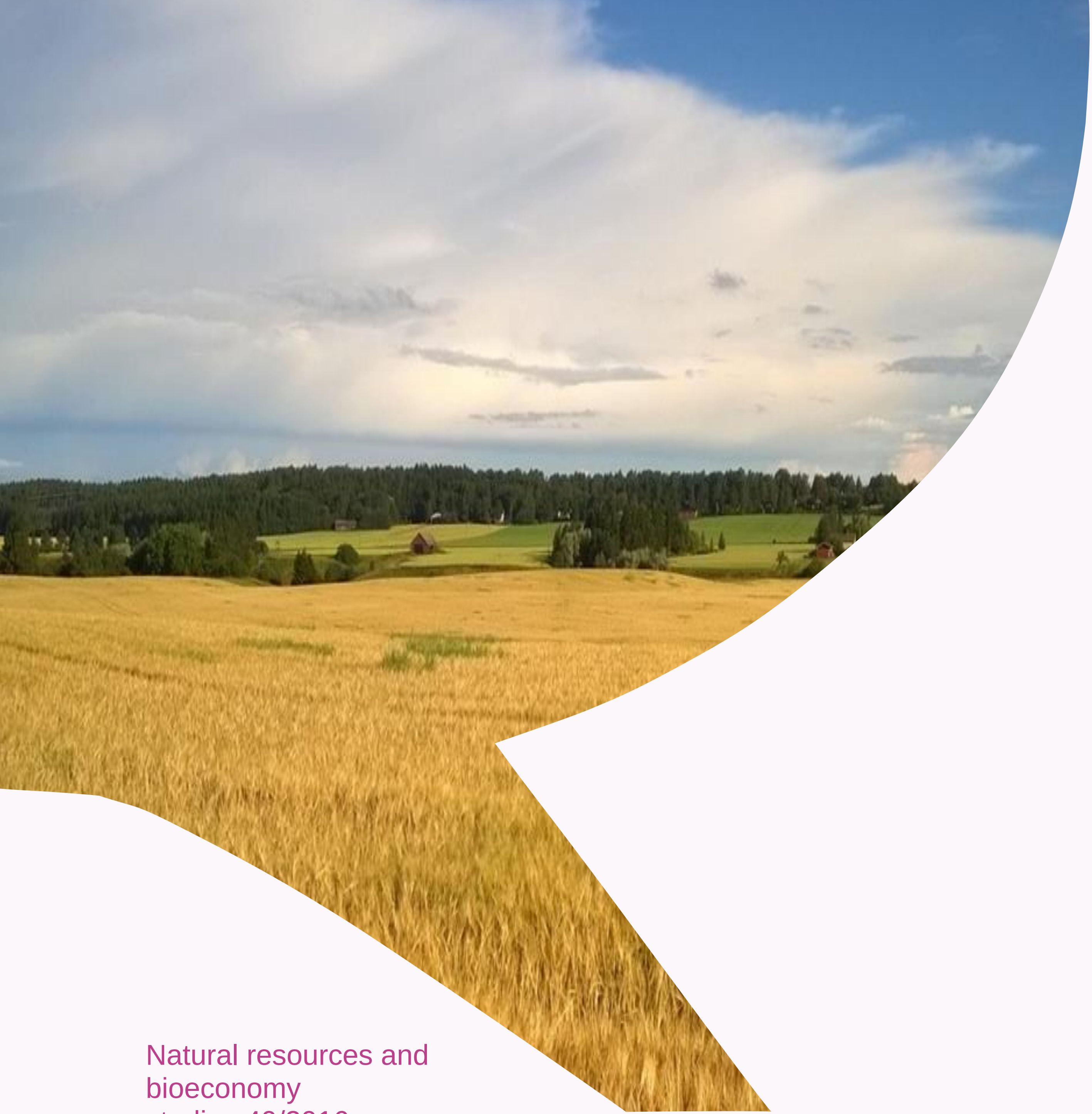

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Manure nutrient content in the Baltic Sea countries

Sari Luostarinen, Susanna Kaasinen (eds)

NATURAL RESOURCES INSTITUTE FINLAND

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Summary

This report was compiled in cooperation between the research organisations responsible for manure data in the Baltic Sea countries and the HELCOM Group on Sustainable Agricultural Practices (HELCOM Agri group).

All Baltic Sea countries have their own methods for determining manure data, i.e. manure nutrient content and also its other characteristics and quantity. As this data is a prerequisite for all manure use and manure-related regulation and it affects the emission reduction targets set, it is important to understand the differences between manure data provision between the countries. Moreover, to share the burden of emission reduction in manure use as equally as possible between the Baltic Sea countries, a more harmonised system might be called for. In order to develop such a system, the state-of-the-art in the countries now (August 2016) is required as the stepping stone towards jointly agreed methodologies and tools for determining manure quality and quantity.

In the following, the current national systems are shortly summarised with more detailed descriptions to be found in the chapters of this report.

In Denmark, a calculation system called “normative manure” is used for determining manure quantity and quality in three steps: as excreted by the animal (ex animal), as collected from housing (ex housing) and after storage (ex storage). The system includes several animal categories, housing systems and manure types, leading to more than 150 possible combinations. The resulting standards are based on average recordings of e.g. feed nutrient content, feed intake and production of meat, milk, eggs and embryos of each type of farm animal in Denmark, and they include nitrogen, phosphorus, potassium, dry matter and volume. The standards are used as the basis of manure fertilisation on all farms, though minor farm-specific corrections with own production data are possible. It is noted that actual manure analysis shows a significant variation in nutrient content compared to the standards. This is often a case of water use and thus dilution. The standards are updated annually by University of Aarhus as based on a contract with the relevant Danish ministry. The updating is done in cooperation with the Danish advisory service.

In Estonia, manure nutrient content is also calculated in three steps (ex animal, ex housing, ex storage) as the calculation system is based on the Danish normative manure system. However, the Estonian system contains less animal categories. The existing system works well with large-scale farms, e.g. cattle farms without grazing. There is also an unofficial online calculation tool available for farmers. Still, the system requires development e.g. in quantifying additives, such as precipitation and process water, and in losses during storage. The system is not updated on a regular basis.

In Finland, manure nutrient content is currently based on sampling and analysis. Farm-specific analysis must be made minimum every five years. Still, farmers have a choice in manure fertilisation: they can use the analysis result or they can use table values. The table values are based on a large database of analysed manure samples. The standards for manure quantity are calculated. Still, a calcuation system for normative manure has also been developed with its first version published during the autumn of 2016. The calculated values are seen necessary e.g. due to the heterogeneous nature of manure and the need to know manure quality and quantity in different steps of the manure management chain and for more detailed animal categories. The results will be immediately used in policymaking and research, including e.g. emission inventories and agri-environmental indicators. Their use in manure fertilisation and nutrient bookkeeping will be discussed prior to the next Rural Development Programme period (2021>).

In Germany, manure standards are based on calculated mass flow analysis. It is not based on manure sampling because manure is heterogenous and reliable sampling requires considerable professional experience. The calculation system works well and is also well accepted. The values take into account ammonia losses in housing, storage and spread. The values are used for fertiliser plan-

ning and nutrient bookkeeping by farmers where analyses are not available. The system is updated every five years.

In Latvia, legislation concerning manure standards entered into force in the end of 2014 (previously only used as guidelines). The new system includes 18 animal categories and is based on scientific research for most categories and literature for a minority of categories. Livestock feeding, housing system and productivity are the basis of the system. Standards are used by farmers, governmental organizations (e.g. control purposes), advisory service, constructors for manure storages and other stakeholders. Still, there is a need for new / updated standards due to changes in livestock feeding, growing livestock productivity and new technologies.

In Poland, the current system is based on a nutrient mass flow model, which deals with all stages of animal production and manure storage (gases, emissions accounted). The model is validated with farm monitoring data and takes into account different productivities and housing systems, such as grazing and straw bedding. The Polish system is currently under revision and could be developed further to include monitoring of 7000 farms where manure samples will be collected and analyzed twice a year. Background information from the farms (crops, animal number, bedding system etc.) will be collected as well. Manure sampling and enquiries are also vital for the stakeholders' point of view and considered very useful for them.

In Russia, farms are not required to keep account of manure nutrient content, but Regional Centres offer manure analysis. However, there are reference manuals used for fertilisation purposes. Document RC-APC 1.10.15.02 contains information for 56 animal categories on manure nutrient content. The data is collected from whole Russia. Regional data for North-West Russia is needed.

In Sweden, a planning tool VERA (mass flow model) calculates manure nutrient content in the different handling steps. In the tool e.g. standard feeding or actual feeding can be used in order to have some flexibility. The planning tool is used in advisory purposes especially in nutrient vulnerable zones. The data is updated but not on a regular basis. There are default values for some parameters like ammonia emissions. The system could be developed as regards more frequent update, validation of errors and dilution of manure. Swedish inventory of fertiliser use is done every second year.

Lithuania did not take part in the discussions or this report. However, they are engaged in the work towards a Baltic project in which joint guidelines for determination of manure quantity and quality will be developed and tested.

Conclusions:
The Baltic Sea countries agree that there is a *need for* enhancing manure utilisation in the BSR and this could be reached via more precise nutrient balances. In order to make them more precise and to ensure a level playing field for all Baltic Sea countries, unifying the procedures of collecting manure data is seen a way forward. All countries have national protocols for manure data provision and they are mostly based on sampling and analysis or modelled calculations. All countries report needs for improving and updating their protocols and the resulting manure data. Many also refer to similar challenges in data provision.

There is a great chance of learning from each other via determining the suggested joint guidelines for manure data provision in close cooperation. The resulting tool, the more precise manure data, would become more effective and give all its users, farmers, advisory, authorities, policymakers, research and also companies developing and providing technologies for manure management and processing, a more solid database from which to plan the most effective ways to make the most of manure and its valuable nutrients (and energy). This is foreseen to also decrease the risk for environmentally harmful impacts from agriculture.

Keywords: manure analysis, fertilisation, manure, modelling, nutrient balance, manure sampling.

Contents

1. Introduction

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Sustainable agricultural production, including efficient use of manure, is one of the key elements for reaching a good state of the Baltic Sea marine environment and other waterways. It is also vital for minimising gaseous emissions from manure management, including greenhouse gases and ammonia with their many detrimental environmental effects. Simultaneously, effective manure management can bring significant opportunities as manure nutrients are more efficiently utilised by crops in an enhanced nutrient recycling.

In order to use manure sustainably, its quantity and quality must be known. Both are influence not only by the animal species but also their production solutions and manure management choices and conditions. The methodologies for determining manure quantity and quality differ between different countries. It has been noted that all Baltic Sea countries have their own systems for collecting manure data and the data is used in variable ways in policymaking and in practical farming. Hence, the countries are not in an equal position when regarding the many targets for decreased emissions from agriculture, even though many of them are related to manure.

