry of Food Agriculture and Fisheries.

Mr. Kristian Snorre Andersen, Title/Division Danish Environmental Protection Agency.

ANNEX D: CHARTS OF MANURE TREATMENT TECHNOLOGIES

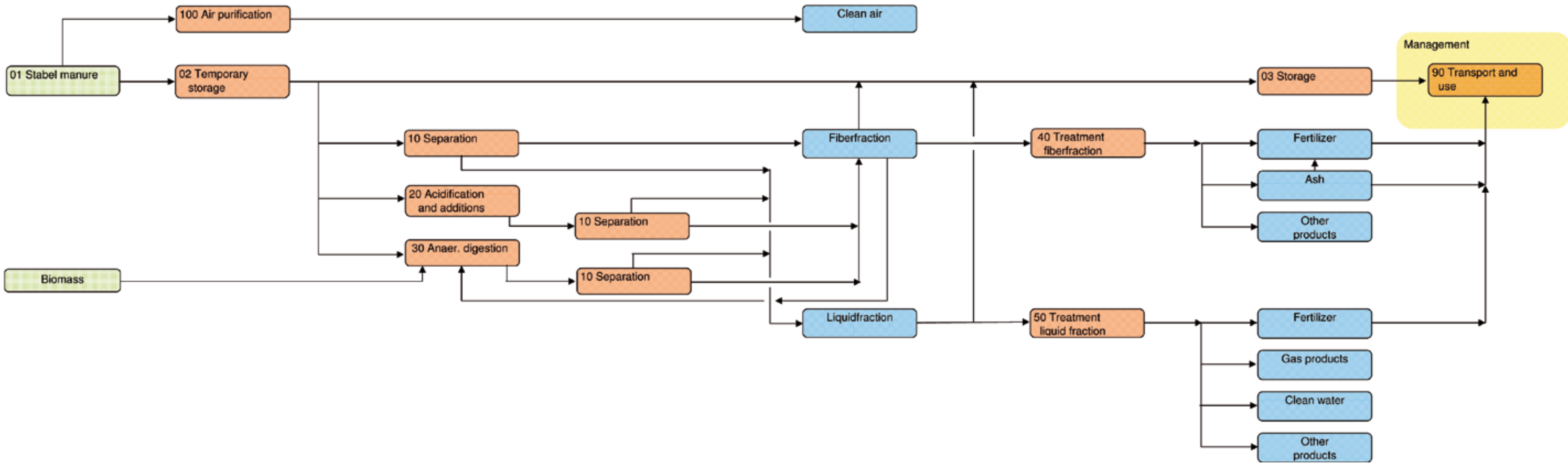

Figure 5: Overview of livestock manure treatment technologies between source and final disposal. The red boxes indicates the group of livestock manure treatment technologies, and the number as well as the name of the technology group in the box refer to more specified figures and tables with descriptions below. The green boxes indicates livestock manure and other biomass that goes into the treatment processes, the blue boxes the intermediary or end products, and the yellow box the management technologies, related with the transport, field spreading and other disposal.

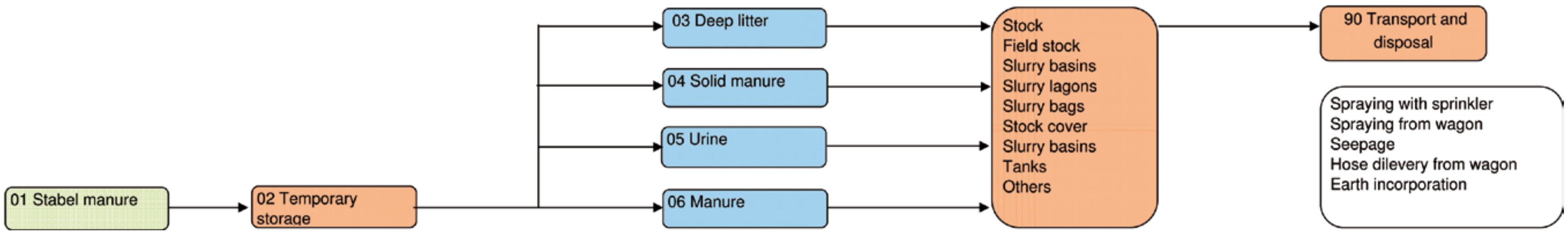

Figure 6: Technologies 02, 03 and 90. The figure illustrates the basic route from source to field for livestock manure. Involved technologies for storage and spreading of livestock manure on the fields are not in focus in this project.

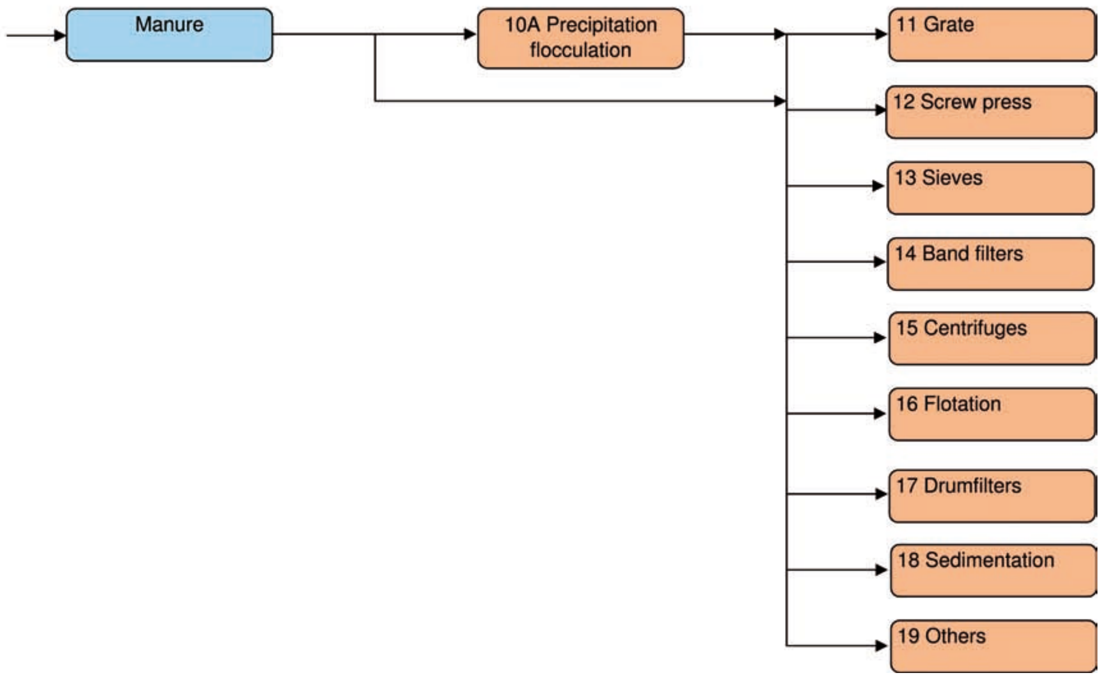

Figure 7: Group 10 is technologies concerning separation. The separation can happen with or without an initial flocculation. There are many separation methodologies, some of them more commonly used than others, which are presented in details below. Separation technologies can in some cases be done after a main treatment.

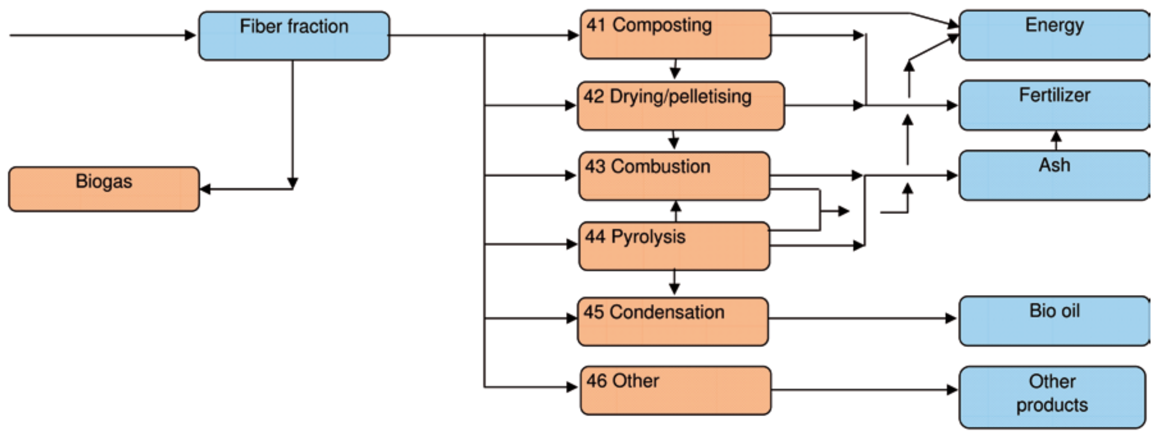

Figure 8: Group 40 comprises the main livestock manure treatment technologies concerning the separated fibre fraction. Often the treatments have the purpose to produce energy or fertiliser products

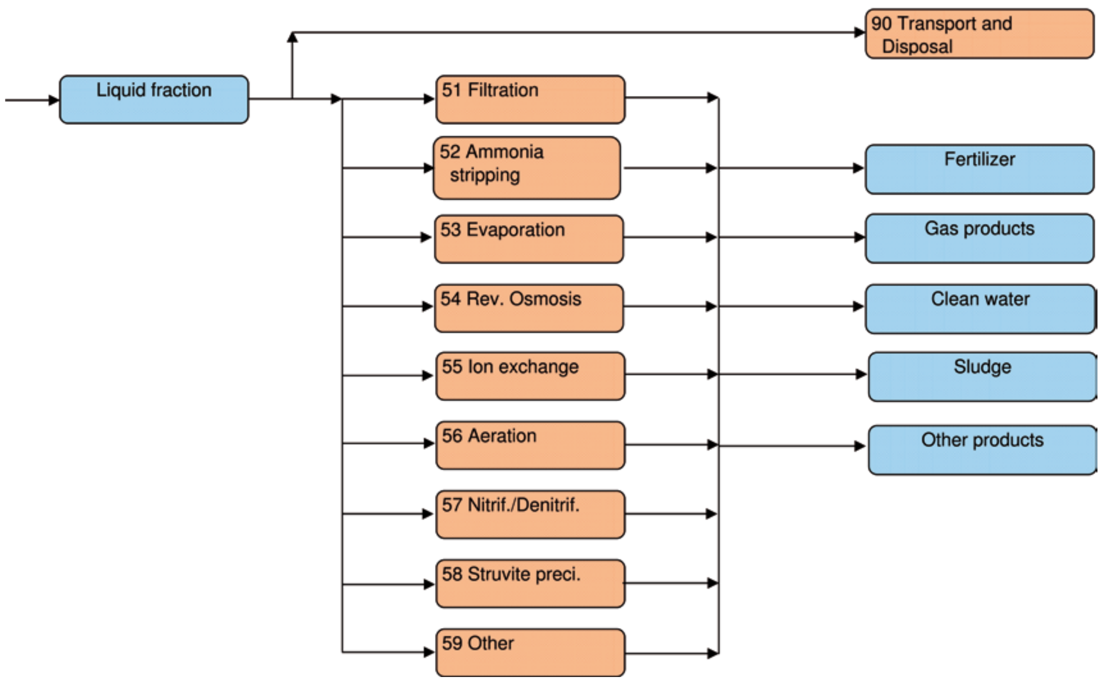

Figure 9: Group 50 comprises the main livestock manure treatment technologies concerning the separated liquid fraction.

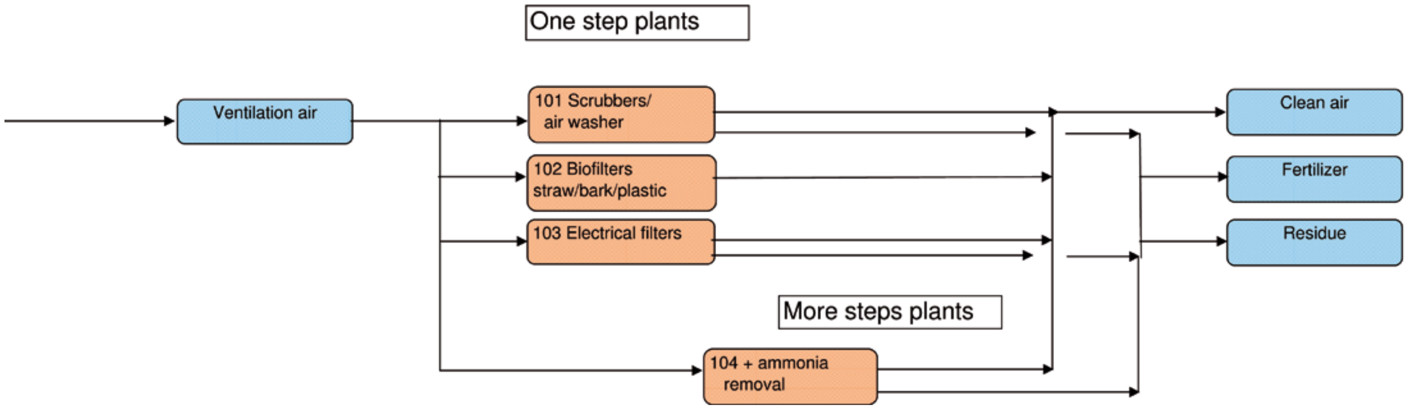

Figure 10: The figure illustrates air treatment technologies, which mainly have the purpose to catch evaporated ammonia from the ventilation air, and as well to reduce the smell from the livestock production. Those technologies are not in focus in this project.

BEST AVAILABLE TECHNOLOGIES FOR MANURE TREATMENT
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ANNEX E: TABLES WITH SHORT DESPRIPTION OF LIVESTOCK MANURE TREATMENT TECHNOLOGIES

<table>
<tr><td>Ref No. 02 - 06</td><td colspan="5">Storage facilities</td></tr>
<tr><td colspan="5">Brief description</td><td>Description of the effect on leaching (positive or negative) of N and P[5]</td></tr>
<tr><td colspan="5">One of the crucial factors in the management of livestock manure is the capability to storage the manure during the year to achieve the possibility to supply the crops when it is most needed. Examples of storage facilities are primarily big concrete tanks, where manure can be stored (typically capacity of 5oo to 5.000 m3). These storage tanks are very simple, but the level of investment is fairly high.

It is possible to install a tight fitting cover on most tanks, primarily to prevent emission of ammonia and odour.