Therefore, the Baltic Sea countries agreed at the 2013 HELCOM Ministerial Meeting to promote and advance towards applying annual nutrient accounting at farm level by 2018 at the latest, to national guidelines or standards for nutrient content in manure establish by 2016, and to develop guidelines/recommendation on the use of such standards by 2018. The HELCOM Group on Sustainable Agricultural Practices has identified these measures, closely related to the principles of circular economy, as their key priorities.

The HELCOM workshop held in Oldenburg, Germany, in April 2015, focused on the promotion of nutrient accounting and highlighted a strong need to elaborate systems for manure nutrient standards, which are applicable in all the Baltic Sea countries and create a joint basis for nutrient accounting and management. The Agri group agreed to organise a workshop focused on standards of manure nutrient content and welcomed the offer by Finland to host the event.

The HELCOM workshop on manure nutrient content in the Baltic Sea countries was held on 19-20 November 2015 at the premises of Natural Resources Institute Finland (Luke) in Vantaa, Helsinki. The workshop was co-organised by the Finnish Ministry of the Environment, Luke and HELCOM. It was attended by all Contracting Parties to the Helsinki Convention, except for Lithuania, representing agricultural and environmental authorities and research organisations, and Coalition Clean Baltic (CCB) and the Baltic Farmers' Forum on Environment (BFFE).

The aim of the workshop was to consider manure standards in more detail and propose how common methodologies for their determination could be derived or developed. The workshop also discussed establishing and seeking finances for a new regional project on creating such methodologies and planning their widely accepted use in the Baltic Sea countries. It was also concluded thet in order to plan such joint guidelines, including manure nutrient content and the basis for manure fertilisation, the state-of the-art of manure data provision in the Baltic Sea countries needs to be known. It was agreed to be this report in cooperation between the members of HELCOM Agri group and relevant national research organisations to provide the necessary background. Moreover, the conclusions presented here are based on both the report itself and the group work and discussions in the November 2015 workshop.

2. National standards for manure nutrient content in the Baltic Sea countries

2.1. Denmark

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History and current use

The interest for quantification of nitrogen (N) and phosphorus (P) content in animal manure has increased over the years. Denmark has a long tradition for calculations of standards for manure composition and content of nitrogen (N), phosphorus (P) and potassium (K). However, the first standards were rough estimates as the basis for the calculations were to a certain extent theoretical. The standards are used for fertiliser planning at all animal farm productions in Denmark. Since the 1990s, the farmers have reported the yearly production and use of manure and mineral fertilisers to the Environmental Ministry, based on these standards. At the time of writing, the Danish manure standards are used e.g. in fertiliser planning, definition of the Danish Livestock Unit (LU equals to "dyreenhed", DE in Danish (1 DE = 100 kg N ex storage)), calculation of ammonia emission and total content of N and P in manure produced by livestock in Denmark.

During the first approximately 20 years, the standards were revised three times (Laursen, 1987; Laursen, 1994; Poulsen & Kristensen, 1997; 1998), but due to the need for more precise standards, the standards are now revised annually and the dimension of the normative system has increased to a quite detailed system. Over the years, the methodology has also changed, but for the last ten years the changes have been minor. However, the complexity and dynamics of the system have increased in order to establish more and more precise values to be used by farmers and authorities.

Aarhus University chairs the work with the normative system on behalf of the Ministry of the Environment and Food, and has built up the actual system. However, many other institutions and members from the Danish agricultural advisory systems are involved in the work. This cooperation has been adopted in order to have access to the latest data and also to ensure that the criteria to documentation are fulfilled. A description of the model including input data and documentation is published in booklets and is available on the Aarhus University website[1].

Model

The calculation of standards for manure nutrient content is divided into three steps. First, the standards ex animal (excretion) are calculated, followed by accounting for inputs and outputs during housing (e.g. emissions and addition of bedding materials in the different housing systems) and resulting into standards ex housing. Finally, inputs and outputs during manure storage are incorporated to calculate standards ex storage.

Currently, the Danish system includes in addition to N and P also K, manure quantity (kg) and dry matter content. The flow dynamics are shown in Figure 1. The system calculates standards for relevant species of livestock in Denmark, including cattle, pigs, poultry, furred animals, horses, sheep and goats. Each species is further subdivided into subcategories and weight classes, age classes etc. relevant for the Danish livestock production (Table 1). Standard values are calculated per produced animal or per animal per year depending on species and category.

[1] http://anis.au.dk/forskning/sektioner/husdyrernaering-og-miljoe/normtal/

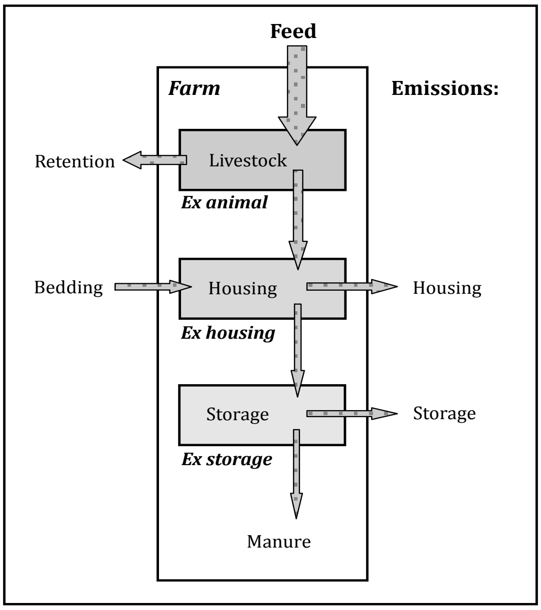

Figure 1. The flow dynamics of the Danish normative manure system which quantifies nutrient content in livestock manure ex animal, ex housing and ex storage.

Table 1. Examples of cattle and pig categories.

Cattle	Pigs
Dairy cow, heavy breed, per year	Piglet (7.1 – 31 kg)
Dairy cow, Jersey, per year	Fattening pig (31 – 110 kg)
Female calf, heavy breed, 0-6 months	Sow, including 30 piglets until veaning
Female calf, Jersey, 0-6 months	
Heifer, heavy breed, 6-27 months	
Heifer, Jersey, 6-25 months	
Bull calf, heavy breed, 0-6 months	
Bull calf, Jersey, 0-6 months	
Bull, heavy breed, 6 months to 440 kg	
Bull, Jersey, 6 months to 328 kg	
Suckler cow, < 400 kg	
Suckler cow, 400- 600 kg	
Suckler cow, > 600 kg	

Standards ex animal

Calculations of standard manure values are performed as a mass balance, i.e. a simple difference between input and output. Input is based on recordings and calculations of feed intake for the different categories combined with knowledge on nutrient concentration in the diets. Thereafter, the nutrient retention in the animal products is calculated based on standard values obtained from published literature. The retention is then subtracted from the the feed input. The excretion is separated into faecal and urinary fractions using digestibility coefficients of the different nutrients. The flow is shown in Equation 1.

Equation 1. Calculation of the Danish manure standards – ex animal (simplified).

Nutrient flow (ex animal) = feed intake × nutrient concentration – nutrient retention

Standards ex housing

The flow of nutrients in manure leaving the housing for storage or to be spread directly on agricultural soil is calculated based on ex animal standards as input. First, the different housing systems relevant for the Danish agriculture are included for each species (and subclass). Table 2 shows examples of housing systems for dairy cows and fattening pigs (30-100 kg).

Table 2. Examples of housing systems for dairy cows and growing-fattening pigs.

Cattle	Pigs
Tie-up housing system with dung channel	Totally slatted floor
Tie-up housing system with floor grating	Partially slatted floor
Cubicles with solid floor	Solid floor
Cubicles with slatted floor	Sub-divided lying area
Deep litter (throughout area)	Deep litter
Deep litter, feeding area with slatted floor	
Straw-bedded sloped floor	

Thereafter, default values for nitrogen loss due to emissions are included for each housing system based on results from experimental studies and qualified assumptions. Hereafter, the contributions of nutrients from bedding materials are added and the absorption of urine into the bedding materials and faeces is calculated in order to establish values for slurry (faeces and urine together) and separately for faeces (manure or deep litter) and urine (liquid manure). For each housing system the manure type (the three mentioned types above) is defined (see Table 2). Hereby, the standards ex housing are calculated (Equation 2).

Equation 2. Calculations of the Danish manure standards - ex housing (simplified).

Nutrient flow (ex housing) = nutrient flow (ex animal) - emission

Standards ex storage

Based on the ex housing standards, the final step takes into account what happens during storage of the different types of manure from different livestock species and categories and species specific manure types. First, the losses of N (due to emissions) and dry matter are subtracted. Furthermore, redistributed nutrients, dry matter and liquid due to leakage of juice from faeces etc. are included in the model. The general model is shown in Equation 3 and examples of model output are shown in Figure 2 and 3.

Equation 3. Calculations of the Danish manure standards - ex storage (simplified).

Nutrient flow (ex storage) = nutrient flow (ex housing) - emission

1 cow per year, heavy breed

Preconditions :	
Milk yield, kg milk/cow per year:	7450
Milk protein, kg/cow per year:	251
FU per cow per year:	6030
Crude protein per FU:	176
Digestible crude protein, g per FU:	131
Phosphorus, g per FU:	5.1
Feed efficiency, %:	82

Ex animal, total excretion:	
Amount:	177 tons
N:	128 kg
P:	23.0 kg
K:	100.0 kg

Amount ex storage: Housing system	Manure type	Manure, t	Dry matter, percentage	Total content:				Content per t manure			
				Kg N	Kg NH_4-N	Kg P	Kg K	Kg N	Kg NH_4-N	Kg P	Kg K
Tie-up housing system with dung channel	Manure +	10.80	20.0	54.8	13.7	21.3	33.6	5.08	1.27	1.97	3.12
	liquid manure	10.41	3.4	58.5	53.8	2.1	72.6	5.62	5.17	0.20	6.98
Tie-up housing system with floor grating	Manure + liquid manure	19.84	10.6	121.7	84.5	23.4	106.3	6.14	4.26	1.18	5.36
Cubicles with solid floor	Slurry	23.17	9.1	115.3	68.0	23.4	106.3	4.98	2.93	1.01	4.59
Cubicles with slatted floor	Slurry	23.17	9.1	121.7	73.9	23.4	106.3	5.25	3.19	1.01	4.59
Deep litter (throughout area)	Deep litter	15.62	30.0	128.5	32.1	26.5	158.6	8.23	2.06	1.69	10.15
Deep litter, feeding area with slatted floor	Deep litter	8.27	31.0	65.8	16.4	13.5	83.5	7.96	1.99	1.63	10.10
	+ slurry	13.05	6.6	59.6	33.8	11.5	50.0	4.57	2.59	0.88	3.83
Straw-bedded sloped floor	Deep litter	14.71	24.0	108.4	27.1	24.2	120.9	7.37	1.84	1.65	8.22

Figure 2. Example of model output (Dairy cows; Poulsen & Kristensen, 1997).

Slaughter pigs, 1 head prod., 68.3 kg gain
(30 kg to 98.3 kg live weight = 30 kg to 75 kg slaughter weight)

Preconditions :	
Gain:	68.3 kg
FU_P per kg gain:	2.94
Crude protein per FU_P:	163 g
Phosphorus per FU_P:	5.3 g

Ex animal, total excretion:	
Amount	0.34 tons
N	3.28 kg
P	0.69 kg
K	1.43 kg

Amount ex storage: Housing system	Manure type	Manure, t	Dry matter, percentage	Total content:				Content per t manure			
				Kg N	Kg NH_4-N	Kg P	Kg K	Kg N	Kg NH_4-N	Kg P	Kg K
Totally slatted floor	Slurry	0.48	6.5	2.73	1.93	0.69	1.43	5.63	3.99	1.42	2.95
Partially slatted floor	Slurry	0.48	7.0	2.74	1.94	0.69	1.46	5.69	4.03	1.44	3.04
Solid floor	Manure +	0.14	23.0	0.91	0.32	0.59	0.74	6.70	2.34	4.34	5.50
	liquid manure	0.32	1.9	1.42	1.31	0.11	0.84	4.37	4.02	0.35	2.57
Sub-divided lying area	Deep litter	0.11	33.0	1.02	0.31	0.37	1.12	9.46	2.84	3.42	10.34
	+ slurry	0.27	5.9	1.37	0.97	0.35	0.71	5.11	3.61	1.29	2.67
Deep litter	Deep litter	0.22	33.0	2.04	0.61	0.74	2.23	9.46	2.84	3.42	10.34

Figure 3. Example of model output (Slaughter = fattening pigs; Poulsen & Kristensen, 1997).

Data input, documentation and revision

The overall system is very flexible because it is easy to recalculate whenever new values for one or more of the parameters are documented, e.g. if the protein content in diets for pigs or dairy cows is lowered. The system is currently based in Excel for input and output sheets.

The main goal for the Danish system is to specify manure standards that reflect the present situation in the Danish livestock production. This requires that most of the input data for the system is based on values coming from databases and statistics, reflecting the current productivity, diet composition and nutrient content, actual housing systems, storage facilities etc. in livestock production in Denmark. However, results and values from research and development are also used, e.g. digestibility coefficients (N, P, K, and dry matter), nutrient contents in the products, emission coefficients during housing and storage. The use of data reflecting the current productivity etc. in practice is a prerequisite for obtaining default manure standards that can be used directly by most farmers.

Some parts of the methods used in the Danish normative system need to be re-evaluated because new results and techniques make it possible to improve the system. Due to the increasing demand for documentation of input data it is very important that the normative system is well described and that the data used for the calculations are reliable and referable to references or well-described expert-estimates. Therefore, documentation and data quality are very much in focus in the Danish system.

Formerly, the same standards were used for several years but today the demand for continuously updated and precise standards is massive because the manure standards are used for e.g. preparation and acceptance of fertiliser plans on each Danish farm. As a consequence, the entire Danish normative system is revised annually. In principle this means that every year the input data is updated based on documented changes, such as changes in diet composition, amount of feed, weight interval, housing system, emission coefficients. Thus, also new standards are published every year.

Possibilities to use corrected values instead of default standard values

The Danish normative system gives default standards for almost 150 categories divided into different animal species and housing systems. This means that most farmers are able to refer their livestock production to relevant standards in the system. These farmers can use the standard values directly and do not have to fulfil any further criteria for documentation.

However, the increasing focus on nutrient utilisation and reducing nutrient loss encourages farmers to change their practices, e.g. use diets with a lower nutrient content or improve the productivity compared to standards. This means that the manure might have a lower nutrient content than the default standard values. As such, there is a demand for possibilities to use actual farm-spcific values and not the default values. To fulfil this demand, the Danish system includes equations for correcting the default values with farm-specific data. For most livestock categories it is now possible to correct for deviations in productivity, amount of feed, or diet composition. However, the farmers have to document deviations from the default values used for e.g. diet composition.

Advantages and challenges of the existing systems at the national level in Denmark

The Danish system is completely adapted to the current Danish livestock production with regard to weight interval of the livestock categories, housing system, storage facilities etc. This is definitely an advantage for the Danish livestock producers and Danish controlling authorities (precise and actual standards). However, for comparisons between other countries the system is detailed and solely adopted to Danish practice although other species and categories, housing systems etc. could be included. Therefore, it is necessary to define and describe what for a normative system should be used. Formation of the actual Danish normative system show that it is not possible to have a system that is very simple and at the same time also reflects all production systems used in practise.

National needs for developing the existing system in Denmark
The Danish system has been developed to calculate nutrient excretion and nutrient concentration in manure. Originally it was published as a service for the users to optimize fertiliser planning. However, there is an increasing focus on nutrient concentration in manure with increasing environmental focus and since N-fertilisation have been lower than economical optimum for years. Moreover, since some Danish biogas plants use a paying model based on dry matter content in slurry, this calls for a revision of the system in respect to both nutrient content and flow of dry matter and water.

Potential of developing and implementing a regional joint basis for an advanced nutrient standards system from the perspective of Denmark
The Danish normative system could form the basis for regional, Baltic guidelines for determining manure nutrient content and manure quantity. This could be accomplished by including new animal categories and housing systems as necessary for other Baltic Sea countries.

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2.2. Estonia

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The existing systems and practices in Estonia

The Estonian formulae for calculating the quantity and quality of manure (ex animal, ex housing, ex storage) are similar to the Danish normative manure system. The Estonian regulation "Calculated values of nutrient content of different types of manure, methodology for calculating manure storage capacity and coefficients for the calculation of animal units"[2] makes it possible to:

- Calculate the average manure quantity and nutrient content by animal species, including different age and production groups (Figure 4),
- Calculate the minimum capacity of manure storage for eight months of manure accumulation (Figure 5).

Põllumajandusministri 14.07.2014 määrus nr 71
„Eri tüüpi sõnniku toitainete sisalduse arvestuslikud väärtused,
sõnnikuhoidlate mahu arvutamise metoodika ja põllumajandusloomade
loomühikuteks ümberarvutamise koefitsiendid"
Lisa 3

Summaarne sõnniku kogus laudas ja selle toiteelementide sisaldus pärast säilitamist sõnnikutüüpide lõikes loomade aastaringse laudaspidamise korral

Nr	Looma liik, vanuse- või toodangurühm	Sõnniku tüüp (kuivaine sisalduse %)	Sõnniku kogus ja toiteelementide sisaldus									
			Kogus t/aasta	Kuivaine %	N kg	NH_4-N kg	P kg	K kg	N kg/t	NH_4-N kg/t	P kg/t	K kg/t
1	Piimalehmad	Vedelsõnnik (≤ 7,9)	24,7	5,9	116,9	30,4	30,1	101,0	4,74	1,23	1,22	4,09
		Poolvedelsõnnik (8,0–19,9)	23,9	14,1	116,9	23,2	30,1	101,0	4,89	0,97	1,26	44,22
		Tahesõnnik (20,0–24,9)	21,8	20,3	95,1	14,8	29,8	89,1	4,36	0,68	1,37	4,09
		Sügavallapanusõnnik (≥ 25)	22,6	27,3	122,7	11,1	33,1	129,7	5,43	0,49	1,47	5,74
2	Ammlehmad, lihaveised (üle 24 kuu)	Vedelsõnnik (≤ 7,9)	–	–	–	–	–	–	–	–	–	–
		Poolvedelsõnnik (8,0–19,9)	8,2	14,6	59,9	3,5	6,9	72,5	7,34	0,43	0,85	8,87
		Tahesõnnik (20,0–24,9)	8,8	24,6	54,9	2,6	7,2	64,9	6,27	0,30	0,82	7,41
		Sügavallapanusõnnik (≥ 25)	10,7	38,3	74,9	1,1	9,9	101,2	7,01	0,10	0,93	9,47
3	Lehmvasikad (0…6 kuud)	Vedelsõnnik (≤ 7,9)	2,7	7,6	14,4	3,3	2,1	17,1	5,29	1,23	0,80	6,38
		Poolvedelsõnnik (8,0–19,9)	2,7	13,2	14,4	2,7	2,2	17,1	5,27	0,97	0,79	6,30
		Tahesõnnik (20,0–24,9)	2,8	24,3	14,0	1,9	2,2	15,6	4,96	0,68	0,80	5,55
		Sügavallapanusõnnik (≥ 25)	2,8	29,1	16,4	1,4	2,6	21,9	5,92	0,49	0,96	7,91
4	Pullvasikad (0…6 kuud)	Vedelsõnnik (≤ 7,9)	2,5	7,6	10,9	3,1	1,3	8,9	4,39	1,23	0,52	3,58
		Poolvedelsõnnik (8,0–19,9)	2,5	12,8	11,8	2,5	1,3	9,0	4,62	0,97	0,52	3,55
		Tahesõnnik (20,0–24,9)	2,6	24,6	11,5	1,8	1,4	8,7	4,35	0,68	0,54	3,28
		Sügavallapanusõnnik (≥ 25)	2,6	29,6	13,9	1,3	1,8	13,7	5,34	0,49	0,69	5,26
5	Lehmmullikad (6 kuud…poegimine)	Vedelsõnnik (≤ 7,9)	11,1	7,6	49,2	13,06	11,1	48,7	4,44	1,23	1,00	4,39
		Poolvedelsõnnik (8,0–19,9)	11,1	13,6	49,2	10,8	11,1	48,7	4,44	0,97	1,00	4,39
		Tahesõnnik (20,0–24,9)	11,6	22,2	45,4	7,9	11,3	44,7	3,91	0,68	0,97	3,84
		Sügavallapanusõnnik (≥ 25)	13,2	33,3	63,8	6,5	14,1	77,4	4,83	0,49	1,07	5,86

Translation: piimalehmad = dairy cows; ammlehmad = suckler cows (meat production, >24 months); lehmvasikad = cow calves (0-6 months); pullvasikad = bull calves (0-6 months); lehmmullikad = heifers (6 months to calving); vedelsõnnik = slurry; poolvedelsõnnik = concentrated slurry; tahesõnnik = farmyard manure; sügavallapanusõnnik = deep litter; kuivaine sisalduse = dry matter content; kogus t/aasta = total amount t/a.

Figure 4. Example of manure amount and chemical composition ex storage by manure type as calculated by the Estonian manure system.

[2] https://www.riigiteataja.ee/akt/116072014008

Indicators describing the age and production groups of cattle are the results of a separate investigation. Also, manure analyses (DM content, chemical composition) are available for farmers. Guidelines for collecting manure samples are available in the web[3].