For solid manure, the storage facilities will be manure pits.</td><td>By being able to store livestock manure safe during periods of the year where it is not appropriate to spread manure in relation to the need of the crops, as would achieve a significant reduction in leaching of nutrients to the recipients. It is very unfortunate to spread manure especially in winter, since at this point no crops are growing to absorb nutrients, and nutrients may potentially be leached.
Also during the summer, it is not appropriate to spread manure, if the sole purpose is getting space in a storage tank which does not have sufficient capacity and at the same time no crop with fertiliser needs.
A proper storage management of manure will in itself have a great effect in preventing point source hot spot pollution.</td></tr>
<tr><td rowspan="2">Innovation stage</td><td colspan="2">Investment price[6], €</td><td rowspan="2">Operational costs[7], € per tonnes</td><td rowspan="2">€ per kg saved N or P leaching</td><td rowspan="2">Complexity of implementation</td></tr>
<tr><td>Basic</td><td>Variable[8]</td></tr>
<tr><td>Research
Pilot
Practice ✓</td><td>€ 10.000 (small tank for 883 m³)</td><td>€ 23</td><td>€ 0,0</td><td rowspan="3">No data</td><td rowspan="3">Low, the complexity of storage tanks is very low, there is no need for trained staff, no special demands of and there are plenty of companies on the market.</td></tr>
<tr><td>Major references</td><td>Condition for leaching reduction effect</td><td colspan="2">Certainty of information</td></tr>
<tr><td>EU Commission, 2003
Landscentret, 2005</td><td>Scenarios I - V</td><td colspan="2">Prices High
Effect on leaching High</td></tr>
</table>

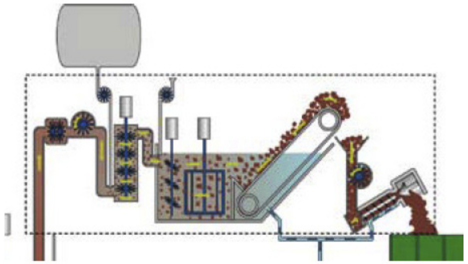
5 If the effect is validated, then a reference is made – else based on own estimates. Includes quantification of the leaching effect.

6 Rough estimate of the investment price for the technology, expressed as 1) a basic price (typically the price for the smallest units) + a variable price per extra installed manure treatment capacity. All prices are in €, and including all costs, as well for projecting, planning, approvals, occupied land or buildings, etc. There is often an economy of scale in the investment price of environmental technologies. An approached formula to explain this economy of scale would often be with the following syntax: Y=aX + b, where b is the basic investment price and a is the variable price, while X is the capacity in tonnes and Y is the investment price."

7 Including consumed electricity, heat, water, chemicals, labour, and other inputs.

8 Per tonnes annual capacity, unless otherwise indicated. For storage capacity the variable investment price is per tonnes size capacity.

BEST AVAILABLE TECHNOLOGIES FOR MANURE TREATMENT BALTIC SEA 2020

<table>
<tr><td>Ref No. 10A</td><td colspan="6">Flocculation</td></tr>
<tr><td colspan="5">Brief description</td><td colspan="2">Description of the effect on leaching (positive or negative) of N and P</td></tr>
<tr><td colspan="5">Flocculation is often used as a pre-treatment technology to mechanical separation systems. In the flocculation process, agents / flocculants aggregate organic particles / fibres in the liquid manure into bigger particles, whose size and other physical properties makes them easier to separate from the rest.

As flocculants are used for instance clay mineral betonite (Henriksen at al., 1998). More conventionally used flocculants are polymers like proprietary cationic polyacrylamide (PAM). Polymers are often mineral oil derivates, which according EU legislation is prohibited to spread on fields. Attention should also be given to the fact that polymers in the nature are broken down to monomers, which can have carcinogen effect.
Generally, flocculation is thus a technology that makes technologies for mechanical separation more efficient. Hjorth (2009) reports trials, which shows that polymer flocculation and drainage of pig slurry leads to a fibre fraction with 29% of the dry matter, 40% of the N, and 90% of the P, as compared to for instance pressurised filtration, which makes the fibre fraction hold only 14% of the dry matter, 3% of the N and 15% of the P.
Flocculation can increase the amount of nutrients in the fibre fraction, compared to more simple separation as screw pressing. In cases where it is necessary to reduce the application of P to the fields, the use of flocculation as a technology would be worth considering. See further explanation at for instance Ref No. 14: Filter pressing.</td><td colspan="2">In case the livestock density in an area is the maximally allowed according the Nitrates Directive, the application of livestock manure would typically mean the double of the needs of the crops concerning P.
By exporting the phosphorus rich fibre fraction to areas with a low livestock density, an over-fertilisation and leaching of excess P can be avoided.</td></tr>
<tr><td rowspan="2">Innovation stage</td><td colspan="2">Investment price, €</td><td rowspan="2">Operational costs,
€ per tonnes</td><td rowspan="2">€ per kg saved N or P leaching</td><td colspan="2" rowspan="2">Complexity of implementation</td></tr>
<tr><td>Basic</td><td>Variable</td></tr>
<tr><td>Research
Pilot
Practice ✓</td><td>€ ~ 50.000</td><td>No data</td><td>€ ~ 0,80</td><td rowspan="3">Varying with the concrete situation.</td><td colspan="2" rowspan="3">Medium
There are several commercial plants/technologies on the market, which are quite easy to install on the farm, provided stable systems, storage tanks etc. on the farm are suitable for this. The investment complexity is fairly high, due to the pre treatment flocculation typically being part of a wider manure treatment system, comprising also mechanical separation.</td></tr>
<tr><td>Major references</td><td>Condition for leaching reduction effect</td><td colspan="2">Certainty of information</td></tr>
<tr><td>1: Nielsen, 2008
2: European Commission, 2003</td><td>Scenarios II – V</td><td>Prices
Effect on leaching</td><td>Medium
High</td></tr>
</table>

Ref No. 12	**Separation by screw pressing**
Brief description	**Description of the effect on leaching (positive or negative) of N and P**
The principle is based on a simple screw mechanism, where the continuously added material is put under pressure and thereby pressing out the liquid part. The capacity is high and, as well as the investment is quite low. The separation efficiency concerning nutrients in the fibre fraction is fairly low, which is related to a simple, but stable technology.	In case the livestock density in an area is the maximally allowed according to the Nitrates Directive, the application of livestock manure would typically mean the double of the needs of the crops concerning P. By exporting the fibre fraction to areas with a low livestock density, over-fertilisation and leaching of excess P can be avoided.

Screw pressing	Content in fibre fraction			
Capacity (t/h)	N	P	% of total volume	% DM (dry matter)
10 - 30	8 – 10 %	10 – 30 %	8 %	10 – 40 %

Innovation stage	Investment price, €		Operational costs, € per tonnes	€ per kg saved N or P leaching	Complexity of implementation
	Basic	Variable			
Research Pilot Practice ✓	€ ~ 35.000	€ 1,00	€ 0,25	No data	**Low** There are several commercial plants/technologies on the market, and is quite easily to install on the farm if the conditions at the farm are suitable concerning stable systems, storage tanks etc.
Major references	**Condition for leaching reduction effect**	**Certainty of information**			
1: Nielsen, 2008 2: EU Commission, 2003	Scenarios II – V	Prices High Effect on leaching High			

Ref No. 14	**Separation by filter pressing**
Brief description	Description of the effect on leaching (positive or negative) of N and P
The principle is based on a system where the material is passing a specific type of filter (band filter). This band filter is constantly turning on rollers to make the material moving and to gain pressure on the material, and thereby the liquid part will pass the filter. Often the band filter separation is followed by a screw pressing unit, to increase the dry matter content in the fibre fraction. The band filter is both efficient and has a good capacity, but the investment is fairly high.	In case the livestock density in an area is the maximally allowed according the Nitrates Directive, the application of livestock manure would typically mean the double of the needs of the crops concerning P. By exporting the fibre fraction to areas with a low livestock density, over-fertilisation and leaching of excess P can be avoided.

Band filter	Content in fibre fraction			
Capacity (t/h)	N	P	% of total volume	% DM (dry matter)
8 - 12	29 %	73 %	9 %	35 %

NB: Data for band filter is with flocculation, see other table.

Innovation stage	Investment price €		Operational costs € per tonnes	€ per kg saved N or P leaching	Complexity of implementation
	Basic	Variable			
Research Pilot Practice ✓	€ ~ 125.000	€ 1,00	€ 1,50	No data	**Medium** There are several commercial plants/technologies on the market, and is quite easily to install on the farm if the conditions at the farm are suitable concerning stable systems, storage tanks etc. But the investment and complexity is fairly high, also due to the pre treatment as flocculation.
Major references	**Condition for leaching reduction effect**	**Certainty of information**			
1: Nielsen, 2008 2: EU Commission, 2003	Scenarios II - V	Prices High Effect on leaching High			

Ref No. 15	**Separation by centrifuge**				
Brief description					Description of the effect on leaching (positive or negative) of N and P
The manure is being centrifuged with 3.000 – 4.000 r/minute, so the liquid is separated from the fibre fraction. The fibre fraction is continuously moved out of the drum by a slower rotating conveyer. The centrifuge has high capacity, and good separation efficiency, but fairly high investment.					In case the livestock density in an area is the maximally allowed according the Nitrates Directive, the application of livestock manure would typically mean the double of the needs of the crops concerning P. By exporting the fibre fraction to areas with a low livestock density, over-fertilisation and leaching of excess P can be avoided.
Innovation stage	Investment price, €		Operational costs	€ per kg saved N or P leaching	Complexity of implementation
	Basic	Variable	€ per tonnes		
Research Pilot Practice ✓	€ ~ 100.000	€ 1,00	€ 0,70	No data	**Medium**, there are several commercial plants/machines on the market, and is quite easily to install on the farm if the conditions at the farm are suitable concerning stable systems, storage tanks etc. But the investment is fairly high, and also the demands for capacity of flow of material/manure.
Major references	Condition for leaching reduction effect	Certainty of information			
1: Nielsen, 2008 2: EU Commission, 2003	Scenarios II – V	Prices: High Effect on leaching: High			

Centrifuge	Content in fibre fraction			
Capacity (t/h)	N	P	% of total volume	% DM (dry matter)
6	20 %	70 %	10 %	30 %

Ref No. 16	**Flotation**
Brief description	**Description of the effect on leaching (positive or negative) of N and P**
Flotation is used extensively in food industry especially for the treatment of process wastewater. By flotation, suspended material can be separated from the liquid phase and concentrated in a sludge phase, skimmed and handled separately. By flotation, water saturated with air under pressure is brought to the bottom of the flotation tank and releases microscopic bubbles to the wastewater or manure to be treated. In contrast to sedimentation, where heavy particles precipitated in a liquid, you get in a flotation formed large light particles brought to the surface of very fine small bubbles, which sits on the suspended material. The suspended material can be scraped off the surface with a mechanical scraper and forms flotation sludge. Virtually all suspended material in the liquid can be removed by this process. A Danish company has applied the flotation in combination with ozone dosing for treatment of manure. Furthermore, there is installed a flotation plant to treat degassed biomass on a single biogas plants in Denmark. Flotation has been used for treatment of manure on pig farms in USA. Flotation is thus a process, which can further purify the liquid fraction after a mechanical separation and a flocculation process. Flotation is often used in combination with chemical flocculation.	By flotation a very high proportion of ammonia in the liquid is discharged with the air, while the suspended material floated. It is therefore necessary to make a collection of exhaust air from flotation if the method should be recommended. This should be done to prevent the ammonia to escape with the exhaust air, which subsequently will lead to a deposition of ammonia.

Innovation stage	Investment price, €		Operational costs, € per tonnes	€ per kg saved N or P leaching	Complexity of implementation
	Basic	Variable			
Research Pilot Practice ✓	No data. However, a plant in Holland, which used flotation in addition to flocculation, drum belt separation, reverse osmosis, and demineralisation, claimed the operational costs for all processes were at a level of € 5 per ton slurry.			No data.	High – typically the technology is part of a high-tech livestock manure management treatment plant.
Major references	**Condition for leaching reduction effect**	**Certainty of information**			
Foged, 2009	Scenarios II to V	Prices: Low Effect on leaching: High			

Ref No. 17	**Separation by drum filters**
Brief description	**Description of the effect on leaching (positive or negative) of N and P**
Drum sieve: The principle is an app. 4 meters long drum, where the material is flowing through inside and the liquid is passing through the drum. Eventually the drum can be mounted with a fibre cloth on the outside to optimize the separation. The drum sieve has often lower capacity, but has fairly good separation efficiency in relation to a low investment.	In case the livestock density in an area is the maximally allowed according the Nitrates Directive, the application of livestock manure would typically mean the double of the needs of the crops – especially concerning P. By exporting the fibre fraction to areas with a low livestock density, an over-fertilisation with P can be avoided, and thus a high degree of leaching of the excess P. According to N, the fibre fraction contains mainly (> 90%) of organic bounded N, which means that it is overall ammonium and nitrate (mineral N) that is left in the liquid part, and that means a substantial reduction in the potential leaching.

Drum sieve	Content in fibre fraction			
Capacity (t/h)	N	P	% of total volume	% DM (dry matter)
2 -3	20 %	30 - 55 %	25 - 27 %	12 %

Innovation stage	Investment price, €		Operational costs, € per tonnes	€ per kg saved N or P leaching	Complexity of implementation
	Basic	Variable			
Research Pilot Practice ✓	€ ~ 25.000	€ 1,00	€ 0,35	No data	**Low**, there are several commercial plants/machines on the market, and is quite easily to install on the farm if the conditions at the farm are suitable concerning stable systems, storage tanks etc.
Major references	**Condition for leaching reduction effect**	**Certainty of information**			
1: Nielsen, 2008 2: EU Commission, 2003	Scenarios II – V	Prices Effect on leaching	High High		

Ref No. 21	Ph adjustment, acidification
Brief description	**Description of the effect on leaching (positive or negative) of N and P**
pH adjustment is done of the liquid livestock manure / fraction in an acid treatment unit where ammonia is bound with sulphuric acid (H_2SO_4) to form ammonium sulphate in order to prevent ammonia emissions from the treatment process. The acidification is thus a technology, which mainly is used for the purpose of reducing emissions from the livestock manure, which are closely related to smell/nuisances from the pig production. Typically 0.5% of the sulphuric acid, equal to 5 kg per tonnes slurry, is able to reduce pH to about 5.5, while pH in fresh pig slurry in a project is measures to about 7.3 (Siegler, 2009). The emission of methane from cattle slurry has been measure to be reduced 67-90 % (Jacobsen, 2009), and we must anticipate a similar effect for pig slurry. The content of N in the slurry is 15-20 % higher than in untreated slurry due to decreased emission of ammonia from the stable, storage and field (Jacobsen, 2009). Tests show that the emissions of laughter gas are reduced with 80%. Field trials have shown higher field effects (bioavailability of nitrogen) of acidified slurry, however with a big variation between responses in different trials (Sørensen, 2006 and Jensen, 2006). See further under additives.	Less emission of ammonia emissions means that less N could return as atmospheric deposition and that more N is re-circulated in the agricultural production rather than ending in the environment. Field trials indicates, that acidification of slurry affects the field effect.