Põllumajandusministri 14.07.2014 määrus nr 71
„Eri tüüpi sõnniku toitainete sisalduse arvestuslikud väärtused,
sõnnikuhoidlate mahu arvutamise metoodika ja põllumajandusloomade
loomühikuteks ümberarvutamise koefitsiendid"
Lisa 8

Sõnnikuhoidla miinimummaht ja keskmised arvestuslikud näitajad sõnnikuhoidla miinimummahu arvutamiseks

Tabel 1. **Sõnnikuhoidla miinimummaht kaheksa kuu sõnnikukoguse säilitamiseks aastaringse laudaspidamise korral**

Nr	Looma liik, vanuse- või toodangurühm	Sõnniku tüüp (kuivaine sisalduse %)	Looma kohta		Loomakoha kohta	
			Sõnniku kogus t/aasta	Minimaalne sõnnikuhoidla maht 8 kuu sõnnikukoguse säilitamiseks m³	Sõnniku kogus t/aasta	Minimaalne sõnnikuhoidla maht 8 kuu sõnnikukoguse säilitamiseks m³
1	Piimalehmad	Vedelsõnnik (≤ 7,9)	24,7	16,5	24,7	16,5
		Poolvedelsõnnik (8,0–19,9)	23,9	17,7	23,9	17,7
		Tahesõnnik (20,0–24,9)	21,8	19,3	21,8	19,3
		Sügavallapanusõnnik (≥ 25)	22,6	25,2	22,6	25,2
2	Ammlehmad, lihaveised (üle 24 kuu)	Vedelsõnnik (≤ 7,9)	–	–	–	–
		Poolvedelsõnnik (8,0–19,9)	8,2	6,0	8,2	6,0
		Tahesõnnik (20,0–24,9)	8,8	7,8	8,8	7,8
		Sügavallapanusõnnik (≥ 25)	10,7	11,9	10,7	11,9
3	Lehmvasikad (0…6 kuud)	Vedelsõnnik (≤ 7,9)	2,7	1,8	5,4	3,6
		Poolvedelsõnnik (8,0–19,9)	2,7	2,0	5,4	4,0
		Tahesõnnik (20,0–24,9)	2,8	2,5	5,6	5,0
		Sügavallapanusõnnik (≥ 25)	2,8	3,1	5,6	6,2
4	Pullvasikad (0…6 kuud)	Vedelsõnnik (≤ 7,9)	2,5	1,7	5,0	3,4
		Poolvedelsõnnik (8,0–19,9)	2,5	1,9	5,0	3,8
		Tahesõnnik (20,0–24,9)	2,6	2,3	5,2	4,6
		Sügavallapanusõnnik (≥ 25)	2,6	2,9	5,2	5,8
5	Lehmmullikad (6 kuud…poegimine)	Vedelsõnnik (≤ 7,9)	11,1	7,4	11,1	7,4
		Poolvedelsõnnik (8,0–19,9)	11,1	8,2	11,1	8,2
		Tahesõnnik (20,0–24,9)	11,6	10,3	11,6	10,3
		Sügavallapanusõnnik (≥ 25)	13,2	14,7	13,2	14,7

Translation: piimalehmad = dairy cows; ammlehmad = suckler cows (meat production, >24 months); lehmvasikad = cow calves (0-6 months); pullvasikad = bull calves (0-6 months); lehmmullikad = heifers (6 months to calving); vedelsõnnik = slurry; poolvedelsõnnik = concentrated slurry; tahesõnnik = farmyard manure; sügavallapanusõnnik = deep litter; looma kohta = per animal; loomakoha kohta = per animal place; sõnniku kogus t/aasta = total manure t/a; minimaalne sõnnikuhoidla maht 8 kuu sõnnikukoguse säilitamiseks = minimum manure storage for 8 months manure production.

Figure 5. Example of minimum manure storage capacity for the eight-month manure quantity by manure type as calculated with the Estonian manure system.

Software for the calculation of manure indicators (based on the regulation) has also been developed and a more detailed version of the software, enabling farm-specific calculation is under development at the time of writing[4] (Figure 6).

[3] http://pmk.agri.ee/index.php?valik=166&keel=1&template=template2teenused.html
[4] http://msr.agri.ee:8888/$/

Figure 6. Software for the calculation of manure indicators

Advantages and challenges of the existing systems at the national level in Estonia
The manure data provided by the system is relatively easy to elaborate on the legislation. On practical level, the system works well for large-scale farms (companies). However, the system application in small- and middle-scale farms is somewhat more complicated because it is more difficult to control the inputs. Moreover, the system works well in farms without grazing and thus more controlled feeding.

National needs for developing the existing system in Estonia
The system is being developed and the farmers and public servants use it quite intensively. Uncertainties are mainly connected with the quantities of additives (precipitation and process water) and losses within the storing period (evaporation of humidity, dry matter decomposition).

Potential of developing and implementing a regional joint basis for an advanced nutrient standards system from the perspective of Estonia
The idea of a joint Baltic basis for determination of manure quantity and quality certainly looks promising from the Estonian perspective. Despite using the joint guidelines, the Baltic Sea countries have the possibility of differentiation according to the peculiarities of their agricultural production. As large-scale production prevails in Estonia, Estonia could share its experience from large-scale production system.

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2.3. Finland

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The existing system and practices in Finland

At the time of writing, definition of manure nutrient content on Finnish farms is regulated by the Government Decree on the restriction of discharge of certain emissions from agriculture (1250/2014), subject to the Nitrates directive (91/676/EC). The Decree requires each animal farm to sample and analyse their manure minimum every five years. However, the farm can choose between basing manure fertilisation on the analyses result or on table values which are derived from a large quantity of manure analysis results from commercial laboratories. This option between farm-specific analysis and table values is also included into the voluntary agri-environmental support scheme of the Rural Development Programme 2014-2020.

Prior to joining the EU in 1995, Finnish manure nutrient content was reported in guidebooks apparently based on analysed manure samples, but more official table values were given after 1995 using data from one commercial laboratory. The current table values were updated in 2014 by SYKE and Luke, as requested by the working group preparing the Government Decree (1250/2014). The working group had representatives e.g. from Ministry of Agriculture and Forestry, Ministry of the Environment, Farmers' Union and research institutions.

The manure quantity as minimum storage capacity per animal category was also updated for the Government Decree (1250/2014) by SYKE and Luke. It was calculated from feeding and excretion with rough average additions of waters and bedding in housing. For solid manures, an estimated 20 % decrease in volume due to spontaneous composting and densing was included. Emissions were not taken into account.

Advantages and challenges of the existing system in Finland

Farm-specific manure analysis or table values are simple and understandable to all stakeholders, thus they are also widely accepted. The table values are based on a large dataset of analysed manures from all over the country. The large size of the dataset behind it adds to the reliability. Moreover, such a dataset would not be available without the legislative requirement for manure analyses minimum every five years. Farm-specific manure analysis increases the precision per farm as long as the farm practices stay relatively stable during the five years of one analysis being valid or the farm re-analyses the manure after larger changes.

Still, the table values are generalisations subjected to several errors. They are currently limited to only a few animal categories/groups and manure types (slurry/solid manure/urine of cattle, slurry/solid manure/urine of pig, solid manure of sheep, goat, horse, broiler, laying hen, turkey, mink and fox). More precise division into different animal categories and manure types is difficult as the samples are poorly identifiable. For example, naming the sample "poultry manure" does not determine which poultry is meant. Additionally, the quality of manure from different animals and different manure systems (slurry, dung and urine, farmyard manure, deep litter) may vary considerably. For example, "cattle slurry" neglects the differences in e.g. breeds, feeding and manure management between farms producing beef or dairy cattle. Practices within farms may also vary significantly in relation to e.g. water usage and bedding choice and amount. All in all, table values should be updated regularly to reflect the change in housing practices.

Farm-specific manure analysis may give a more precise result. Still, the chance of errors is significant due to several reasons, such as poor sampling of the heterogeneous material, errors in sample preparation and/or errors/variation in analysis methods. The latter has been noticed e.g. when comparing the datasets of two separate commercial laboratories in Finland.

The short-comings of the current system may lead to overfertilisation on some farms and underfertilisation on others, depending on the choice between analysis and table values and their representativeness of the actual farm-specific manure. The effects on farm economy and the environment also vary accordingly.

Moreover, there are noted inconsistencies in the the data provided by Finland (as also other EU member states) to European Commision as the system for e.g. excretion calculation has not been totally systematic and only some data has been made available.

National needs for developing the existing system in Finland

Due to the afore-mentioned challenges in the current Finnish system, Finland decided to develop a more precise and regularly updated normative system for provision of manure data. SYKE and Luke built a first version of the system during 2014-2016, funded by the Ministry of the Environment. At the time of writing, the system is being documented (Grönroos et al., 2016). The results of the system will be immediately used e.g. in agri-environmental indicators and emission inventories. The possibility to also base manure fertilisation plans and nutrient bookkeeping on the normative data will be discussed prior to the next Rural Development Programme period (2021->).

The system includes models for calculating quantity and quality for different manure types and many specific animal categories. The calculation starts from feeding and excretion and then proceeds to different housing systems and consideration of the emissions thereof as a mass balance (Figure 7). It provides manure data ex animal, ex housing and ex storage for 74 different animal categories in four manure types and considering different housing types.

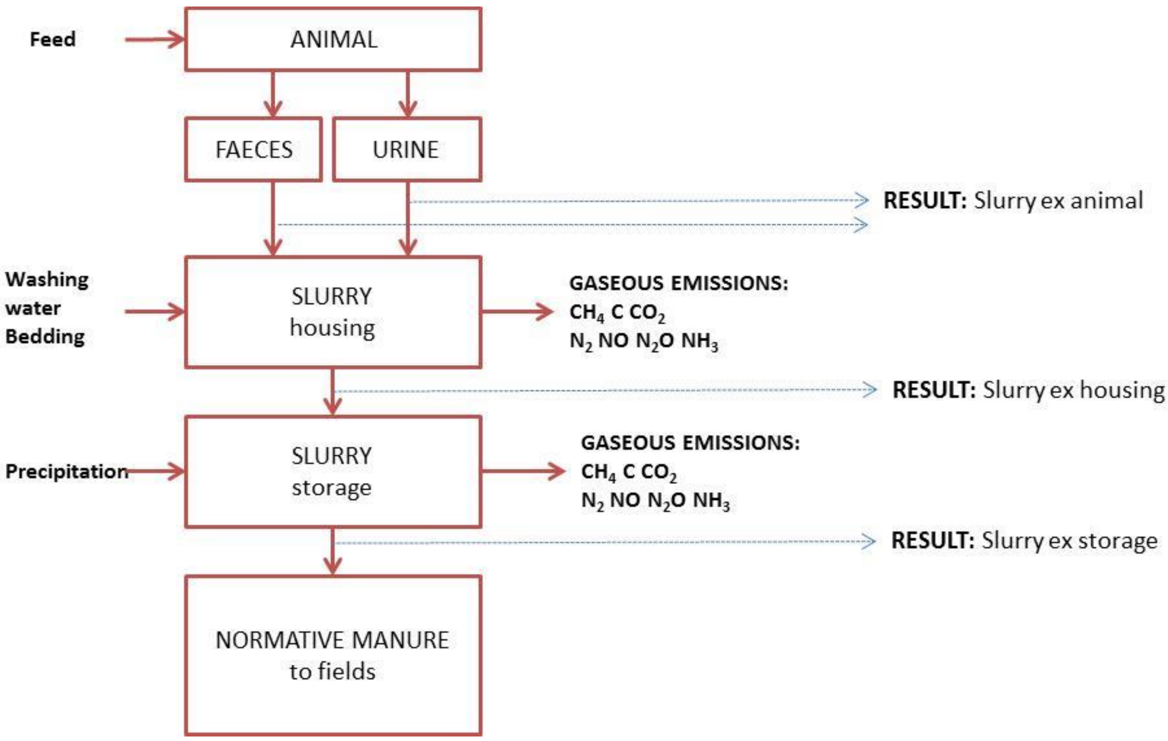

Figure 7. Slurry mass balance calculation as an example of the Finnish normative manure system.

The system is a large and complex model, but it can be developed to all manure types, specific animal categories and even a farm-specific tool. A successful normative manure system provides an equal basis for development and implementation of manure utilisation for all stakeholders. The system is documented and thus transparent, and regularly updated. The uniform basis for manure utilisation enhances the effectiveness of measures on different levels from policy making to practical farming.

Normative manure system may seem difficult to understand due to its complexity. Also, the result may not be quite the same as the old manure analysis of a specific farm. To make the system acceptable to all stakeholders, it should be created in co-operation and dialogue with them. Such cooperation has been started and will be continued as an integral part of system development.

Potential of developing and implementing a regional joint basis for an advanced nutrient standard system from the perspective of Finland

No joint protocol exists to normative manure systems, making them all unique and incomparable even if the underlying principles were mostly similar. A common baseline from which to define the national systems would assist significantly in making more comparable and uniform systems. Moreover, it would assist all relevant organisations involved in the national manure data provision to solve challenges in the practical sampling and analysis, in collection of the necessary background data and in the many formulas required in the complex models already available. Dialogue between different stakeholders would also ensure that the joint guidelines for manure data provision and the resulting manure data would reply to the needs of all stakeholders in the best possible manner.

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2.4. Germany

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The existing systems and practices in Germany

National standards for nutrient excretion of animal farms are usually derived by farmers from the German Fertilisation Ordinance (BMELV, 2007). However, the calculation does not proceed further to consider the manure management and the changes in manure during housing and storage.

The nutrient excretion is calculated on the basis of a mass balance approach. The exported N in animal products (nutrient retention by animal or in animal products) is subtracted from the nutrient intake by feed. The exact methodology is described in `Arbeiten der DLG, Band 199´ (DLG, 2005; 2014). An overview to the methodology is given in Table 3.

Table 3. Mass balance approach for calculation of nutrient excretions.

	Feedstuff A, kg * nutrient content (N = raw protein : 6.25, P, K)
+	Feedstuff B, kg * nutrient content (N = raw protein : 6.25, P, K)
=	**Feed nutrient intake (N, P, K)**
-	Mass increase, kg * nutrient content (N = raw protein : 6.25, P, K)
-	Milk, kg * nutrient content (N = raw protein : 6.25, P, K)
-	Eggs, kg * nutrient content (N = raw protein : 6.25, P, K
-	Wool, kg * nutrient content (N = raw protein : 6.25, P, K
=	**Nutrient excretion with faeces and urine (N, P, K)**

The preconditions for the mass balance calculation assume that the production methods are based on good agricultural practice. Furthermore, standard values for nutrient contents in animals and animal products as well as standard values for nutrient contents in feedstuffs are given in several spread sheets. Two examples for the calculation of the mass balance are given here for the animal groups `cattle´ and `poultry´ in the categories `poultry farming´ (Table 4) and `dairy farming´ (Table 5), respectively.

Table 4. Calculation of nutrient excretion in the sub-category `broilers´. Comparision of the two production methods `standard diet´ and `N-/P- reduced´ with a mast duration of more than 40 days and a growth rate of 2.2 kg gain/animal.

Production method **Efficiency** (2.2 kg gain/animal; 14.2 kg gain/animal place/year) **Feed expences** (kg/animal)		**Standard diet**			**N-/P- reduced**	
Starter		0.3			0.3	
Mast		2.8			2.8	
Final mast		1.1			1.1	
Mass balance (g/animal place/year): **Nutrients**	**N**	**P**	**K**	**N**	**P**	**K**
Input	984	181	227	918	154	227
Output (product)	515	74	29	515	74	29
Standard excretion	469	107	198	403	80	198

Table 5. Calculation of nutrient excretion in the sub-category `dairy production´. Comparision of the two production methods `grassland farm´ and `mixed farm´ at an efficiency level of 8000 kg energy corrected milk (ECM) each (assumption: output related to 4% fat and 3.4% protein plus 0.9 calves).

Production method **Efficiency** **Feed expenses** (per cow and year)		**Grassland farm** 8000 kg ECM			**Mixed farm** 8000 kg ECM		
Grass	t DM	1.6			1.0		
Grass silage	t DM	2.2			1.3		
Maize silage	t DM	0.7			2.2		
Straw	t DM	0.2			0.2		
Soybean meal	t	0.1			0.3		
Wheat	t	0.2			0.2		
MLF (18/3)	t	1.7			1.5		
MLF (16/3)	t	-			-		
Minerals	t	0.015			0.025		
Mass balance (kg/cow/year): **Nutrients**		**N**	**P**	**K**	**N**	**P**	**K**
Input		175.1	26.3	148.9	161.3	25.6	125.7
Output (product)		43.4	8.2	12.1	43.4	8.2	12.1
Standard excretion		131.7	18.1	136.8	117.9	17.4	113.6

Advantages and challenges of the existing systems at the national level in Germany

The national standards for nutrient excretion of animal farms in Germany are well documented in DLG (2014) and officially published in the annexes of the German Fertiliser Ordinance (BMELV, 2007). These figures are obligatory for all farmers as long as the nutrient contents in animal manure are not

a) known to the stakeholder by virtue of prescribed labeling,
b) calculated by the stakeholder based on data obtained from the competent authority designed by Länder law and
c) calculated by the stakeholder or its agent using scientifically recognised analysing techniques.

The official nutrient standards in the annexes of the German Fertiliser Ordinance and the nutrient standards which are regularly updated and published by specialised authorities of lower administration level designed by Länder law, are well accepted by stakeholders. The methodology and the standard values published by DLG are updated at irregular intervals in order to keep up with the changes in animal production systems (feeding, yield etc.).

National needs for developing the existing system in Germany

The existing national system has to be considered as solid and usable, as it has been introduced several years ago and is already well accepted by all stakeholders. It has been further developed and updated at irregular intervals by national expert groups. A further development of the national system is envisaged and will be discussed in various national expert panels.

Potential of developing and implementing a regional joint basis for an advanced nutrient standards system from the perspective of Germany

As the methodology for the calculation of national standards for nutrient excretion in Germany is well-established and scientifically recognised, it could be a basis for the development and implementation of joint Baltic standards and guidelines.

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2.5. Latvia

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The existing systems and practices in Latvia

The table of amount (quantity) and quality of livestock manure of different species is included in the Latvian Regulation Regarding Protection of Water and Soil from Pollution with Nitrates Caused by Agricultural Activity (adopted on 23 December 2014). The data on 18 livestock species are included in this Regulation. The data on 12 animal species (dairy cow, suckling cow with a calf, young fattening cattle, piglets, sow with piglets, pig for fattening, goat with kids, sheep with lambs, horse, laying hen, broiler, deer) were revised based on the results of scientific research. The data on other six animal species were obtained from published research or literature. The amount of manure and its nutrient (NPK) content is laid down for solid manure and liquid manure (slurry), separately.

The scientific research project "Improvement of manure standards and specification of animal units" was implemented from 2007 till 2009. The specification of manure quality and quantity produced by different livestock species was developed on basis of scientific methodology (Establishment of Criteria for the Assessment of the Nitrogen Content of Animal manures. European Commission, Final Report November 1999) and on basis of the data on livestock feeding, livestock housing system and productivity (N manure = N diet – N animal products – N losses from buildings and manure storage and grazing, where N diet is product of feed consumption and N content of the diet). The manure standards were calculated on basis of data on feed intake, productivity level, bedding type, housing system and manure handling.

The manure samples for chemical investigation were applied in accordance with methodology of international standards. They were analysed for DM (dry matter), total –N, NH_4 – N, pH, P, K, Mg, Ca and organic matter. Feed samples were also analysed for chemical composition (DM, total –N, NH_4 – N, P, K and total protein). The results obtained in accordance with EC methodology were compared with the results of manure chemical content (manure analyses).

The manure standards are used in Latvia by:

1. farmers (e.g. preparation of fertilisation plan, fulfilment of requirement of Nitrate Directive of the amount of livestock manure applied to the land each year per hectare containing 170 kg N, calculation of animal density, in nutrient bookkeeping);
2. ministries as well as other state (governmental) organisations (e.g. elaboration of national regulations, establishing requirements for agricultural activities, calculating the GHG emissions, granting the aid in the framework of Rural Development Plan, granting permissions for constructing and reconstructing of animal houses and manure storage facility);
3. controlling authorities (e.g. control of the rate of manure application, fertilisation plans, balanced fertilisation, capacity of manure storage, animal density);
4. advisory services;
5. constructors of manure storages (calculation of storage capacity).

Advantages and challenges of the existing systems at the national level in Latvia

Upon including manure standards in Regulation, the data on manure quality and quantity became obligatory for farmers, authorities and other stakeholders. This approach makes carrying out of economic activities easier for above mentioned and especially for operators in agricultural sector. An individual farmer can no longer take own manure samples and have them analysed in any laboratory. The choice is between the standards in the Regulation or manure sampling by an official sampler authorised by an accredited certification institution and the analysis performed by an accredited laboratory.

Regular revision of manure standards is necessary because there are structural changes taking place in the agricultural sector. Also changes in livestock feeding strategy, increasing livestock productivity, new technologies in manure management and some other factors need to be regularly updated as they influence manure quantity andquality. The farmers (especially pig breeders) and advisory service also would like to revise the national standards, especially the amount of manure produced and its nitrogen content.