Innovation stage	Investment price, €		Operational costs, € per tonnes	€ per kg saved N or P leaching	Complexity of implementation
	Basic	Variable			
Research Pilot Practice ✓	€ 100.000 (?)	50 (?)	2 (?)	€ 2-2½ (N)	Low – each farm can easily attach an acidification unit to the slurry system at the farm.
Major references	**Condition for leaching reduction effect**	**Certainty of information**			
Jacobsen, 2009 Sørensen, 2006 Jensen, 2006	The effect will be found at all farms.	Prices: Low Effect on leaching: Medium			

Ref No. 22	**PH increasing, liming**
Brief description	**Description of the effect on leaching (positive or negative) of N and P**
It is in some cases relevant to increase the pH in the manure substrate. This is for instance the case in connection with N-stripping – see below. A Swedish company has described a concept whereby livestock manure with more than 50% dry matter undergoes a drying and sterilization process, where only energy generated by calcium oxide hydration process is used. As a reagent is used very high reactivity lime oxide. The product becomes a soil liming fertiliser in a dry sterilized form. The reactive lime used in the process is serving as a source of energy for the drying and as sterilizing agent for all bacteria and viruses (pathogens) present in the manure, and as liming agent changing soil pH.	Probably no effect in case of N-stripping, which as mentioned typically is done to avoid anaerobic digestion inhibition. The effect connected with the use of lime for drying the manure will make it more economic to transport the manure to other areas – however, pig manures are almost always in the form of slurry, for which the technology apparently is not relevant.

Innovation stage	Investment price, €		Operational costs, € per tonnes	€ per kg saved N or P leaching	Complexity of implementation
	Basic	Variable			
Research ✓ Pilot Practice	No data	No data	No data	No data	Low – mixing of the manure with lime can probably be done with machinery that is available on most farms.
Major references	**Condition for leaching reduction effect**	**Certainty of information**			
Knut Hovland	Scenarios II to V	Prices: None Effect on leaching: Low			

Ref No. 23	**Temperature and pressure treatment**
Brief description	Description of the effect on leaching (positive or negative) of N and P
Treatment of slurry by raising the temperature to more than 72 degrees shall be made on a number of Danish biogas plants, as this is a veterinary requirement. The slurry is hygienic and at the same time a bigger portion of the organic matter is made accessible to biological degradation afterwards. This can increase the biogas yield if the slurry is subsequently used in biogas plants. A combination of high pressure and high temperature (pressure cooking) has been used for pre-treatment of the fibre fraction of separated slurry. By the treatment a hygienic product is made and at the same time higher proportions of cellulose and hemicelluloses is made available for subsequent biological treatment. The process is very energy consuming and ammonia is discharged with the exhaust air and has to be collected, to prevent air pollution. As a standalone treatment this form of treatment cannot be recommended but can be beneficial in some cases in combination with biogas plants. The process is also called hygiening in case the treated material is comprised by EU's Animal By-products Directive. Temperature and pressure treatment can be done of biomass substrates with high cellulose and lignin content in order to obtain a higher biogas yield of such fractions.	No direct effect. However, the treatment will, in case it is applied to plant fibres, make the anaerobic treatment more efficient because it opens the cell structures so the anaerobic bacteria can digest the substrate more efficiently. It is claimed that the biogas production in this way can be increased with 20 - 60%. A larger part of the N would similarly be converted to the more readily available ammonium N, wherefore the digestate would have relatively higher field effect.

Innovation stage	Investment price, €		Operational costs, € per tonnes	€ per kg saved N or P leaching	Complexity of implementation
	Basic	Variable			
Research Pilot ✓ Practice ✓	€ 50.000 (?)	-	€ 5 (?)	Depends on the situation of the individual farm.	High –this is typically part of a complex livestock manure treatment facility
Major references	Condition for leaching reduction effect	Certainty of information			
Foged, 2009	The digestate is used to fertilise crops according a fertiliser plan.	Prices Low Effect on leaching High			

Ref No. 24	**Adding other chemical to manure, here under enzymes**
Brief description	Description of the effect on leaching (positive or negative) of N and P
Under the generic denomination of manure additives are a group of products made up of different compounds that interact with the manure, changing its characteristics and properties. These products are applied to the pig manure in the pits, and the following effects are described to different degrees in the label of every product: 1. a reduction in the emission of several gaseous compounds (NH3 and H2S) 2. a reduction of unpleasant odours 3. a change in the physical properties of the manure to make easier its use 4. an increase in the fertilising value of the manure 5. a stabilisation of pathogen micro-organisms. Usually, the items 2 and 3 are the main reasons for their use at a farm level. Below the techniques 1 – 5 are detailed. <u>1. Additives for reducing the emission of several gaseous compounds</u>: The decrease in gaseous emissions achieved through its use (mainly NH_3 and H_2S) is one of the most interesting yet controversial points. It has been well documented that up to 90 % of the N produced by the pigs is as urea. When the urease produced by faecal micro-organisms comes into contact with urea, the following reaction occurs: $CO(NH_2)2 + 3 H_2O \Rightarrow 2 NH_4 + HCO_3 + OH$ This reaction is highly influenced by temperature and pH, for example, under 10 °C or at a pH below 6.5 the reaction stops. <u>2. Additives for reducing unpleasant odours</u>: Odour results from the mix of different compounds under anaerobic conditions. More than 200 substances involved have been identified, such as: ▪ volatile fatty acids ▪ alcohols (indol, skatole, p-cresol, etc) ▪ H_2S and derivatives ▪ ammonia ▪ other N compounds (amines and mercaptans). There is a huge variation in the proportion and concentration of every substance depending on the type of farm, nutrition and nutritional management, and climatic conditions. This could explain why in many instances the effectiveness of these compounds against odours could not be proven under farm	The effects on leaching in concerning N related with the additive effect on emission on ammonia and other N compounds. Less emission of ammonia emissions means that less N could return as atmospheric deposition and that more N is re-circulated in the agricultural production rather than ending in the environment. The effect on P leaching is associated with the use of additives in processes to separate the manure in fractions, allowing the fibre fraction with a high content of P to be exported to areas with a low livestock density.

conditions.

3. Additives for changing the physical properties of the manure: The objective of the additive is to make the manure easier to handle. These additives are probably the most used and their effects are well known. Their use results in an increase in manure flowing, an elimination of superficial crusts, a reduction of solved and suspended solids and a reduction in the stratification of the manure. However, these effects were not demonstrated in every comparable case.

Their application might make the cleaning of the manure pits easier, and thereby might shorten the cleaning time required and allow a saving in water and energy consumption. Moreover, since the manure is more homogeneous, it eases the manure's agricultural use (better dosing).

4. Additives for increasing the fertilising value of the manure: This effect is in fact derived from the reduction in NH_3 emissions, thereby keeping this N retained in the manure (in many cases through the increased synthesis of the microbial cells, giving higher levels of organic N).

5. Additives for stabilising pathogens micro-organisms: There are many different microorganisms in manure, part of these contribute to the gaseous emissions and odours. It is also possible to find faecal coli forms and Salmonella and other pig pathogens, virus, eggs of flies and nematodes in the manure.

Usually, the longer the storage period the higher the decrease in pathogens, because of the different requirements of temperature and pH. The pH decreases within the first month of storage (from 7.5 to 6.5 because the microbial synthesis of volatile fatty acids) which has a negative effect on pathogens survival. Some of the manure additives have been designed to control them, especially the eggs of flies.

Types of manure additives

- masking and neutralising agents: These are a mix of aromatic compounds (heliotropin, vanillin) that work by masking the manure odour. The agent is easily destroyed by manure micro-organisms. Its actual efficacy is questionable.
- adsorbers: There are a large number of substances that have demonstrated an ability to adsorb ammonia. Some types of zeolites called clinoptilolites have shown the best effect, being added either to the manure or to feed on ammonia emission. They are also able to improve soil structure and have the added benefit that they are not toxic or hazardous. Peat gives similar results and is also sometimes used.
- urease inhibitors: These compounds stop the reaction described earlier preventing urea from being transformed into ammonia. There are three main types of urease inhibitor:
    1. phosphoramides: applied directly to the soil. Show a good effect. They work better in acid soils, but could affect soil micro-organisms
    2. yucca extracts (Y. schidigera): many trials have been done to assess its potential but the available information is controversial, showing good results in some cases, but no effect

at all in other cases 3. straw: considered as an adsorbant in many references. However besides the absorbing effect, it also increases the C:N ratio. Its use is controversial because in many other works it shows an increase in ammonia emissions. ■ pH regulators: there are two main types: 1. acid regulators: usually inorganic acids (phosphoric, hydrochloric, sulphuric). In general they show good effects but their costs are very high and the substances themselves are dangerous. Their use is not recommended at farm level (!) 2. Ca and Mg salts: these salts interact with manure carbonate, decreasing the pH. They could increase the fertilising value of the manure but could also increase the salinity of the soil (chlorides). They are used sometimes, but mainly in combination with other additives. ■ oxidising agents: Their effects are through: ■ oxidation of the odour compounds ■ providing oxygen to aerobic bacteria ■ inactivating the anaerobic bacteria that generate odorous compounds. The most active are strong oxidising agents such as hydrogen peroxide, potassium permanganate or sodium hypochloride. They are hazardous and not recommended for farm use. Some of them (formaldehyde) could be carcinogens. Ozone application has demonstrated its efficacy but operational costs are very high. ■ flocculants: are mineral compounds (ferric or ferrous chloride and others) or organic polymers. P is highly decreased but their use generates waste that is difficult to manage (see also above) ■ disinfectants and antimicrobials: chemical compounds that inhibit the activity of the micro-organisms involved in odour generation. They are expensive to use and with sustained use an increase in dosing is needed ■ biological agents: these can be divided into: 1. enzymes: their use is to liquefy solids. They are not hazardous. The actual effect depends strongly on the type of enzyme, the substrate and a proper mixing 2. bacteria: ■ exogenous strains: they have to compete with natural strains which makes getting good results more difficult. Their use is better in anaerobic pits or lagoons to reduce the organic matter producing CH_4 (sowing of methanogens bacteria is more efficient and	

sensitive to pH and temperature). High efficacy but frequent re-sowing has to be carried out

- promote natural strains: this is based on adding carbonate substrates (increased C:N ratio). Its effect is based on the use of ammonia as a nutrient, but they need a sufficient source of C to develop an efficient synthesis process, changing ammonia on the organic N of cell tissue. Re-sowing has to be carried out too, to avoid reverting to the starting point. They are not hazardous and no significant cross-media effects have been reported.

Overall efficacy of manure additives and farm use: Nowadays there are many manure additives in the market, but the efficacy has not been demonstrated in every case. One of the main problems is the lack of standard techniques to test and analyse the results. Another problem with their use is that many trials have only been developed under experimental conditions in laboratories and not on-farm, where big variations in nutrition, the management of nutrition, pH and temperature can be found. Besides this, there is also sometimes a huge volume of manure to be mixed with the additive in a pit or lagoon, and the results achieved often depend a lot more on the mixing efficiency than on the lack of efficacy of the additive. Improving the flow characteristics seems to be strongly related with a good mixing.

The efficacy of every compound is highly dependent on the correct dosing, right timing and a good mixing. In some cases a small effect has been observed of an increase in the fertilising value, but this effect is related to the type of crop, the time of application and dosing.

It has to be highlighted that in many cases the effects on human or animal health or other environmental effects by using additives are not known and this, of course, limits their applicability.

Innovation stage	Investment price, €		Operational costs, € per tonnes	€ per kg saved N or P leaching	Complexity of implementation
	Basic	Variable			
Research Pilot Practice ✓	€ 500 (small)	Depends	Depends	Depends on the situation of the individual farm.	Low
Major references	Condition for leaching reduction effect	Certainty of information			
European Commission, 2003	More P in produced livestock manure than can be consumed by the crops on the farm.	Prices: High Effect on leaching: Low			

<table>
<tr><td>Ref No. 31</td><td colspan="5">Anaerobic digestion</td></tr>
<tr><td colspan="5">Brief description</td><td>Description of the effect on leaching (positive or negative) of N and P</td></tr>
<tr><td colspan="5">Anaerobic digestion is a bacteriological fermentation process, whereby homogenised liquid biomass of a constant temperature of 30-45˚C (mesophile) or 55˚C (thermophile), and due to the ability for pumping with a maximal dry matter content of 12.5%, is fermented by anaerobic microorganisms, which are naturally occurring in especially cattle manure. The fermentation leads to the biogas production, which typically has a methane content of 60-65%. The hydraulic retention time is normally from 15-40 days, and the process happens in one or two stages, with the latter giving a slightly higher biogas production. Propellers are normally installed in the digestion tanks to ensure the digestate remains homogenous and gives a maximal release of biogas. The biogas production depend much of the type of biomass – see figures in the literature.
Typically 15% (mesophile process) to 25% (thermophile process) of the energy production from a biogas plant is used to heat up the digester. About 3-4% of the energy is used as electricity consumption for pumping, mixing, transport and other. The remaining energy production can be used for farm purposes or sold.
The community plants also serve as centres for re-distribution of manure in the region.</td><td>Field trials performed by Danish Agricultural Advisory Service have proven 17-30% higher field effect of N in digested livestock manure, compared to non-digested livestock manure – however, the increase of the field effect is higher for cattle slurry than for pig slurry, wherefore we in this report assume 10% increase of the field effect. The digestate is more homogenous, e.g. less lumpy, nutrients more evenly spread out, making the digestate easier to seep evenly into the crop root area, enabling better nutrient uptake from crops.</td></tr>
<tr><td rowspan="2">Innovation stage</td><td colspan="2">Investment price, €</td><td rowspan="2">Operational costs,
€ per tonnes</td><td rowspan="2">€ per kg saved N or P leaching</td><td rowspan="2">Complexity of implementation</td></tr>
<tr><td>Basic</td><td>Variable</td></tr>
<tr><td>Research
Pilot
Practice ✓</td><td>75.000</td><td>50</td><td>2,00</td><td rowspan="3">Kg saved N leaching[9] = 10 % * 25,000 * 5 kg = 12,500 kg. Price per kg saved N leaching = € 0,70 (same as price for N in commercial fertiliser), assuming
■ there can be produced 290 m³ methane per tonnes volatile solids (VS);
■ a payment for electricity of app. € 102 per MWh, the annual revenues levels out the annual costs;
■ run-off and emissions are unchanged, and that what is not taken up by the crop is leached to the aquatic environment sooner or later;
■ the excess heat produced can be utilised; and
■ the 10% increased field effect is taken into consideration in the fertiliser planning.</td><td rowspan="3">Medium – biogas plants range from being small and simple to large and complex / high tech. There is generally a large economy of scale and large biogas plants would typically require a range of permits, including building permits and environmental approval.</td></tr>
<tr><td>Major references</td><td>Condition for leaching reduction effect</td><td colspan="2">Certainty of information</td></tr>
<tr><td>Birkmose et al., 2007 (all issues)</td><td>The digestate is used according a fertiliser plan.</td><td colspan="2">Prices High
Effect on leaching High</td></tr>
</table>

9 The size of the biogas plant example complies with the size of the model scenarios, table 5 section 2.1.6.

Ref No. 41	Composting
Brief description	**Description of the effect on leaching (positive or negative) of N and P**
Composting of solid manure is a form of aerobic treatment which can occur naturally in livestock manure heaps. High porosity (30 – 50 %) is required for sufficient aeration. Temperatures in the compost heap are between 50 and 70 °C and kill most of the pathogens. Compost with a dry matter of up to 85 % can be produced. Suitability for application depends on the structure of the manure, but requires a minimum dry matter content of 20 %. Typical livestock manure heaps do not satisfy the requirements for thorough composting. With controlled application, manure is composted in stacks of a size that suits the aerobic conditions and the use of machinery. Best results are obtained by using well-chopped straw and solid manure in the right proportions and by controlling temperature and moisture content in long narrow 'windrows'. Composting can also be performed in a barn (e.g. pre-dried manure). Specific systems have been developed that consist of a combination of tanks with aeration and stirring equipment to enhance the fermentation process and containers or boxes for further fermentation and drying. Properly composted solid manure significantly reduces the volume of material spread to land and the amount of odour released. For easier handling, pelletizing is applied in addition to composting.	Composting is done in order to make livestock manure stable, i.e. able to transport and store without further moulding or fermenting, without seeping, and without evaporations. Further, the purpose of composting comprises advantages as being a cheap way to reduce the water amount, and a possibility to kill weed seeds and pathogens. The effect on leaching is negative: Barrington et al. (2002) have reported that N losses from pig/straw manure through seepage is between 12 and 22%, and that further 31 to 57% N is lost during the composting as emissions of N_2 and N_2O, in total a loss of 53 to 69% of the N. Composting of livestock manure in closed containers would probably make the economy in this technology even worse.

Innovation stage	Investment price, €		Operational costs, € per tonnes	€ per kg saved N or P leaching	Complexity of implementation
	Basic	Variable			
Research Pilot Practice ✓	For a composting plant that treats 2,000 tonnes manure with 1,360 tonnes sawdust and producing 1,800 tonnes compost: ■ For a turned windrow system, an appropriate tractor and turner could easily cost € 35,000 to € 40,000. ■ If buildings are constructed for all four activities (mixing, composting, curing and storage), total construction costs could be € 82,000 to € 100,000 for an operation of this size.	No data	Around € 20 as an average, depending on the efficiency.	The question cannot be answered because there is a negative effect on the leaching.	Composting can be organised on every farm, however, there exists more advanced and industrial composting technologies, which probably have a large economy of scale.

Major references	Condition for leaching reduction effect	Certainty of information	
Ministry of Agriculture, Food and Fisheries. 1996 Barrington et al., 2002	Composting has no leaching reduction effect – on the contrary, the process itself is often reason for leaching.	Prices Effect on leaching	Low High

Ref No. 41A	**Composting of liquid livestock manure**
Brief description	Description of the effect on leaching (positive or negative) of N and P
On some installations for the intensive rearing of pigs, aerobic treatment is used to reduce odour emissions from pig slurry and, in some cases, to reduce its N content. Liquid manure is composted by means of aeration (liquid composting) or by mixing it with an adequate amount of litter. The mixture can then be composted in a stack or drum. In aeration, aerobic treatment is used to improve the properties of liquid manure without drying and solidifying the manure. Manure contains large quantities of nutrients for plants and micro-organisms, as well as microbes that are capable of utilising these nutrients. The air conducted into liquid manure starts aerobic decomposition, which produces heat, and as a result of the aeration bacteria and fungi which use oxygen in their metabolism multiply. The main products from the activity of micro-organisms are carbon dioxide, water and heat. Designs are site-specific and take into account loading rate and the time treated slurry needs to be stored before being applied to land. Such systems may include the use of mechanical separators. (France, particularly Brittany, has some treatment plants for reducing N and P, while many countries have a few examples of aerobic treatment for reducing odour e.g. Germany, Italy, Portugal and the UK). Aeration is also applied to prepare slurry for it to be used to flush gutters, tubes or canals under slatted floors.	See the description for composting. It is a risk for any of the aeration technologies, especially for nitrification-denitrification, that there are formed laughing gas, N_2O, in connection with the aeration and the conversion of N that is accelerated due to that. The long lifetime (150 years) of laughing gas, N_2O, in the atmosphere contributes to its large radiative-forcing potential, which is 310 times that of carbon dioxide (CO_2).

Innovation stage	Investment price, €		Operational costs, € per tonnes	€ per kg saved N or P leaching	Complexity of implementation
	Basic	Variable			
Research Pilot Practice ✓	For a composting plant that treats 2,000 tonnes manure with 1,360 tonnes sawdust and producing 1,800 tonnes compost: ■ For a turned windrow system, an appropriate tractor and turner could easily cost € 35,000 to € 40,000. ■ If buildings are constructed for all four activities (mixing, composting, curing and storage), total construction costs could be € 82,000 to € 100,000 for an operation of this size.	No data	Around € 20 as an average, depending on the efficiency.	The question cannot be answered because there is a negative effect on the leaching.	Composting can be organised on every farm, however, there exists more advanced and industrial composting technologies, which probably have a large economy of scale.
Major references	Condition for leaching reduction effect	Certainty of information			
Ministry of Agriculture, Food and Fisheries. 1996 Barrington et al., 2002	Composting has no leaching reduction effect – on the contrary, the process itself is often reason for leaching.	Prices: Low Effect on leaching: High			

Ref No. 42	**Drying and pelletizing**
Brief description	**Description of the effect on leaching (positive or negative) of N and P**
It is not possible to store the fibre fraction from slurry separation offhand, and that is a parameter which reduces the interest for separation. Though it is possible to dry the fibres followed by a pelletizing process and then be able to store it. The smell is reduced by this process as well. If installed on a biogas plant, the heat for the drying is provided by exhaust gas from gas motors. The dryer is typically a co-current rotary dryer. The hot exhaust gas makes the water evaporate by direct heating. After the drying unit the final product is separated by gravity in a separation chamber. The dry sludge (90 % dry matter) falls through a rotation feeder valve into a screw conveyor that transports the final product to a store. The separated gas from the dryer flows into a series of cyclones. A blower, situated after the cyclones, ensures the gas flows in the whole drying system. Some new variations of this technology re-uses the steam from the evaporation process for heating up purposes. And thereby a much better energy balance. After the drying process the dry fibres are often pressed into pellets during a pelletizing process. Thereby the volume of the biomass will decrease significantly, and the result is a homogenous storable biomass. The investment is rather heavy, and too expensive to install on a single farm plant. But it might be quite interesting for bigger common separation – or biogas plants. The investment price below is based on a capacity at 1,5 tonnes per hour.	Leaching reduction is associated with the spreading effect, described above. Complete drying of the fibre fraction makes it economically possible to transport the product far away to areas with low livestock density.

Innovation stage	Investment price, € Basic	Investment price, € Variable	Operational costs, € per tonnes	€ per kg saved N or P leaching	Complexity of implementation
Research Pilot Practice ✓	Heavy. Drying: € 250.000 Pelletizing: € 200.000	€ 50	€ 10 – 40 - Dependent on type of technology and the local energy prices.	Experience from Spain is that pellets with a content of 7:5:6 NPK alone in heat consumption costs 17 kWh heat per kg pellets for the drying using the traditional technology. The heat consumption includes heat used for other processes in the plant. To this comes the depreciation and running of the plant. However, commercial solutions are seen, where the heat from burning the pellets are more than sufficient to run the drying process.	High – this technology is not a stand-alone technology, but is part of a complex livestock manure treatment plant with technologies like pH-adjustment, mechanical separation, and other. The technology is not suitable on single farm plants.
Major references	**Condition for leaching reduction effect**	**Certainty of information**			
CBMI, 2009	Scenarios II - V	Prices: Medium Effect on leaching: High			

Ref No. 43	**Combustion of fibre fraction or solid manure**
Brief description	Description of the effect on leaching (positive or negative) of N and P
Combustion can be made of separated fibre fractions, deep litter or other dry manure types. As a result of the high temperature all the odorous components are eliminated. The hot flue gases leaving the second chamber go through a heat exchanger, in which water is heated. The benefit of this technique is the production of an ash that can be used as a fertiliser and of hot water which is used for heating and which therefore saves fossil fuel use. Technically combustion works unproblematic, and can be fully automated, but fibres from slurry should according to the EU Waste Incineration Directive (2000/76/EF) be treated as waste, resulting in regulations of the smoke from combustion. This requires detailed measurements not applicable for farm scale use. The result is that fibres in practice should be incinerated in large waste combustion or CHP plants in combination with other biomasses such as straw, wood chips or household wastes.	Most of the N will be converted to N_2, and therefore not leach. Generally, combustion concentrates the P of the fibres or the solid manure, in the ash. The ash content of slurry fibres is relatively high (15-35%). The ash P is not well suited for plant uptake, but when treated with acid is can be made plant available. The ash should be reused for fertiliser production. In this case the resulting P-use could be better adapted to the crop needs. Combustion will loose the N content of the fibre fraction, some of it in the form of NOx. These can, however, be cleaned off the smoke and thereby reducing the air pollution. However, often the ash is being used for other purposes, such as road fill, cement production, thereby reducing the risk of P leaching, but also loosing potential fertiliser from the production cycle. In some countries there are specific requirements as to the measurements of the emitted smoke increasing the cost of this technology. In addition, in Denmark there is a 'waste-tax' on fibres for combustion. Economically it is doubtful at present in some countries and not presently being used in target countries.

Innovation stage	Investment price, €		Operational costs, € per tonnes	€ per kg saved N or P leaching	Complexity of implementation
	Basic	Variable			
Research Pilot ✓ Practice ✓	Not relevant at farm scale as it should be delivered to large existing combustion plants	-	Not relevant to calculate separately	Cannot be calculated at present. Economic feasibility studies should be made in all target countries. Potentially a rather expensive technology.	Easy to implement technically, with legislative challenges in relation to the interpretation of the EU Waste Incineration Directive
Major references	Condition for leaching reduction effect	Certainty of information			
Jørgensen et al., 2008	Scenarios II to V.	Prices ? Effect on leaching High			

Ref No. 44	**Pyrolysis / Thermal gasification**
Brief description	Description of the effect on leaching (positive or negative) of N and P
Thermal gasification can give higher efficiency as compared to combustion and fewer problems with corrosion. Thermal gasification adds heat (with or without oxygen, depending on the technology) to the incoming biomass and consists of two processes: Pyrolysis converting most organic substances into gasses at some 400-700° Celsius in a Circulating Fluid Bed reactor giving rise to a charcoal, which in the following gasification in a second reactor also will be turned into gas. The resulting gas is not at present useful for all engine types. Thermal gasification of the solid separation fraction has been implemented on pilot basis in combination with other technologies. At present the process has faced the same challenges as the combustion technology by the EU Waste Incineration Directive (2000/76/EEC) and therefore it is not available on the market.	Thermal gasification has some advantages as compared to combustion due to lower temperatures in the process: ■ Less NOx emission ■ Less dioxin emission ■ More readily reuse of ash-P Generally, the P is not lost in this technology and can apparently be used directly into fertiliser production. Most of the N will be converted to N_2, and therefore not leach.

Innovation stage	Investment price, €		Operational costs, € per tonnes	€ per kg saved N or P leaching	Complexity of implementation
	Basic	Variable			
Research ✓ Pilot ✓ Practice	Not presently available as standalone technology at farm scale	-	Cannot be calculated at present	Cannot be calculated at present. Economic feasibility studies should be made in all target countries. Potentially a rather expensive technology.	Difficult to implement technically, with legislative challenges in relation to the interpretation of the EU Waste Incineration Directive
Major references	Condition for leaching reduction effect	Certainty of information			
Jørgensen et al., 2008	Scenarios II to V.	Prices ? Effect on leaching High			

<table>
<tr><th>Ref No. 46</th><th colspan="5">Composting of manure with larvae of the housefly</th></tr>
<tr><th colspan="2">Brief description</th><th colspan="4">Description of the effect on leaching (positive or negative) of N and P</th></tr>
<tr><td colspan="2">A method for composting manure using the housefly larvae has been subject to resent research at the University of Alicante. The aim for the project is to address 3 major problems. 1. Overload of manure and nutrients in areas with dense livestock production. 2. Need for high quality protein feeding. 3. Odour emissions in relation to manure management. Those three problems can all be met if the manure is composed by fly larvae. More than half of the organic matter in the manure as well as the nutrients is been transformed in to larvae, which later can be used as feeding ex. in fish farming. The residue is at odour less dry compost, easy to distribute and apply.</td><td colspan="4">Principally this technology can convert the main part of the N and P into flies, which is used as a feed ingredient, and thus re-circulated in the agricultural production, and eliminating the risk of being leached.</td></tr>
<tr><th rowspan="2">Innovation stage</th><th colspan="2">Investment price, €</th><th rowspan="2">Operational costs,
€ per tonnes</th><th rowspan="2">€ per kg saved N or P leaching</th><th rowspan="2">Complexity of implementation</th></tr>
<tr><th>Basic</th><th>Variable</th></tr>
<tr><td>Research ✓
Pilot
Practice</td><td>No data</td><td>No data</td><td>No data</td><td rowspan="3">No data.</td><td rowspan="3">Unclear, but probably the technology would require large space.</td></tr>
<tr><th>Major references</th><th>Condition for leaching reduction effect</th><th colspan="2">Certainty of information</th></tr>
<tr><td>CBMI, 2009</td><td>The N and P cannot be used in an environmentally safe to fertilise crops.</td><td>Prices
Effect on leaching</td><td>No
Medium</td></tr>
</table>

<table>
<tr><th>Ref No. 51</th><th colspan="6">Ultra filtration</th></tr>
<tr><th>Brief description</th><th colspan="6">Description of the effect on leaching (positive or negative) of N and P</th></tr>
<tr><td>Ultra filtration is made on raw slurry or the liquid separation fraction. It is a type of pre-treatment for the reverse osmosis treatment, both technologies being part of a high tech manure treatment facility where the liquid part is purified up to (or near to) clean water. The ultra filtration process will remove suspended solids as well as bacteria and virus, while small dissolved molecules passes the filtration and can be removed by reverse osmosis, where the pore size of the membranes is smaller.

The membranes can clog and must be in such cases be cleaned. Membrane must typically be replaced every second year to ensure optimal function.