Further, it must be noted that currently much attention is being paid to the measures reducing emissions from agricultural activities that can be achieved by improving manure management, altering animal feeding patterns and applying new technologies in manure management and use.

National needs for developing the existing system in Latvia

As mentioned above, improvement of manure standards and specification of data is very important. The Ministry of Agriculture and institutions under the responsibility of the Ministry are ready to improve the system, but we need to take into account that implementation of such scientific research projects require considerable financial resources as the totality of analysis carried out is an essentially important part of the project. They should be performed thoroughly to receive valid results. The time interval for revision and for which livestock groups should be determined via evaluation the changes in the livestock sector.

Potential of developing and implementing a regional joint basis for an advanced nutrient standards system from the perspective of Latvia

Latvia hopes that potential harmonisation of manure standards/guidelines will facilitate implementation of the principles of Best Agricultural Practice for every Baltic Sea country and the entire region. Joint efforts, experience, laboratory and research capacity will produce a better result. The problem is the same for every country and there is no great differences in the area of concern. Upon working together, the final result will be more advantageous, sophisticated and useful and also a possibility to compare the performance of every country will be greater as compared with situation when every country has different standards and guidelines. The Baltic Sea countries have much in common despite geography, and regional differences (if any) can most likely be taken into account. Technically, the advantage is to take into account larger data sets for developing standard figures and greater possibilities for validation procedures.

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2.6. Poland

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The existing systems and practices in Poland

The first elements of the natural fertiliser control and application system in Poland were set out in 2004, directly related to Poland's accession to the European Union. The elements of the system were constituted naturally, within the framework of the tasks, and currently the structure of the system is not fully closed and its nature is dispersed. The modus operandi of the system is based on two pillars (Figure 8). The first pillar comprises legal acts and control mechanisms for their implementation. Since the nutrient issues are placed at the border between agriculture and environmental protection, these acts and the control are carried out by the departments of Agriculture and Environment.

As regards the Ministry of Environment, at this moment in time the Ministry itself, the National Water Management Authority, the Regional Water Management Authority and the Provincial Inspectorate for Environmental Protection are involved in the work. The structures of the Ministry of Environment also include the National Centre for Emissions Management, acting as the national administrator, estimating the total dispersion of nitrogen compounds from agriculture. As for the Department of Agriculture, the Ministry of Agriculture and Rural Development as well as the National Chemical and Agricultural Station with Regional Stations are involved in the work. Scientific research of the research institutes from both ministries as well as the Agricultural Advisory Centre is considered the second pillar.

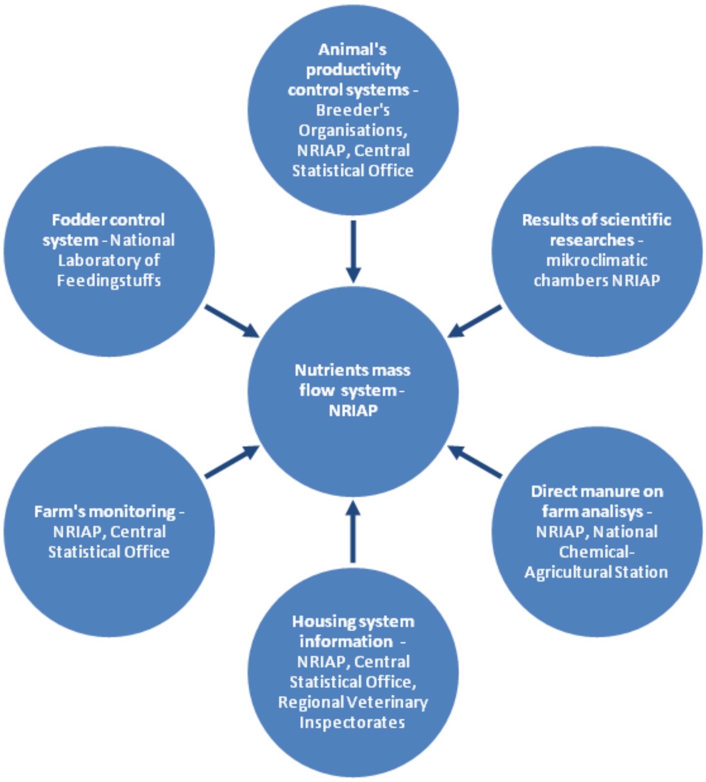

Figure 8. Structure of database sources in NRIAP nutrient mass flow system.

History

The issues of environmental protection, including water quality, substantially gained in importance starting from the political transformation in 1989, and became one of the leading elements of Polish policy. Earlier, the issues related to fertilising were important especially for the production, by influencing crop quantity and quality, soil quality and organic life. However, since the 1970s, when the gradual development of industrial agricultural production in Poland started, the impact of fertilisation on water quality appeared in legal regulations. The Journal of Laws of 1974 No. 38, item 230 introduced the Water Law and first limitations in this regard. However, food security was a priority of the dynamically developing country at the time and the issues of natural environment quality remained in the background. Agriculture had a marginal influence on water quality and the dynamically developing industry and power production were much more important.

In 1980s, the development as well as the increasing scale and concentration of industrial production turned the spotlight on agriculture. A wide range of industry standards, regulating natural fertiliser use, have been introduced to animal breeding. After 1990, these standards lost their legal force and the introduction of new regulations was necessary. Initially, they were scattered across different acts, including e.g. the Construction Law (1994) or the Regulation of the Ministry of Agriculture and Rural Development (1997) on the technical conditions and location for agricultural facilities. Also the amended Water Law and the Nature Conservation Act attempted to regulate only the basic issues of environmental meaning. Only in 2000, the Act on Fertilisers and Fertilisation was adopted (Journal of Laws of 2000 No. 89, item 991) which, for the first time, in detail, but not exhaustively, regulated the issues of the use of natural fertilisers. Whereas, in 2003, the first areas at risk of pollution from agricultural sources (Nitrogen Vulnerable Zones NVZ) were identified in Poland.

So far, two vital changes of the existing elements of the system have been introduced in Poland. The first one was the Regulation of the Council of Ministers of 18 January 2005 on the detailed conditions and procedure of granting financial assistance for the adaptation of farms to EU standards covered by the Rural Development Plan (Journal of Laws No. 17, item 142) that was implemented due to Poland's accession to the European Union. The second one was introduced in 2013 and involved amending standards due to changes in production methods that occurred in 2002-2012.

Current situation

Currently in Poland there is a legally regulated measure to determine the natural fertiliser storage areas and techniques, which is available in the form of tables and formulae for the calculation of admissible doses for the individual farm. These quantities and recommendations are calculated for individual farms according to the number of animals and the size of the utilised agricultural area. Admissible dose of nitrogen in natural fertilisers currently stands at 170 kg N/ha, however, for various voluntary RDPs (Rural Development Programmes) the dose may be lower. For instance, for the integrated farming, in arable land it is 150 kg N/ha and on permanent pasture areas – 120 kg N/ha. Moreover, double limits were introduced for farms located within the high risk areas: obligatory fertilising plans for farms over 100 ha and nitrogen limits for natural and mineral fertilisers (from all sources) dependant on the type of crop – for farms under 100 ha.

Natural fertiliser application control is carried out by the Services of Inspectorate Protection (Figure 9). Under the Act on Fertilisers and Fertilisation, fertilising plans are controlled on those farms which should owe the plan, and is carried out by the Environmental Protection Inspectorate services. As for the IED farms (Industrial Emissions Directive), lack of documentation may be subject to verification carried out by the Voivodeship Inspectorate for Environmental Protection. In case the farmer does not have a positively approved fertilising plan, the Inspectorate issues the decision to suspend the husbandry or breeding of animals. Producers, who are the purchasers of natural fertilisers and do not have positively approved fertilising plans, or apply the fertilisers contrary to the plan, are liable to a fine. Nitrate Directive Action Programmes: monitoring of agricultural pollution and the obligations of agricultural activity in the NVZs shall be carried out by the Voivodeship Environmental Protection inspectors in line with Article 32 of the Act on Fertilisers and Fertilisation.

Scientific support and advice is carried out by scientific institutes: e.g. Institute of Soil Science and Plant Cultivation – National Research Institute and the Institute of Technology and Life Sciences as well as the Agricultural Advisory Centre.

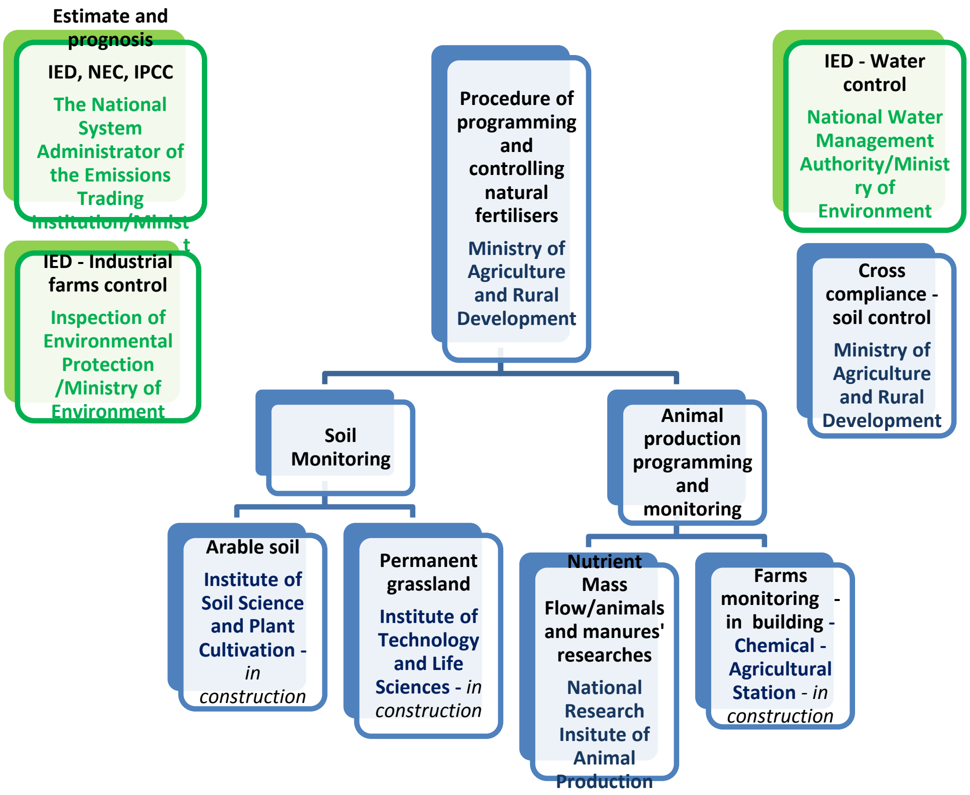

Figure 9. System of programming and controlling natural fertilisers in Poland.