The ultra filtration process produce a liquid fraction, which contains the suspended solids and other, and a purified fraction to further purify in a reverse osmosis process.</td><td colspan="6">As for the other separation technologies.</td></tr>
<tr><th rowspan="2">Innovation stage</th><th colspan="2">Investment price, €</th><th colspan="2" rowspan="2">Operational costs,
€ per tonnes</th><th rowspan="2">€ per kg saved N or P leaching</th><th rowspan="2">Complexity of implementation</th></tr>
<tr><th>Basic</th><th>Variable</th></tr>
<tr><td>Research
Pilot
Practice ✓</td><td>No data</td><td>No data</td><td colspan="2">€ 1.0 to 5.5</td><td rowspan="3">Depends on the situation of the individual farm.</td><td rowspan="3">High – will be part of a high-tech manure treatment plant.</td></tr>
<tr><th>Major references</th><th>Condition for leaching reduction effect</th><th colspan="3">Certainty of information</th></tr>
<tr><td>Massea et al., 2007</td><td>Scenarios II - V</td><td colspan="2">Prices
Effect on leaching</td><td>Low
High</td></tr>
</table>

Ref No. 52	**N-stripping**
Brief description	Description of the effect on leaching (positive or negative) of N and P
By stripping a part of the dissolved ammonia in a liquid can be removed by evaporated to the air. Subsequently, the evaporated ammonia is collected in concentrated form in a second liquid. It is thus possible to move ammonia from the manure slurry to a second liquid and use this as a concentrated fertiliser. N-stripping is a two stage process: The first part happens in a stripping column, where air is added to release the ammonia. The released ammonia is transferred to an absorption column, where the ammonia is captured with acidified water. Ammonia in aqueous solution is volatile and requires special equipment if it should be used as fertiliser. By acidifying the liquid with sulphuric acid you can form an ammonium fertiliser which is stable in storage. Ammonia stripping can be conducted at manure or degassed manure. Work is underway to develop a stripper permanently transforming the ammonia formed in the biogas process. Stripping of ammonia can improve the biological turnover of biogas plants as ammonia in high concentrations is deleterious to the turnover. Stripping processes are well known from many industrial applications. The process can for instance be used in order to prevent the inhibition effect on the anaerobic digestion of high N concentrations in the substrate as for instance chicken manure.	By stripping ammonia from manure you can produce a fertiliser, either in the form of an aqueous solution of ammonia or an ammonium sulphate solution. The fertiliser can be transported and used as a direct substitute for commercial fertiliser. There are made several demo scale trials with production of both aqueous ammonia solutions as ammonium sulphate solutions.

Innovation stage	Investment price, €		Operational costs, € per tonnes	€ per kg saved N or P leaching	Complexity of implementation
	Basic	Variable			
Research Pilot Practice ✓	No data	No data	€ 3 to 10 per kg N removed	Depends on the situation of the individual farm.	High – this is not a stand-alone technology, but rather a component of a high-tech livestock manure treatment facility.
Major references	Condition for leaching reduction effect	Certainty of information			
CBMI	Scenarios II - V	Prices - Effect on leaching High			

Ref No. 54	**Reverse osmosis**
Brief description	Description of the effect on leaching (positive or negative) of N and P
Inverse membrane osmosis is used in a variety of industrial applications. Reverse osmosis is a membrane filtrating technology by use of a semi-permeable membrane, and the technology can achieve a very good quality of treated water. Reverse osmosis of slurry requires a pre treatment of the slurry to remove the coarsest particles, thereby extending the operating time of filtration. Typically, a pre-treatment consist of a simple mechanical separation followed by ultra filtration. Several Danish companies have been working for years with membrane filtration technologies for treating manure and built a couple of full-scale plants, although not currently in operation. The technology requires conducting regular rinses and regeneration of membranes. The cost of operating a reverse osmosis plant can be quite significant and has been one of the barriers to the use of the technology. The cost is partly due to the high energy consumption to create the high operating pressures, cleaning and costs for replacement of membranes. The process can remove 99% of the organic matter and up to 99.5% of the salts. For manure treatment the K ion still remain in the water fraction and might set limits for the use of this as irrigation water. The input in the process is a liquid fraction, for instance coming from ultra filtration. Acidification of the feed fluid would typically be necessary to ensure a good nutrient removal.	As for the other separation technologies. With reverse osmosis, it is possible to obtain a water quality of the treated slurry which makes it possible to discharge the liquid fraction directly to the recipient. It is thus possible with this technology to produce potable water. Operating costs for the technology is so great that pt. there is no the basis for the use of technology in the Baltic region.

Innovation stage	Investment price, €		Operational costs, € per tonnes	€ per kg saved N or P leaching	Complexity of implementation
	Basic	Variable			
Research Pilot Practice ✓	No data	No data	No data	Depends on the situation of the individual farm.	High – this is not a stand-alone technology, but rather a component of a high-tech livestock manure treatment facility.
Major references	Condition for leaching reduction effect	Certainty of information			
Massea et al., 2007	Scenarios II to V.	Prices Low Effect on leaching High			

<table>
<tr><th>Ref No. 55</th><th colspan="5">Ion exchange and demineralisation</th></tr>
<tr><th>Brief description</th><th colspan="5">Description of the effect on leaching (positive or negative) of N and P</th></tr>
<tr><td>De-mineralisation means removing of minerals from almost clean water by filtration and/or chemical sedimentation. The process has currently only practical relevance for the treatment of manure in cases where the liquid fraction shall be disposed of in the nature.</td><td colspan="5">No direct, but the technology would (in this case) typically be part of a high-tech livestock manure treatment plant, and the effect on leaching shall therefore be evaluated on basis of the effect of the entire plant.</td></tr>
<tr><th rowspan="2">Innovation stage</th><th colspan="2">Investment price, €</th><th rowspan="2">Operational costs,
€ per tonnes</th><th rowspan="2">€ per kg saved N or P leaching</th><th rowspan="2">Complexity of implementation</th></tr>
<tr><th>Basic</th><th>Variable</th></tr>
<tr><td>Research
Pilot
Practice ✓</td><td>Low</td><td>Low</td><td>Low</td><td rowspan="4">Depends on the situation of the individual farm.</td><td rowspan="4">Low – can easily be installed at all farms, but depends on a high and complicated purification of liquid fractions before the de-mineralisation.</td></tr>
<tr><th>Major references</th><th>Condition for leaching reduction effect</th><th colspan="2">Certainty of information</th></tr>
<tr><td rowspan="2">Foged, 2009</td><td rowspan="2">Scenarios II - V</td><td>Prices</td><td>High</td></tr>
<tr><td>Effect on leaching</td><td>High</td></tr>
</table>

Ref No. 56	**Aeration**
Brief description	Description of the effect on leaching (positive or negative) of N and P
The term “aerobic treatment” refers to biological treatment processes that occur in the presence of oxygen. In these processes, aerobic microorganisms oxidize bio-available organic and nitrogenous compounds. Removal of these oxygen demanding compounds provides a means to reduce odor emission and to reduce ammonia emissions. Aerobic treatment has not been used much in treatment of liquid or slurry manure primarily due to the relation between the benefits and the extra costs associated with operating the motors, compressors or fans required to supply enough oxygen to support aerobic bacteria. Several types of aeration of slurry were tested. Aeration may be partly to convert ammonia to nitrate, which can subsequently be transformed into free N by denitrification, partly to reduce levels of organic matter in the liquid fraction. Nitrification (conversion of ammonia to nitrate) is very energy-intensive in terms of power consumption for aeration, stirring, etc. If nitrate subsequently is converted into free N by denitrification a portion of the organic material in the slurry will be consumed. N and organic matter is lost in the process, and at the same time significant amounts of energy are consumed. The amount of aeration needed (in increasing order) depends on whether it is desired to just reduce odour, or completely remove the oxygen demand of the organic matter, or to supply enough oxygen for oxidation of ammonium to nitrate.	See comments under composting – reference numbers 41 and 41A.

Innovation stage	Investment price, €		Operational costs, € per tonnes	€ per kg saved N or P leaching	Complexity of implementation
	Basic	Variable			
Research Pilot Practice ✓	Low – can be performed without existing pumps, equipment and machinery on the farm		Probably < € 1 per ton	Depends on the situation of the individual farm.	Low.
Major references	**Condition for leaching reduction effect**	**Certainty of information**			
Foged, 2009	Scenarios II - V	Prices High Effect on leaching High			

Ref No. 56A	**Ozonation**
Brief description	**Description of the effect on leaching (positive or negative) of N and P**
Ozone is a very powerful oxidising agent and reacts very rapidly with almost anything. Ozone must be produced locally because it is unstable and cannot be stored. Ozone is used as flocculant for the separation of manure by flotation. Methods for ozone treatment and separation of manure are being developed, and there are great expectations to the technology. Ozone treatment combined with the flotation of the suspended material in the slurry forms a clear liquid and a concentrated sludge. The fluid can then be further processed to a very high quality, while the sludge fraction should be handled as flotation sludge. The use of ozone can be applied for the remediation of nuisance odorous chemicals in liquid manures. Gaseous ozone is bubbled directly into liquid manure in a continuously stirred batch reactor. Olfactometry determinations demonstrate a significant reduction in odours in ozonized samples as compared to raw and oxygenated samples, however, with big variation among technology suppliers. Volatile fatty acids, nitrate, phosphate and ammonia concentrations were unchanged by ozonation. The biochemical oxygen demand (BOD) and the chemical oxygen demand (COD) is essentially unaffected by ozonation, with the ozone concentrations tried. Ozone can be generated from oxygen in the atmosphere or by pure oxygen. Operating costs for the production of ozone is relatively high. Although it is theoretically possible to oxidize a very large portion of the organic matter in the slurry with ozone is not technically and economically feasible.	Unidentified.

Innovation stage	Investment price, €		Operational costs, € per tonnes	€ per kg saved N or P leaching	Complexity of implementation
	Basic	Variable			
Research Pilot Practice ✓	No data	No data	No data	N/A	Low – can be installed at every farm
Major references	**Condition for leaching reduction effect**	**Certainty of information**			
CBMI	N/A	Prices High Effect on leaching High			

Ref No. 57	Nitrification-denitrification
Brief description	**Description of the effect on leaching (positive or negative) of N and P**
The nitrification-denitrification process converts the N in the slurry to free N, N_2, a process that is commonly used in waste water treatment facilities. Biological conversion of ammonia to N gas is a two step process. Ammonia must first be oxidized to nitrate; nitrate is then reduced to N gas. These react ions require different environments and involve two tanks, an anoxic tank and an anaerobic digestion tank. The first step in the process, conversion of ammonia to nitrite and then to nitrate, is called nitrification (NH3 NO2 NO3). The process is summarized in the following equations: ■ $NH_4 + 3/2\ O_2 \Rightarrow NO_2^- + 2H+ + H_2O$ ■ $NO_2^- + 1/2\ O \Rightarrow NO_3^-$ It is important to note that this process requires and consumes oxygen, and thus contributes to the BOD (biochemical oxygen demand). The process is mediated by the bacteria Nitrosomonas and Nitrobacter, which require an aerobic (presence of oxygen) environment for growth and metabolism of N. Thus, the nitrification process must proceed under aerobic conditions. The second step of the process, the conversion of nitrate to N gas, is referred to as denitrification. This process can be summarized as: ■ $NO_3^- + 5/6\ CH_3OH \Rightarrow 1/2\ N_2 + 5/6\ CO_2 + 7/6\ H_2O + OH^-$ This process is also mediated by bacteria. For the reduction of nitrate to N gas to occur, the dissolved oxygen level must be at or near zero; the denitrification process must proceed under anaerobic conditions. The bacteria also require a carbon food source for energy and conversion of N. The bacteria metabolize the carbonaceous material or BOD in the wastewater as this food source, metabolizing it to carbon dioxide. This in turn reduces the BOD of the sewage, which is desirable. However, if the sewage is already low in BOD, the carbon food source will be insufficient for bacterial growth and denitrification will not proceed efficiently. In the aerobic digestion tank the conversion of ammonia to nitrate and nitrite takes place. In the anoxic tank, microorganisms use the free oxygen in nitrate compound as a source of energy. The process produces more bacteria and removes N from the slurry by converting it into free N gas, which is released into the air. The system is build so that oxygen is provided to the slurry by way of tiny aerating bubbles provided by diffusers.	See the description for composting, technology references number 41 and 41A.

Innovation stage	Investment price, €		Operational costs, € per tonnes	€ per kg saved N or P leaching	Complexity of implementation
	Basic	Variable			
Research Pilot Practice ✓	No data	No data	No data, however a Spanish plant visited by CBMI in June 2009 used 15-20 kWh per ton, alone for electricity, but including separation and composting operations.	Depends on the situation of the individual farm.	High – shall be implemented as a community plant.
Major references	**Condition for leaching reduction effect**	**Certainty of information**			
CBMI, 2009	Scenarios II - V	Prices Low Effect on leaching High			

Ref No. 58	**Struvite precipitation**
Brief description	Description of the effect on leaching (positive or negative) of N and P
Struvite formation means the crystallization of N and P in the form of struvite ($MgNH_4PO_4$ $6H_2O$), also called MAP, which is a slow releasing and valuable fertiliser. The struvite precipitation is forced by introduction of the Mg_2^+ ion, for instance in the form of $Mg(OH)_2$ and $MgCl_2$ $6H_2O$. pH adjustment will often be necessary to force the process. Struvite precipitation has so far not been developed to commercial stage as a livestock manure treatment technology.	Struvite precipitated from manure can be used as a fertiliser product. Since struvite contains both ammonia and P, this can be removed from the manure or be applied or used otherwise. Struvite can be used directly as a fertiliser with a slow release of nutrients, according to German and many other studies. Struvite precipitates as crystals that can be removed as a dry product that can be transported as a stable fertiliser. Precipitation of struvite and use of this can potentially have a beneficial influence on the leaching of both N and P.

Innovation stage	Investment price, € Basic	Investment price, € Variable	Operational costs, € per tonnes	€ per kg saved N or P leaching	Complexity of implementation
Research ✓ Pilot ✓ (wastewater) Practice	No data	No data	No data	No data	Low – can principally be implemented at every farm.

Major references	Condition for leaching reduction effect	Certainty of information
Hjorth, 2009	Scenarios II - V	Prices High Effect on leaching High

Ref No. 59	**Algae production on liquid manure substrates**				
Brief description			Description of the effect on leaching (positive or negative) of N and P		
Pilot research has started in for instance Holland on the feasibility of algae production on liquid manure substrates. The challenging idea behind this is to utilise the facts that algae grows well in waters that are rich on plant nutrients, that algae in pilot studies has shown incredible high productivity levels, and that they are relatively easy to recover bioenergy sources from, in the form of plant oil that can replace fossil fuels. Plant nutrients can be re-circulated in the agricultural production, the P being of very high quality that could be used as feed ingredient. The production would result in three components: Plant oil, a rest-fibre fraction and reject water, which dependent on local price conditions can be cleaned up to the economic optimal level.			The expected effect is similar to that of the separation technologies described above: The rest-fibre fraction would be possible to export to areas with low livestock density.		
Innovation stage	Investment price, €		Operational costs, € per tonnes	€ per kg saved N or P leaching	Complexity of implementation
	Basic	Variable			
Research ✓ Pilot Practice	No data	No data	No data	No data	Probably high
Major references	Condition for leaching reduction effect	Certainty of information			
CBMI	Scenarios II - V	Prices High Effect on leaching High			

Ref No. 93	**Field application: Surface spreading (trailing hoses)**				
Brief description				Description of the effect on leaching (positive or negative) of N and P	
In the term of field application, surface spreading using trailing hoses is one of several options. The technology places the manure on the surface, between the rows of the crop. Principle: Flexible rubber hoses are installed with an internal distance on app. 30 cm on a wide section (often 24 m), mounted behind on the manure tanker. The hoses are 'trailing' along the soil surface, while 'laying' the manure on the surface in rows, below the green part of the crop.				This technology significantly increases the field effect, if compared to the reference of aerial spreading (splash plate). The technology has very little, if any, effect on the leaching of P, unlike shallow injection which is not covered here, but is gaining popularity in practices.	
Innovation stage	Investment price, €		Operational costs, € per tonnes	€ per kg saved N or P leaching	Complexity of implementation
	Basic	Variable			
Research Pilot Practice ✓	€ 25.000 – 50.000 (sufficient for a large pig farm)	€ 0,5	€ no data	No data	**Medium**, use of the technology needs trained drivers, fairly new slurry tankers etc.
Major references	Condition for leaching reduction effect	Certainty of information			
1: EU Commission, 2003 2: Landscentret, 2005	Scenarios I - V	Prices High Effect on leaching High			

<table>
<tr><td colspan="1">Ref No. 94</td><td colspan="6">Constructed wetlands</td></tr>
<tr><td>Brief description</td><td colspan="6">Description of the effect on leaching (positive or negative) of N and P</td></tr>
<tr><td>Constructed wetlands mean an area, where a liquid fraction is flooded into. The area is grown with a catch crop, which will capture the N, P and other residues. The crop can be harvested and digested in a biogas plant, for instance. The liquid fraction that is let to the area is typically cleaned up to an economic optimum, In order to minimise the area of the wetland.

Examples of constructed wetlands: In the USA such wetlands are used for the disposal of the liquid fraction that are collected from feedlots (Foged, 2009), in Holland for reject water from a nitrification-denitrification plant (Foged, 2009), and in Denmark they are seen in connection to high-tech biogas plants, also for reject water.</td><td colspan="6">The effect shall typically be seen in combination with the entire effect of the livestock manure treatment facility to which the constructed wetlands belongs.</td></tr>
<tr><td rowspan="2">Innovation stage</td><td colspan="2">Investment price, €</td><td colspan="2" rowspan="2">Operational costs, € per tonnes</td><td rowspan="2">€ per kg saved N or P leaching</td><td rowspan="2">Complexity of implementation</td></tr>
<tr><td>Basic</td><td>Variable</td></tr>
<tr><td>Research
Pilot
Practice ✓</td><td>Prices are probably similar to prices of lagoons. Typically € 50,000</td><td>€ 40</td><td colspan="2">Low</td><td rowspan="3">Varying with the concrete situation.</td><td rowspan="3">Medium – can be constructed at all farms, but typically the wetlands are only a small part of a complex livestock manure treatment plant.</td></tr>
<tr><td>Major references</td><td>Condition for leaching reduction effect</td><td colspan="3">Certainty of information</td></tr>
<tr><td>Foged, 2009</td><td>Scenarios II - V</td><td colspan="2">Prices
Effect on leaching</td><td>Medium
Medium</td></tr>
</table>

Ref No. 111	**Official P norms for fertilising**				
Brief description	Description of the effect on leaching (positive or negative) of N and P				
Official P norms for fertilising. EU has no demands for official P norms for fertilising, but they have anyway been introduced in Finland, Lithuania, Sweden and Germany, in most cases as a maximal application rate per ha, independent of the crop grown. P fertiliser norms are internationally convened via HELCOM, and can furthermore be imposed via EU's Water Framework Directive.	Official P fertiliser norms would hinder an annual spreading of P above some average levels for the typical environmentally safe application of P. The norms would, however, not consider the P leaching risk from specific fields.				
Innovation stage	Investment price, €		Operational costs, € per tonnes	€ per kg saved N or P leaching	Complexity of implementation
	Basic	Variable			
Research Pilot Practice ✓	Low	Low	Low	Low	Low
Major references	Condition for leaching reduction effect	Certainty of information			
CBMI	Scenarios II to V.	Prices High Effect on leaching High			

Ref No. 112	**P-index**				
Brief description	Description of the effect on leaching (positive or negative) of N and P				
The purpose of a P index is to assess the risk of P delivery to surface waters. The index is a tool to help conservation planners, landowners/land users and others to evaluate the current risk from P reaching surface water from a specific site, and to determine factors which dominate the risk due to P transport to surface waters. It will also assist landowners/land users in making management decisions to reduce the risk. The P-index has an erosion component, which considers shell and rill erosion, P enrichment, total soil P, filter strip, sediment delivery, distance to a stream, and the long term biotic availability of particulate P in surface water ecosystems. . A runoff component considers water run-off based on a modification of the runoff curve number, soil tests, rate time and method of P application. An internal drainage component considers the presence of tiles, water flow to tile lines, surface water recharge to subsurface flow, and soil tests. Establishing of non-cultivated buffer zones along streams, and terraces in the steep fields, would dramatically reduce the P-index. The whole index is a formula, which is easily calculated annually once the specific parameters for the given field have been determined.	The P-index is a tool, that directly can assess the risk of P leaching, and therefore whether there is a need for not spreading livestock manure on a certain field.				
Innovation stage	Investment price, €		Operational costs, € per tonnes	€ per kg saved N or P leaching	Complexity of implementation
	Basic	Variable			
Research Pilot Practice ✓	Low	Low	Low	Low	Low
Major references	Condition for leaching reduction effect	Certainty of information			
1: Mallarino et al., 2005 2: Natural Resources Conservation Services (NRCS), 2004	High P-index levels	Prices High Effect on leaching High			

<table>
<tr><th colspan="4">Ref No. 113</th><th colspan="2">Certification of persons, who transport or spread livestock manure</th></tr>
<tr><th colspan="4">Brief description</th><th colspan="2">Description of the effect on leaching (positive or negative) of N and P</th></tr>
<tr><td colspan="4">Certification of persons, who transports, spread or in other ways handle livestock manure. Certification can happen on basis of an initial training of 6 hours + test, and a 2 hours annual update + test.</td><td colspan="2">It is expected the training will have a reduction effect on leaching, because it will ensure persons who handle livestock manure understands how to secure a precise spreading and how to avoid leakage.</td></tr>
<tr><th rowspan="2">Innovation stage</th><th colspan="2">Investment price, €</th><th rowspan="2">Operational costs,
€ per tonnes</th><th rowspan="2">€ per kg saved N or P leaching</th><th rowspan="2">Complexity of implementation</th></tr>
<tr><th>Basic</th><th>Variable</th></tr>
<tr><td>Research
Pilot
Practice ✓</td><td>Low</td><td>Low</td><td>Low</td><td rowspan="3">Varying with the concrete situation.</td><td rowspan="3">Low</td></tr>
<tr><th>Major references</th><th>Condition for leaching reduction effect</th><th colspan="2">Certainty of information</th></tr>
<tr><td>Foged, 2009</td><td>If leaching happens due to spills, in-correct dosing, mis-management of manure in relation with transport and spreading.</td><td colspan="2">Medium</td></tr>
</table>

ANNEX F: QUESTIONNAIRE ON THE EFFECTIVENESS OF THE EU INTEGRATED POLLUTION AND PREVENTION CONTROL DIRECTIVE (2008/1/EEC)

PURPOSE:

To validate the strength and effectiveness of the directive to prevent and limit N and P leakage from industrial animal farms, focus installations for the intensive rearing of pigs influence on waterways and the Baltic Sea.

To help identify the current best available manure handling technologies, and main obstacles for their implementation.

STAKEHOLDERS:

1. EU Commission, civil servant responsible for elaboration and implementation of Directive (Interview)
2. IPPC Technical Working Group/National Authorities responsible for national implementation of Directive(Internet Survey)
3. National/Regional Authorities monitoring installations for the intensive rearing of pigs compliance with directive (Internet Survey)

KNOWLEDGE SOUGHT:

A. Quality of recommended BATs – N/P

- What criteria regarding N/P emissions apply for BATs for Intensive Rearing of Poultry and Pigs?
- How effective are these criteria to prevent N/P leakage from Installations for the intensive rearing of pigs?
- How are BATs validated and chosen by EU Commission?
- How is prevention of N/P leakage from Intensive Rearing of Poultry and Pigs prioritized during the validation of BATs
- Form and quality of process to elaborate BREF (Ref. doc. On BAT for Intensive Rearing of Poul try and Pigs?
- How does EU gather information on BATs? (From what regions, and what stakeholders, on what regularity, who at EU validates?)
- Relevance/quality of BAT Reference Documents (BREFs)

B. Communication of BATs – N/P from EU to member states

- How are BATs communicated to member states?
- With what regularity?
- To who?
- How is it validated that the information is received, read and spread and used in permit processes

C. Communication of BATS – N/P nationally

- How are BAT communicated to farmers?
- With what regularity?
- How is it validated that the information is received, read and used?

D Compliance with directive

- How does EU commission ensure that Member states implement IPPC directive?
- How does EU commission ensure that recommended BATs are implemented in Member States? (information exchange, guidance development, visits to authorities and training)
- How does EU act if compliance is dissatisfactory?
- To what extent is BAT – N/P compliance ensured when regional/local authority is permitting animal farms?
- How is implementation of BAT – N/P monitored by regional/local authorities?
- How is violation of permits/disregarding use of BAT – N/P sanctioned?

E Quality of national monitoring

- How are compliance checks carried out?
- How decisive is the BREF document on BAT for Intensive Rearing of Poultry and Pigs when issuing permits for new pig farms, and when inspecting existing?

F Quality of EU monitoring

- How does EU check the application of IPPC Directive in national legislation?
- How does EU ensure the use of the BREFs in national license permitting, and monitoring of farms?

G. BATs

- What are the three BATs to prevent N/P-leakage from installations for the intensive rearing of pigs?
- What are the main obstacles to comply with the Directive

INTERVIEW QUESTION TO EU COMMISSION

Quality of recommended BATs – N/P

- What criteria regarding N/P emissions apply for BATs for Intensive Rearing of Poultry and Pigs?
- How effective are these criteria to prevent N/P leakage from Installations for the intensive rearing of pigs?
- How are BATs validated and chosen by EU Commission?
- How is prevention of N/P leakage from Intensive Rearing of Poultry and Pigs prioritized during the validation of BATs
- How is the procedure to elaborate BREF (Ref. doc. On BAT for Intensive Rearing of Poultry and Pigs?
- How does EU gather information on BATs? (From what regions, and what stakeholders, on what regularity, who at EU validates?)

Communication of BATs – N/P from EU to member states

- How are BATs communicated to member states?
- With what regularity?
- To who?
- How is it validated that the information is received, read and spread and used in permit processes

Compliance with directive/EU monitoring

- How does EU commission ensure that Member states implement IPPC directive? E.g. if application of IPPC Directive should be incorporated in national legislation?
- How does EU commission ensure that recommended BATs are implemented in Member States? (Information exchange, guidance development, monitoring?)
- How does EU ensure the use of the BREFs in national license permitting, and monitoring of farms?
- How does EU act if compliance with the Directive is dissatisfactory?

QUESTIONNAIRE TO TECHNICAL WORKING GROUP

1. **How effective is the IPPC Directive in reducing N/P leakage from Installations for the intensive rearing of pigs?**
   - Effective
   - Not Effective
   - Comment:

2. **How effective is the IPPC Directive in promoting Best Available Techniques (BATs) to reduce N/P l eakage from Installations for the intensive rearing of pigs?**
   - Effective
   - Not Effective
   - Comment:

3. **How effective is EU commission secretariat responsible for IPPC Directive in collecting information on and evaluating the potential of upcoming techniques to reduce N/P leakage from Installations for the intensive rearing of pigs?**
   - Effective
   - Not Effective
   - Comment:

4. **How prioritized is prevention of N/P leakage from Intensive Rearing of Poultry and Pigs, relative to other objectives within the BREF document e.g. reducing water use and energy, during the elaboration of BREF documents?**
   - Prioritized
   - Not prioritized
   - Comment:

5. **How effective are the techniques listed in present the Reference Document on Best Available Techniques for Intensive Rearing of Poultry (BREF document from July 2003) to prevent/reduce N/P leakage from Installations for the intensive rearing of pigs?**
   - Effective
   - Not Effective
   - Comment:

6. **To what extent are the techniques listed today in the BREF document implemented in your country? If you answer "To a low extent" on the previous question, please comment on why.**
   - To a high extent
   - To a low extent
   - Comment:

7. **Which current available techniques (either already listed in the BREF from 2003, or other) are in your opinion the most effective to reduce N and P at installations for the intensive rearing of pigs, under the regulation of the IPPC directive? Please list three and comment on the advantages of each one:**
   - 1:
   - 2:
   - 3:
   - Comment:

8. **What are the main obstacles for the large scale implementation of the techniques you have listed above?**
   - 1:
   - 2:
   - 3:
   - Comment:

QUESTIONNAIRE TO COMPETENT NATIONAL AUTHORITIES

9. **How effective is the IPPC Directive in reducing N/P leakage from Installations for the intensive rearing of pigs?**
   - Effective
   - Not Effective
   - Comment:

10. **How effective is the IPPC Directive in promoting Best Available Techniques (BATs) to reduce N/P leakage from Installations for the intensive rearing of pigs?**
    - Effective
    - Not Effective
    - Comment:

11. **To what extent are the techniques listed today in the BREF document implemented in your country? If you answer "To a low extent", please comment on why.**
    - To a high extent
    - To a low extent
    - Comment:

12. **How are recommended BATs for reducing N and P leakage from installations for the intensive rear-ing of pigs in the IPPC directive communicated to pig farmers concerned in your country?**
    - When issuing permits
    - At regular monitoring?
    - Other?

13. **How is it validated that the information is received and used?**
    - Comment:

14. **How is compliance with the recommendations in the IPPC Directive /BREF document for Intensive Rearing of Poultry and Pigs ensured?**
    - Comment:

15. **How decisive is the BREF document for Intensive Rearing of Poultry and Pigs when issuing permits for new installations for the intensive rearing of pigs?**
    - Decisive
    - Not decisive
    - Comment:

16. **How effective are the techniques listed in the present Reference Document on Best Available Techniques for Intensive Rearing of Poultry**

(BREF document from July 2003) to prevent/reduce N/P leakage from Installations for the intensive rearing of pigs?

- Effective
- Not Effective
- Comment:

17. **Which current available techniques (either already listed in the BREF/2003 or other) are in your opinion the most effective to reduce N and P at installations for the intensive rearing of pigs, under the regulation of the IPPC directive? Please list three and comment on the advantages of each one:**
    - 1:
    - 2:
    - 3:
    - Comment:

18. **What are the main obstacles for the large scale implementation of the techniques you have listed above?**
    - 1:
    - 2:
    - 3:
    - Comment:

ANNEX G: MEMBERS OF THE TECHNICAL WORKING GROUP FOR INTENSIVE LIVESTOCK FARMING, BALTIC SEA REGION

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ANNEX I: REPORT FROM ROUNDTABLE DISCUSSION

BACKGROUND

Researchers/experts, who represent the countries in the target area in the European IPPC Bureau at JRC in Seville, as well as farmer's organisations and authorities, are important stakeholders for the project.

It is important that the project consult the stakeholders to ensure trust and ownership to the recommendations the project will develop, to ensure that the project link up to and support other initiatives concerning livestock manure treatment technologies and the implementation of the IPPC Directive, and in order to prepare for later, successful implementation of the projects recommendations.