In simple terms, the admissible nitrogen dose per a farm's unit area is calculated based on common standards, by means of calculation of the nitrogen load from the product of the number of animals, annual fertiliser production and nitrogen concentration in fertiliser unit. The result is divided by the area of fertilised land (Equation 4.

Equation 4 Method of fertiliser dose calculation:

$$\text{Fertiliser dose (N kg/ha)} = \frac{\text{Number of animals x fertiliser production per animal x N concentration in fertiliser unit}}{\text{Total UUA}}$$

For the purposes of the above formula, the farmer must document the number of animals owned during the year, within individual technological groups, as well as the UAA. All production factors, N concentration, as well as methods of calculating the animal number, can be found in the official documents. The latter ones are determined on the basis of the results of scientific research and data from production practice monitoring.

Nutrient mass flow methods in practice

Animal nutrition, carbon, nitrogen and phosphorus retention capacity of the organisms, disposal of animal products (milk, eggs, meat) as well as the loss of plant nutrients during storage are the starting point for standardisation of the quality and quantity of natural fertilisers. This method is in line with the commonly adopted nutrient mass flow model (Figure 10). Acquisition of representative data regarding the national livestock production is the key issue and in Poland a database especially designed by the National Research Institute of Animal Production is available, using many independent monitoring sources. Therefore, those are not theoretical values, based on formulas and coefficients, but actual farm data, based on the monitoring of Polish livestock production.

Information regarding the animal nutrition is crucial in order to determine the quantity and concentration of natural fertiliser. In Poland, the demand for protein, energy, calcium, phosphorus and other micro- and macro-elements as well as their concentrations in animal feed are regulated by Animal Nutrition Standards, separately for ruminants (National Research Institute of Animal Production – INRA) and other animals (Polish Academy of Sciences - Jabłonna). These standards are mandatory in line with the "feed and food law" (the Feeding stuffs Act of 22 July 2006, Journal of Laws of 2006 No. 144, item 1045 as amended), as well as the Act of 21 August 1997 on animal protection (Journal of Laws of 2003 No. 106, item 1002) Animal Nutrition Standards apply to the welfare needs of animals as well as production. They are compatible with the DLG and INRA standards.

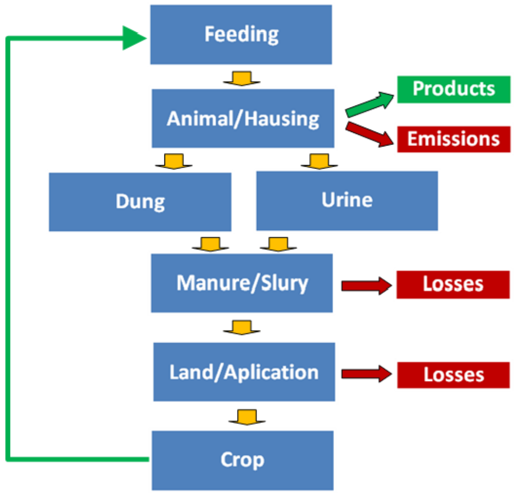

Figure 10. The nutrient mass flow principle followed in Polish manure data provision.

Information regarding animal nutrition and technological group standards is modified by the data from the national animal feed and feed material control monitoring via the Fodder control system, run by the National Laboratory for Feeding stuffs in Lublin. This is the source of information regarding the protein and energy content in Polish feedstuff as well as the nutritional compositions.

Nutrition information are modified according to data regarding the productivity of individual livestock species, collected from the national livestock control and productivity systems run by animal breeding associations.

Background information on animals

As for species which do not have specified systems of productivity control, the productivity data are collected from the up-to-date database of the National Statistical Office and National Research Institute of Animal Production direct monitoring. The latter applies to the maintenance systems as well as the analysis of the natural fertiliser content. At the same time, since 1961, a database regarding the evaluation of livestock productivity control, based on the monitoring of a representative population in livestock production farms, is held by the National Research Institute of Animal Production. Their documents regarding the NPK content of natural fertilisers originating from livestock are based on the population of 1080 cows, 1800 pigs, 3000 laying hens, 7000 chickens for fattening, 400 sheep, 250 horses, 200 goats, 100 ducks, 200 turkeys and 3500 farmed foxes, minks, raccoon dogs, and rabbits annually. The livestock manure, following prior content analysis, are collected in prisms or containers of 5 tonnes capacity and, in line with the applicable law, stored for 4 or 6 months (on NVZ). During the storage period, averaged samples are collected for content analyses and the emissions of volatile compounds are measured. The quality analyses include the determination of dry mass content, pH, crude ash, organic substance, specific weigh, nitrogen, phosphorus, potassium and carbon. The results undergo statistical analysis by the single variant method, using software, Lotus, Statgraph and Statistica. Based on the analysis of collected data, the quantities of natural fertiliser produced annually for each technological group of livestock species, the NPK concentration per unit mass and volume of natural fertilisers from deep litter, shallow litter, and litter-less systems are drawn up.

Consideration of emissions

Scientific research is the important issue affecting determination of the volume of gaseous losses from animal breeding and natural fertiliser storage. Because of the complicated measuring equipment and the need of continuous measurement, unlike the fertiliser content analysis, the emissions must be determined by means of scientific research. This applies to the NH_3 and NO_x emissions from livestock buildings as well as fertiliser storage areas. However, as regards nutrition and animal feed, only textbook emission factors are taken into account, for the purposes of fertiliser content analysis or atmospheric pollution, this method is rather vague. Such elements as livestock density in the buildings, temperature, maintenance system, air exchange and movement affect the emissions significantly. Therefore, in the National Research Institute of Animal Production, micro-climate chambers with fully regulated micro climate and air flow, with continuous air composition measurement, are used the purposes of volatile emission evaluation. As regards the natural fertilisers, in field experiments, aerodynamic tunnel method is used, also with regulated air flow and measurements, using portable equipment. The obtained results undergo statistical analysis and are included in the natural fertiliser control and application system, as a loss index in the nutrient mass flow method. The aerodynamic tunnel method is also used at the National Research Institute of Animal Production to test emissions from soil application of natural fertilisers.

Livestock Unit

The natural fertiliser control and application system also specifies the method of calculating the necessary sizes of manure boards, slurry and liquid manure containers. For the first step of calculations, all animals in the farm must be brought to a common denominator, such as the DJP index. This is an official index set up for each technological group and correspond to the European Livestock Unit (Großvieheinheiten – GVB, la Unitat de Bestiar Gros – UBG, Unité-Gros-Bétail – UGB). Subsequently, by multiplying the DJP value by the calculated surface or volume index and specifying the pasture time (A) and the specific maintenance and equipment system indicator, we obtain the size of an individual farm's storage area. The above listed indicators are drawn up by the National Research Institute of Animal Production, based on the results of farm monitoring, and they take into account the character of the production, including e.g. the volume of the manure remaining on the pasture, the number of days the animals remain on the pasture, the precipitation levels affecting the capacity of containers, covering the manure storage containers and boards, manure volume changes caused by drying and many more.

Soil and plant nutritional needs

In Poland, the concentration of plant nutrients and changes during natural fertiliser storage are subject to numerous scientific studies. Scientific work carried out by universities and polytechnic institutes are short-term and focused on the development of innovative solutions in the field of genetics, animal and plant breeding, biotechnology, animal nutrition, fertiliser processing methods – including the co-generation of energy, soil fertilising and treatment methods. Scientific institutes to the Ministry of Agriculture and Rural Development also carry out research in this field, however, to a large extent, they focus on long-term research of phenomena and processes constantly present in agriculture. In Poland, since 1997, the mineral nitrogen content in soils is monitored, within the framework of the Nitrates Directive (Figure 11). The programme was initially implemented in 700 control farms within a task assigned to the Institute of Soil Science and Plant Cultivation in Puławy by the Ministry of Agriculture and Rural Development, and since 2000 as a task carried out by the National Chemical and Agricultural Station, in line with the Act on Fertilisers and Fertilisation. In 2007 new monitoring points were designated in order to evenly cover the country, and additional research of basic indicators of chemical fertility of the soil, including phosphorus, potassium, and magnesium, was carried out. The monitoring network was arranged in such a way that at least one point was located in each municipality, and in municipalities with stocking density higher than average – two or three points. Currently, samples are collected from approximately 4 000 points with defined geographical coordinates, located on arable land. In each point the soil is tested twice a year: in early spring and in autumn. The analyses are carried out by Regional Chemical and Agricultural Stations and the results are collected in databases. Results of the analyses are processed by the Institute of Soil Science and Plant Cultivation – National Research Institute. In order to include the monitoring of mineral nitrogen content in Polish soils into the planned Polish natural fertiliser management system, it should be expanded by questionnaires addressed to the sampled farm owners. The questionnaire should allow to collect following the information:

- the type, dose and time of applied mineral, organic and natural fertilisers
- stocking density
- other information.

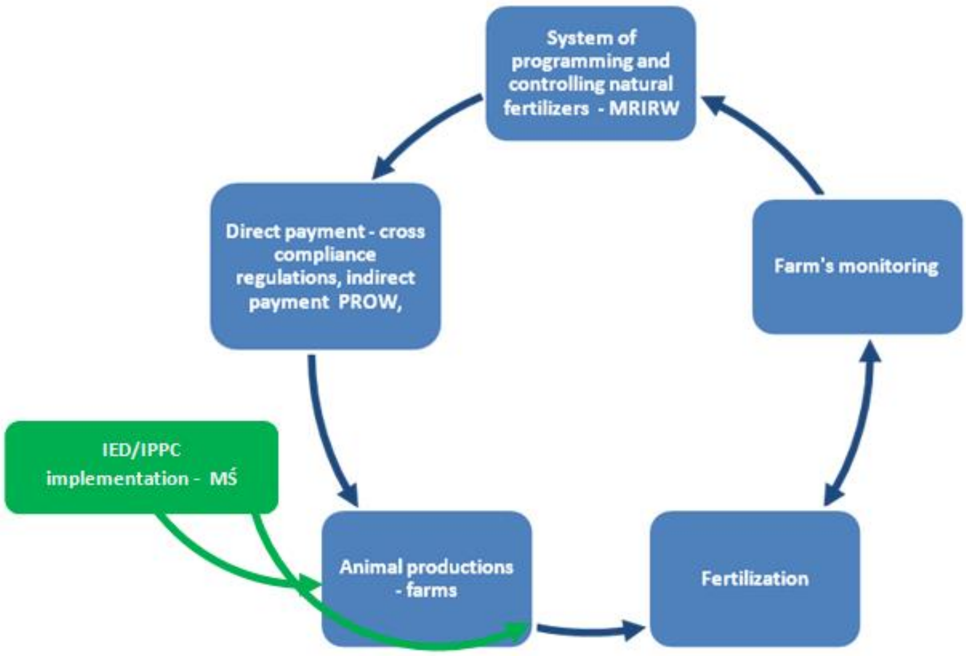

Figure 11. Functional scheme of natural fertiliser regulation and application in Poland.