A roundtable discussion with the stakeholders was on this background built into the project activities, and it took place at The Royal Academy of Sciences in Stockholm on 29 September 2009. Individual meetings were organised after the roundtable discussion with selected stakeholders, who were unable to participate in the roundtable discussion.

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AGENDA

1. Welcome, Conrad Stralka, Baltic Sea 2020
2. Introduction and programme, moderated by Project Leader Henning Lyngsø Foged
3. Presentation of participants
4. Presentation of the project, Lotta Samuelson, Baltic Sea 2020, and Henning Lyngsø Foged, CBMI
5. Expert statement about leaching of N and P from pig manures, Fredrik Wulff, Baltic Sea 2020
6. Presentation of complete list of technologies which are identified within the project, their advantages and disadvantages, Henning Lyngsø Foged, CBMI
7. Discussion about prioritising the manure treatment technologies against the parameters defined in the project, moderated by Henning Lyngsø Foged, CBMI
8. Results of survey and discussion about IPPC Communication and Implementation, Henning Lyngsø Foged, CBMI
9. Summing up and concluding, Lotta Samuelson, Baltic Sea 2020

DISCUSSED

Re. 1: Welcome

Conrad Stralka informed in his welcome about the activities of Baltic Sea 2020.

Re. 2: Introduction

Henning Foged emphasized in his introduction how important we consider the stakeholders in relation to the ultimate success criteria for the project – a higher degree of livestock manure treatment to reduce the leaching of N and P. Henning Foged also said that the project should be seen as supporting and linking up to other initiatives concerning livestock manure treatment technologies.

Re. 3: Presentation of participants

The meeting had 11 participants from 5 of the 8 target countries.

Re. 4: Presentation of the project

Lotta Samuelson mentioned especially that the overall objective of the "Best Practice Manure Projects" is to reduce leaching of nutrients from large installations for the intensive rearing of pigs around the Baltic Sea. Phase 1 of the project concluded that according to statistics from EU Joint Research Bureau, nutrients in manure put on fields in the Baltic Sea catchment area exceeds the nutrient discharge from households in the same area. Baltic Sea 2020 will focus on reducing nutrient leaching in manure from installations for the intensive rearing of pigs to the aquatic environment.

Henning Foged pointed out that the IPPC Directive is 13 years old, it came into force in a period where livestock manure treatment was rarely happening, and since then has a major structural development had taken place in the pig production sector. Danish installations for the intensive rearing of pigs had an average of 550 pigs per farm with pigs in 1996, including both sows, piglets and fatteners – today this figure is 2.250! It seems justified that the project on this background considers, whether livestock manure treatment technologies should be given more focus in the administration of the IPPC Directive.

Vaclovas Beržinskas said during the discussion, water monitoring should be part of the project and that part of the problem with leaching is a setback that the environmental permitting institutions do not wish to deal with complicated issues.

Re. 5: Expert statement

Fredrik Wulff focused in his presentation on the input of N and P to the Baltic Sea from agricultural production in the form of fertilisers and feed. The agriculture sector is calculated to provide for 50% of the total nutrient load to the Baltic Sea. The EU legislation as well as voluntary actions by farmers has resulted in more efficient use of fertilisers and excess nutrients to the waterways leaching is expected to decrease n the coming years. Denmark has had a large decline in its use of mineral fertiliser, but simultaneously a large increase in imported protein feed.

Professor Wulff cited a Finnish study, which had shown that 11% of N and 17% of P had leached from manures spread in the autumn, while the leaching was 33% of N and 59% of P in manures spread in the winter.

Ulla-Britta Fallenius commented that the most important data is the specific amounts of nutrients that actually reach the Baltic Sea, and not what is put on fields.

Lena Rohde said similarly, that it would be interesting to know how much actually is retained in the produced pork, and also pointed out that Denmark in the period with increased import of (N in) protein feed also had increased its export of (N in) pork.

Re. 6: Presentation of complete list

Henning Foged started the presentation with explaining how the word technologies and leaching had been defined in the project. He said that more than 30 livestock manure treatment technologies had been listed, and are being described with respect to their effect on leaching, their cost, etc. Included in the complete list of technologies were also technologies like legally based P norms for fertilising and the use of a P-index (inspired from his visit to USA).

Ulla-Britta Fallenius commented that anaerobic digestion does not have effect on leaching because the input and output amounts of N and P are the same. She also mentioned that HELCOM already had bound member states to introduce P norms.

It was clarified from the discussion that several countries already had P norms (Sweden, Lithuania, and Finland) and that HELCOM Action Plan decides P norms in all Baltic nations. Henning Foged said that this was not the case for Denmark. Vaclovas Beržinskas pointed out that HELCOM is without sanction possibilities, and that its role is restricted.

Re. 7: Prioritising technologies

Henning Foged informed that the current list with technologies will be reduced; technologies with no apparent leaching reduction effect will be removed as will technologies which are likely to have some environmental hazards (e.g. leaching or other unacceptable environmental hazards). The list shall also be reduced with technologies which currently are un-validated and/or still at research level and with technologies for which there could be ethical considerations hindering their effective dissemination. The rest of the technologies are ranked according the Project Leaders view on a combination of their cost-efficiency, complexity of implementation, legal and other bottlenecks.

Prioritising will happen on basis of facts in a pragmatic way, by Henning Foged and his colleagues in discussion with Baltic Sea 2020. A group discussion followed, on whether;

- Aerobic treatments should be down-prioritised due to their risk of production of laughter gas and loss of N?
- Whether evaporation and drying is un-ethical due to its high energy consumption?
- Whether incineration/combustion and other technologies for removal of plant nutrients are un-ethical because they cause higher consumption/production of mineral fertilisers, with the incurred energy consumption and negative climate effect.

Henning added that

- Technologies that ensure the recirculation of plant nutrients in the agricultural production have an economic advantage – the value of the N and P is typically € 10 per ton slurry (the cost of storing and spreading the liquid or solid manure is typically of the same magnitude)
- Technologies, which comprise bioenergy recovery has an economic advantage, as the gas has an economic value. Additional to this they are beneficial for the society, because they make the countries more independent of imported energy resources, give a more diversified energy supply, and helps to reach international conventions and obligations in relation with climate gases and environmental loads. In some cases these society benefits have direct monetary values.
- Technologies that cannot ”stand-alone” or have clear economies of scale would typically have an advantage of being implemented via farmer cooperation or a service provider.

Thyge Nygaard said that anaerobic digestion gives a better field effect, and that it therefore also limits the amount of N that otherwise could be leached. Henning Foged said that the Danish Agricultural Advisory Service in their field trials had documented 17–30%

higher field effect in digested slurry. A longer discussion happened about the field effect. It was finally concluded that the field effect is a useful indicator for evaluation of some of the livestock manure treatment technologies' effect on leaching reduction.

The matter about farmer cooperation was also subject for many comments. It was generally the opinion, that the project could promote larger livestock manure treatment plants for combined technologies, and that this even would take away the structural development pressure on the pig producers, which somehow would be a result in itself.

Re. 8: Survey result

The time was scarce, and Henning Foged said that although only 10 persons had completed the survey at that stage he saw some clear trend in the answers:

- All respondents says there is a considerable leaching of N and P that ends in the marine environment (30% leaching of N and 21% leaching of P)
- There is a clear expectation to an increase in the deployment of livestock manure treatment technologies (from an estimate of 3% in 1990 to an expectation to 38% in 2020)
- 7 out of 10 respondents see a link between leaching and livestock manure treatment technologies
- Respondents consider the implementation of the IPPC legislation to be rather effective, but also that it does probably not have the focus on leaching of N and P and how this could be reduced with livestock manure treatment technologies

Henning concluded that "As use of livestock manure treatment technologies becomes more and more widespread, and as (some of them) have an effect on leaching of N and P (and sometimes also other environmental effects), there is a clear justification to increase the focus on livestock manure treatment technologies in the BREF for installations for the intensive rearing of pigs".

Re. 9: Summarising and concluding

Lotta Samuelson thanked for the participation and the good input into the discussions. Baltic Sea 2020 will send conclusions from the meeting to participants, and will also consider sending out the project report for comments.

ANNEX J: KEY ELEMENTS OF POLISH LEGISLATION IN RELATION TO N AND P LEACHING

The Water Law – article 47 of this regulation states the overall rule that all agriculture activities should prevent N chemical compounds discharges into water. Moreover it states that Directors of Regional Water Management Authority will specify ground water and surface water susceptible to N chemical compounds from agricultural sources and areas particularly vulnerable from which runoff of N from agriculture sources to the waters ought to be limited.

Regulation of Minister of Environment on criteria of outlining water susceptible to N discharges from agriculture – this regulation sets the criteria describing water which should be classified as water polluted with nitrates and water in danger of being polluted with nitrates. It also describes thresholds above which eutrophication process starts in water.

Regulation of Minister of Environment on specific requirements to be met by action programs aiming to mitigate N runoff from agriculture – this regulation describes actions and procedures which prevent N runoff from agriculture into water.

Implementation of the Nitrate Directive: Poland has assigned 21 areas, ca 5% of the Polish agricultural land, as particularly vulnerable to nitrates from agricultural sources. The outflow of N from these areas to water should be reduced. These areas (N Vulnerable Zones, VNZ) have been legally empowered by 11 regulations of Regional Water Management Board directors (published in the Official Journals of specific regions).

Polish Inspection for Environmental Protection (IEP) monitors farms operating in NVZ, including these which do not fall under IPPC regime.

The Polish act on fertilisers and fertilizing transposes the Resolution of the European Parliament and the council No 2003/2002 of 13.10.2003 on fertilisation into polish law. It set certain obligations which should be fulfilled by farmers when using manure:

- The dose of manure applied during the year may not contain more than 170 kg N (N) pure component per 1 ha of agricultural land (Article 17. 3),
- IPPC pig farm with more than 2 000 places for productive pigs with weight more than 30 kg or 750 places for sows is obliged to:
    - Make a plan of fertilization, comprising regulations in legal acts and “Good Agriculture Practise” (below).
    - Make use of at least 70% of manure on the farm arable land and the rest of 30% can be sold, on bases of written agreement that a purchaser has to prepare fertilisation plan in 30 days. (Article 18.1).
    - Manure and slurry are stored only in sealed containers enabling the collection of at least 4-monthly production of fertiliser. These tanks should be closed tanks (Article 25.1),
    - Fertilisers other than manure and slurry must be stored on the impervious plates which are secured in such way that leaks are not released into soil (Article 25.2).
- The Polish Inspection for Environmental Protection prepares information on requirements for IPPC farms to achieve an integrated permit. The regional chemical-agricultural stations conduct controlling activities, including nutrient treatment, on these installations each year.

The act on fertilisers and fertilization prohibits the use of (most important prohibitions):

- fertilisers on soils flooded with water and covered with snow or frozen for depth of 30 cm and during rainfall (Article 20.1.1),
- manure in a liquid form on soils without plant cover located on slopes above 10% and the vegetation intended for direct human consumption (Article 20.1.2a),

- manure in liquid form – during the growing season of plants for direct human consumption (Article 20.1.2b).

Code of Good Agricultural Practice: For the purpose of achieving the objectives of the Common Agricultural Policy of the European Union, Code of Good Agricultural Practice was introduced by Polish Ministry of Agriculture and Ministry of Environment. It is a set of principles and recommendations based on law in Poland in the scope of environmental protection and advice on how to reduce the negative impact of agriculture on the environment. Good agricultural practice is being implemented by farmers on a voluntary basis, however, it is associated with the possibility of getting the single surface payment.

A farmer who wants to introduce good agricultural practice should ensure the appropriate use and storage of natural and artificial fertilisers and plant protection products, keep proper economy in grassland, protect soil and keep adequate water state. The farmer should also apply nutrient management regulations and implement crop rotation with accompanying agriculture system that protects the soil.

As part of good practice the farmer should also care about work safety, maintenance of machinery and equipment in good conditions, maintaining tidiness and order within the farming business. Good agricultural practice also provides appropriate conditions for animal husbandry.

Sources:

Personal communication, Chief Inspector of Environmental Protection, Andrzej Jagusiewicz, Polish Inspection of Environmental Protection

Helsinki Commission Report from Land-based Pollution Group, Eleventh meeting, Sopot, Poland, 16-18 May 2006, Agenda Item 5.1.

ANNEX K: KEY ELEMENTS OF DANISH LEGISLATION IN RELATION TO N AND P LEACHING

POLICIES

Denmark had, due to developments in nitrate levels of the ground water, already taken decisions in 1985 on policy goals and introduced legislation to implement these goals. EU's Nitrates Directive was issued first six years after, heavily inspired of the instruments that were already taken into use in Denmark to reduce leaching:

- relation between the livestock manure production and the agricultural land;
- required storage capacity for livestock manure; and
- restrictions on spreading time for livestock manures.

In order to ease the introduction of the regulations in a pedagogic and understandable way there was defined a so-called Animal Unit, by which it without respect to animal type, feed intensity, production system, bedding type or other is possible to precisely define the requirement to the relation between agricultural land and the livestock production. 1 Animal Unit was determined to 100 kg N ex. storage, and shall not be mixed with other conversion factors for livestock, for instance the Large Livestock Units, which most countries uses, and where 1 cow is 1 Large Livestock Unit, but which has no connection to the environmental load of the livestock.

The policy plans during the years in relation to leaching is seen from the table below.

The latest policy plan is the "Green Growth Plan", which has been issued by the Danish Government in April 2009. The plan sets the goal of reducing the leaching with 210.000 ton N and 19.000 ton P latest

Year	Plan	Significant elements in legislation:
1985	NPO-plan	- regulation of allowed animal units per ha - min. storage capacity for animal manure
1987	Water Environment Action Plan I	- 50% reduction in N-leaching from agr. - 65% "autumn green fields" - Slurry in autumn only to winter covered fields
1992	Sustainable agriculture	- Slurry only to grass or oilseed rape in autumn - Max. N-standards for crops (N-quota per farm) - Min. utilization of N in animal manure - Fertiliser plans and -accounts.
1998	Water Environment Action Plan II	- 10% decrease of N-standards (The N-quota) - 6% "super" green fields in autumn - 15% higher utilization of N in animal manure
2005	Water Environment Action Plan III	- 50% reduction of the P leaching - 13% reduction of the N leaching

by 2015. The goals shall be reached for instance via the establishing of more buffer strips along streams. Additionally, the plan includes the goal of having at least 50% of all livestock manures treated for energy purposes by 2020, and mention that principally all livestock manures should be treated in the future.

CONCRETE LEGISLATION

The current legislation in Denmark to implement the provisions of EU's Nitrates Directive is found in

- Lovbekendtgørelse nr. 757 af 29. juni 2006 om jordbrugets anvendelse af gødning og om plantedække (Law about use of fertilisers and about plant cover)
- Bekendtgørelse om jordbrugets anvendelse af gødning og om plantedække i planperioden 2008/09 (Regulation about use of fertilisers and about plant cover for the planning period 2008/09)
- Miljøministeriets bekendtgørelse nr. 1695 af 19. december 2006 om husdyrbrug og dyrehold for mere end 3 dyreenheder, husdyrgødning, ensilage mv. (Regulation about animal husbandry)
- Lov nr. 418 af 26. juni 1998 om afgift af kvælstof indeholdt i gødninger m.m. (Law about exise taxation of N in mineral fertiliser)
- Bekendtgørelse nr. 1596 af 19. december 2007 om direkte støtte til landbrugere efter enkelt-betalingsordningen (Regulation about direct subsidisation of farmers according the ssingle payment scheme)
- Bekendtgørelse nr. 345 af 13. maj 2008 om krydsoverensstemmelse. (Regulation about cross compliance)
- Bekendtgørelse om kvælstofprognosen for 2009, der udsendes omkring 1. april 2009. (Regulation about the N prognosis)

The mentioned legislation says for instance, that installations for the intensive rearing of pigs must dispose of 1 ha of agricultural land for spreading of livestock manure for each 1,4 Animal Units, installations for the intensive rearing of pigs must have 9 months storage capacity for livestock manure, the field effect of pig slurry must be at least 75%, there must be elaborated fertiliser plans according official fertiliser norms and manure standards latest by 21 April, and there must be submitted fertiliser accounts (in 2010 latest 1 February for the previous harvest year 2008/09).

The Danish Nature Protection Law contains provisions regarding distances between stables and watercourses, the quality of the floors in the stables, etc. The law holds as well the provisions in relation to the IPPC Directive concerning requirements for environmental permitting of intensive livestock farms – and again Denmark was on the forefront with the requirements, which came already in 1974, 15 years before the IPPC Directive was issued by EU.

In 1999 the IPPC Directive was built into the Nature Protection Law, and it was decided that intensive livestock farms in Denmark was defined as farms with more than 250 Animal Units, no matter whether pigs, poultry or cattle. In 2006 came additionally a new Law on Approval of Livestock Farms, which determines, that

- hobby farms (for instance 2 cows or 10 sheep) is under control and shall comply with some soft environmental regulations;
- small farms with 3–15 animal units shall inform the authorities of change in livestock production;
- farms with 15–75 animal units (Annex 2) needs an environmental approval;
- farms with 75–250 animal units (Annex 2) needs an environmental approval – screening;
- farms with more than 250 animal units (Annex 1) needs an Environmental Impact Assessment (EIA) approval; and
- authorities who handle environmental applications and EIA applications are paid by the applicant.

The Danish Environmental Protection Agency organises in connection to the environmental permitting the so-called technology lists, which are the Danish versions of the BAT's. The Danish technology lists are stronger than the BAT's contained in the BREF document, as it for instance is not allowed to broad spread slurry in Denmark; it has to be applied with band laying systems, and in case of bare soils and grasslands the slurry must be injected.

ANNEX L: STRUCTURAL STATISTICS AND MAP OF INSTALLATIONS FOR THE INTENSIVE REARING OF PIGS IN DENMARK, SWEDEN AND POLAND

STATISTICS

The statistics in the tables below are made to indicate the structure and sizes of pig farms in Denmark, Poland and Sweden. They are based on available official statistics from different sources, and therefore there is not full consistency between the different tables.

There is drastic structural change in the Danish pig production, illustrated by the fact that there in 2008 were 5.819 pig herds in Denmark, while this number was 17.688 and 34.322 in 1998 and 1988, respectively.

Denmark

Tot. no of production pigs in holdings	Farms		Production pigs (>=50kg)	
	No	%	No	%
<2000[C]	4.559	92,3	2.127.846	61
2000-2999[A]	247	5,0	617.377	18
3000-4999[A]	119	2,4	475.941	14
>=5000[A]	12	0,2	283.619	8
Sum[A]	378	100	1.376.936	100
Absolute No[C]	4.937		3.504.781	

Tot. no of sows in holdings	Farms		Sows	
	No	%	No	%
<500[C]	2.186	74	406.656	38
500-999[A]	594	20	445.203	42
1000-1499[A]	123	4	153.689	15
1500-4999[A]	0	0	0	0
>=5000[A]	61	2	53.685	5
Sum[A]	778	100	1.059.232	100
Absolute No[C]	2.964		1.059.233	

Tot. no of pigs in holding	Farms		Total pigs	
	No	%	No	%
< 2000	3.560,0	61	2.394.884	19
2000-2999	1.577,0	27	5.020.358	39
3000-4999	0,0	0	0	0
>=5000	682,0	12	5.322.406	42
Sum[A]	5.819,0	100	12.737.648	100
Absolute No[C]	5.819,0		12.737.648	

Sources:	
(A)	Personal information: Danmarks Statistiks Bibliotek og Information. European Statistical Data Support. Karsten Kjeld Larsen, e-meil: kkl@dst.dk +45 39 17 33 78. Data from 2008.
(B)	European Commission Directorate - General Environment. 2009. Monitoring of Permitting Progress for Existing IPPC Installations. -Data from 2008
(C)	Livestock by country, unit and type. StatBank Denmark. Http://statbank.dk/statbank5a. Visited 2009.10.05. Data from 2008

Poland

Tot. no of production pigs in holding	Farms		Production pigs (>=50kg)	
	No	%	No (*)	% (**)
< 2000(E)	414.476	99,97	4.069.602	83,8
2000-4999(D)	44	0,01	157.482	3,2
5000-9999(D)	31	0,01	173.234	3,6
10000-24999(D)	31	0,01	342.485	7,1
>=25000(D)	3	0,00	112.499	2,3
Sum total	414.585	100	4.855.300	100
Absolute No(A)			4.855.300	
(*) Calculated on the median base of particular herd size ranges				
(**) percent pigs recalculated on the basis of absolute number of pigs				

Tot. no of sows in holding	Farms		Sows	
	No	%	No (*)	% (**)
<750	data not available	-	data not available	
750-1999(D)	19	-	25.866	-
2000-4999(D)	14	-	42.243	-
5000-9999(D)	1	-	10.000	-
>=10000(D)	0	-	-	-
Sum(D)	34	100	78.109	100
Absolute No(A)			1.587.400	

No of IPPC provisions (B)	2008(B)	2009 (C)
For production pigs (6.8b)	116	67
For sows (6.8c)	6	33
For production pigs and sows (6.8 b and c)		44

Sources:	
(A)	GUS, 2008 (CBS, Poland) Publication available on http://www.stat.gov.pl/, data from 2008,
(B)	European Commission Directorate - General Environment. 2009. Monitoring of Permitting Progress for Existing IPPC Installations. Data from 2008
(C)	Ministry of Environment, 2009. http://ippc.mos.gov.pl/ippc/?id=53., data from 2009
(D)	Personal information: Ministry of Agriculture and Rural Development, Head of Dept Hanna Kostrzewska, 2009, March.
(E)	Personal information : M.Wolowicz@stat.gov.pl, Central Statistical Office

Sweden

Tot. no of production pigs in holdings	Farms		Production pigs (>50kg)	
	No	%	No (*)	%
<2000	2.073	96,2	1.065.908	77
2000-4999	74	3,4	258.963	19
>=5000	8	0,4	60.000	4
Sum(A)	2.155	100	1.384.871	100
Absolute No(C)			974.100	

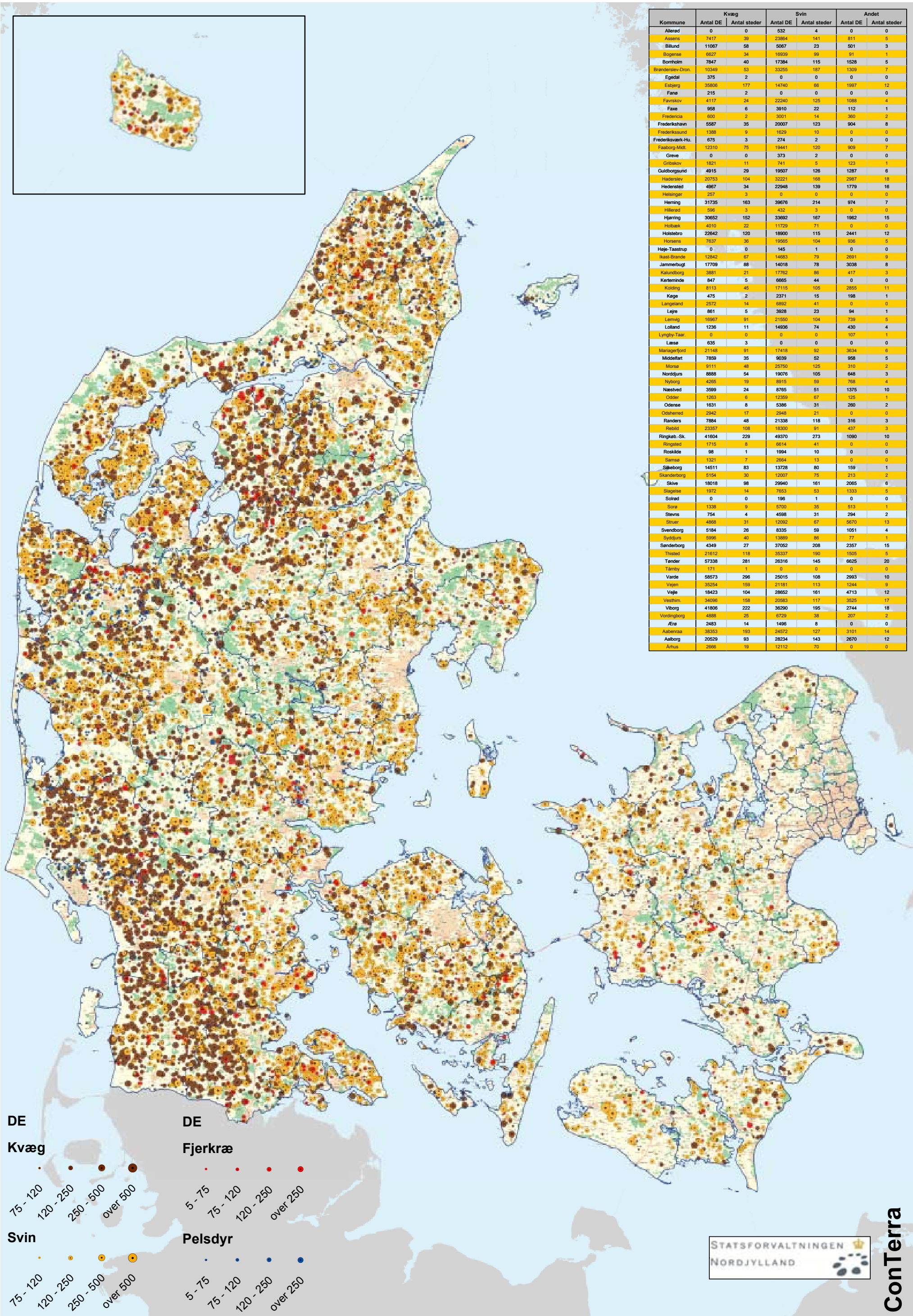
Tot. no of sows in holdings	Farms		Sows	
	No	%	No (*)	%
<750	2.302	99,0	322.543	90
750-1499	16	0,7	17.992	5
1500-2249	6	0,3	11.247	3
2250-3999	2	0,1	6.124	2
Sum(A)	2.326	100,0	357.906	100
Absolute No(C)			357.906	

Tot. no of pigs in holding	Farms		total pigs	
	No	%	No (*)	%
<2000	4.391	98,0		
2000-4999	82	1,8		
5000-9999	8	0,2		
Sum(A)	4.481	100,0	0,0	0,0
Absolute No(C)			1.609.300,0	

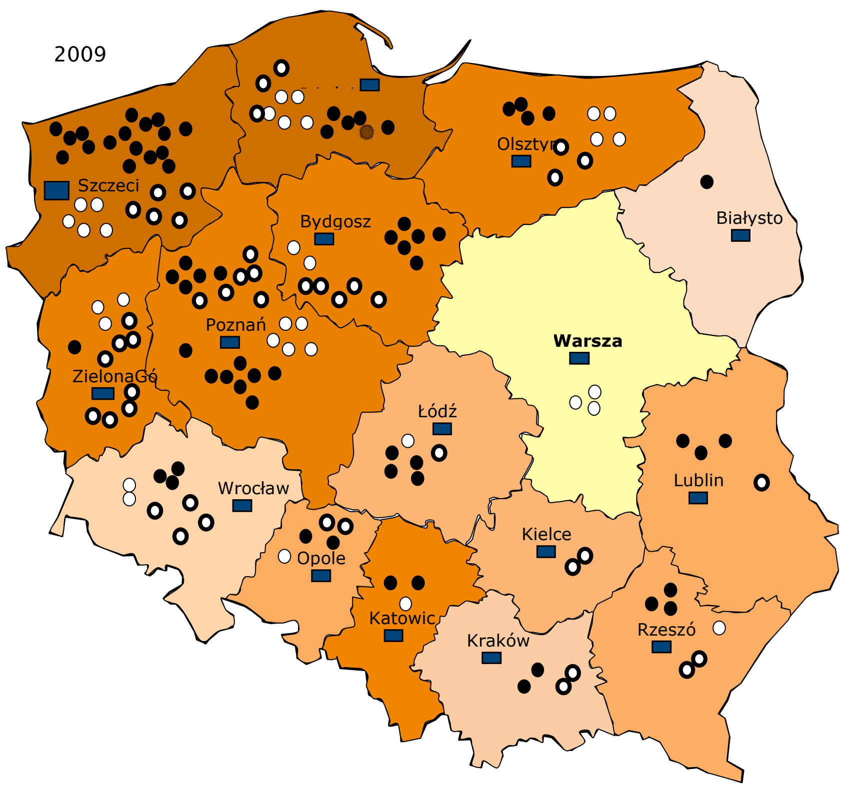
No of IPPC provisions (B)	2008
For production pigs (6.8b)	102
For sows (6.8c)	15
Sources	
(A)	personal information: Jeanette Mikhael, e-mail: Jeanette.Mikhael@sjv.se, 2009
(B)	European Commission Directorate - General Environment. 2009. Monitoring of Permitting Progress for Existing IPPC Installations. Data from 2008
(C)	SCB, 2008. www.scb.se

MAPS

The Danish map shows all pig farms, while only IPPC farms are shown on the Polish map. A larger version of the Danish map can be downloaded from http://www.cttools.dk/downloads/Husdyr_Placering_DK.pdf, in which case the text in the top right box with figures for distribution of different livestock types on Danish municipalities, can be read.



ANNEX L: STRUCTURAL STATISTICS AND MAP OF INSTALLATIONS FOR THE INTENSIVE REARING OF PIGS IN DENMARK, SWEDEN AND POLAND



Map of IPPC installations * in Poland and pig density in voivodships (pigs in IPPC installations/voivoidship) **

Sources:

*Ministry of Environment Protection, http://ippc.mos.gov.pl/ippc/?id=53. Data from 10.09.2009,
** Ministry of Agriculture and Rural

Legend:

- ● swine
- ○ sows
- ⭘ swines and sows

<1.500	1.500-4.999	5.000-19.999	20.000-49.999	50.000-99.999	>100.000

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