Advantages and challenges of the existing systems at the national level in Poland

The currently existing elements of the Polish system are combined with area payments, being a condition for adapting farms to EU standards which, in turn, was a conditio sine qua non for applying for payment. Over the next 9 years of operation, regulations governing the individual elements of the system were enhanced by the additional legislation of the Ministry of Environment and the Ministry of Agriculture and Rural Development. Among other things, the NVZ and Best Available Techniques BAT were introduced. A significant increase in the importance of individual elements of the system associated with the introduction of mechanisms to control that system on farms and further promotion were related to the introduction of minimum environmental protection cross-compliance requirements in 2009. In this context, there was a lively debate in the country, but on the merits of changing the current nature of payments. Assumptions of the fertiliser control and application system, which were already known to farmers, did not prove controversial. Only the threat of having payments reduced or lost due to failure to meet natural fertiliser requirements met with negative feedback and was regarded as too drastic.

At present, the production standardisation system raises no reservations. It is easy to implement and understandable to farmers. The undeniable benefits of a more consistent fertiliser control and application system should include bringing fertilisation in domestic animal production to order. Over the last decade, the production, storage and application of natural fertilisers have become one of the most important farm organisation elements. In terms of significance, breeders place them on an equal footing with the production performance achieved and their economic viability. Undoubtedly, that perception of environmental protection is a measure of a huge breakthrough that has been made in the minds of farmers over the last 10 years. That approach also proves the operation of the system itself successful. Breaking its rules is now seen also as an image-related issue, not only in market but also social terms, particularly at the level of even small local communities. Also consumers' positive pressure, for whom the existing fertiliser control and application system is a guarantee of quality, but also a weapon to enforce own expectations, is not insignificant at this point.

National needs for developing the existing system in Poland

The existing elements of the national system have proven themselves successful over the last decade of operation and they are recognized both at the administrative level as well as directly by farmers and other individuals and institutions that operate in agriculture- and environment-related areas. Large farms adapted to its requirements, treating them as new production conditions. Of course, the awareness of breeders differs, thus affecting their attitude to the existing system. As in any business, environmental protection issues are considered as an additional category of capital and operating costs that makes production more expensive and reduces profits. On the other hand, however, the risk of image-related losses poses the same threat to profits made in such a market situation. Hence, the existing system is acceptable and stable. However, any change in that system is the object of a discussion between the government and farmers. Nevertheless, assumptions behind those changes are not its subject, but rather their impact on farm investments and additional expenditures to comply with procedures. That process is typical of any democratic structure in which the level of awareness and the time necessary to adapt to new regulations are most important.

Despite ongoing work to establish a national system, it should be inherently assumed that the system is to be continuously developed in the future not only to meet evolving needs, but also for the sole purpose of improvement. Changes should involve the clarification of norms and taking account of different on-farm conditions as well as adaptation to the development of agricultural technologies, the scale and concentration of production.

Changes in clarifying the norms are aimed at determining actual environmental threats on each farm in the most equitable manner. An ideal model provides for identifying the quality and quantity of natural fertilisers and the way they are applied for each farm separately which is impossible for technical and financial reasons. Hence, standards are averaged and methods unified under the existing system for the purpose of production in general. In the future, the system should apply to many groups in order to respond to needs more accurately but, at the same time, not to lose its transparent form and ease of application, in particular for control mechanisms. An example of this in the national system was grouping horses by species into small and large ones. Dairy cows were divided by milk yield into 3 groups. Furthermore, the range of species was extended to include animals which had not been previously bred in Poland (e.g. ostriches, fallow deer, deer).

Changes in the adaptation of the system to on-farm conditions are due to the fact that Poland ranks second in the number of farms in the European Union (1.9 million farms), right after Romania.

Such a large number of farms means that their production methods are very diverse and differ in intensity, so are natural and soil conditions as well as their production size, scale and concentration. The growing season in Poland lasts from 150 to 220 days, while in both areas agricultural production is pursued. The average annual temperature in utilised agricultural areas varies from 8.0 to 6.3°C and annual rainfall – from 500 to 1 300 mm. There are as many as 9 quality classes of arable land, most of which is medium- and low-quality land. In Poland, depressions, lowlands and mountain areas are used for agricultural purposes. Taking more account of the specificity of natural conditions in the natural fertiliser control and application system is in line with producers' expectations and contributes to equalising opportunities and tackling inequalities. The system can also be changed in the future by applying guidelines to e.g. differentiate the handling of natural fertilisers depending on the length of the growing season, the climate zone, but also location in relation to rivers and lakes as well as topography. The guidelines could also refer to the technical parameters of installations to store fertilisers only and even to animal maintenance and feeding systems. The guidelines could make the level of fertilisation adapted to the type of soil and even to a crop species and the time of application (fertiliser equivalents).

Technological progress in agriculture needs to be taken into account so that the planned/designed natural fertiliser control and application system could function properly. After 10 years of having the Polish system in operation, some of its elements were amended in 2013. The changes introduced were found legitimate in view of genetic progress – animal yield growth, progress in animal maintenance systems, new techniques for removing, storing and applying fertilisers. Nevertheless, technological progress should also be considered as positive, wherever such solutions reduce pressure of agriculture on the environment. Slurry separation, multi-phase feeding, tightly covered reservoirs, lower protein content in feed, slurry application to deeper soil layers are exemplary solutions to be promoted in the system through properly established norms.

The planned system should also be developed as regards its structure. The most urgent need in this regard seems to be getting clear and fast feedback from the area covered by the system on whether its operation is effective. That feedback should also indicate some changes or even trends taking place in homogeneous farm groups. In addition to currently applicable procedures for applying natural fertilisers, it seems therefore necessary to monitor domestic farms as well. Mostly information on the quality and quantity of fertilisers produced as well as conditions for storing natural fertilisers, as elements influencing environmental impacts of applying NPK fertilisers, should be monitored. The next step may be soil analysis for nutrient content and forms and even obtaining data on the specificity and nature of production of facilities under monitoring. Of course, achieving a methodical monitoring system is a huge problem, as it should correspond to different production profiles and methods, various locations and even production scales. It seems that only such a system that makes use of monitoring data on own operation is capable of self-development and improvement.

Summary and conclusions

The elements of the natural fertiliser control and application system in operation in Poland are based on the so-called nutrient mass flow and remain completely compatible with systems in force in other countries (Germany, UK, France, Austria etc.). However, there are certain factors which make it different from those systems because of the nature of Polish agriculture – a more extensive level of production – native breeds, animal bedding used commonly, lower milk and egg yield as well as animal body weight gains. It seems that the same method (nutrient mass flow) should be adopted for the Baltic Sea area as a whole, but it should be made possible to reflect the specificity of numerous national conditions. A similar principle applies to estimating emissions as regards NEC or IPCC. It is currently hard to determine whether such an extensive system will be transparent enough and easy to apply.

The greatest opportunities for unifying the control and application of natural fertilisers should be sought for industrial farms (covered by the IED) that, throughout the European Union, apply the same methods, breed genetically very similar animals and feed them much the same way. Such unification would be compatible with CAP objectives for equalising production competitiveness conditions in the EU Member States, but it would apply to one country only. In this context, even large farms from the Baltic States could become less competitive to their counterparts in Belgium, the Netherlands or France. Furthermore, as for medium- and, particularly, small-sized farms which are declared to be of particular concern to the CAP under the current perspective, unification can provoke negative reactions. Their sustainable development is based heavily on local conditions and resources which differ significantly even in the Baltic Sea area.

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2.7. Russia

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The existing systems and practices in Russia

Manure of cattle and pigs and poultry can be an important, and sometimes the only source of nutrients for soil to provide mineral nutrition of crops. At the same time, they can pose a risk of pollution of natural ecosystems and water sources by nitrogen and phosphorus compounds. Information about the exact content of the nutrients in the manure is necessary for the preparation and use of an objective balance of nutrients on the animal building and in the farm, and to prepare the proper manure management scheme and then calculate its fertiliser doses for field crops.

Under ideal conditions, it can be assumed that for healthy organism which ended the growth, the amount of nitrogen in food from one side and nitrogen in faeces, urine, and products in gaseous form, from another is usually the same, and this is called the nitrogen equilibrium. However, in real terms, the ratio of entering the body of farm animals/poultry amounts of nitrogen and phosphorus, and emerged from it formed a more complicated way. Therefore, the determination of these elements in the livestock waste is an important prerequisite for the proper management of flows of nutrients on the farm.

Currently a number of methods of chemical analysis for the determination of total nitrogen and phosphorus in organic samples have been developed. In Russia, the following methods for determining the content of nitrogen and phosphorus in manure are officially recommended for use:

1. Organic fertilisers. Methods for determination of total nitrogen, State Standard 26715-85.
   a) Total nitrogen determined by the Kjeldahl method on installations of varying complexity;
   b) Total nitrogen is determined photometrically after wet ashing of the sample similar to Kjeldahl method. Measured absorbance of indophenol compound formed in alkaline medium at interaction of ammonia with a hypochlorite and sodium salicylate.
2. Organic fertilisers. Method for determination of total phosphorus.
   The sample is ashed similar to the Kjeldahl method. Then the absorbance of phosphomolybdic complex recovered ascorbic acid in the presence of antimony catalyst is measured.

Agricultural companies generally do not use the determination methods of nutrients measurement in manure because of complexity of the analysis without the special laboratory. For practical purposes, an average value of manure nutrient content is showed in various reference manuals. Regional centres of the Russian agrochemical service can conduct analyses of organic fertilisers if they receive orders.

More popular is the document RD-APC 1.10.15.02-08 “Guidelines for the Technological design of removal systems and preparation for the use of manure" [1], which is used for different purposes. The document was developed by a group of leading agricultural research institutions in Russia and approved by A.V. Petrikova, the State Secretary - Deputy Minister of Agriculture of the Russian Federation on April 29, 2008. It replaced a similar document approved in 1999. The document is intended for use in the design of newly constructed and reconstructed enterprises for cattle, pig and poultry farms. It contains a large number of different information related to the disposal of manure or litter, so the advantage is an integrated approach. The document describes the following methods for handling of manure:

- Methods of removing the manure/litter from places of livestock/poultry and transportation;
- Methods of composting manure and manure to produce compost;
- Methods of separation of manure into fractions, followed by composting;
- Methods of anaerobic treatment (biogas);
- Methods of biological treatment of the liquid fraction of manure and liquid manure;
- Methods of storing manure/litter;
- Methods of using organic fertilisers

The document also contains information on standards of output and characteristics of manure (the estimated average daily amount of manure and its moisture from one animal of different gender and age groups), shows the average nutrient content (Table 6).

Table 6. Nutrient content of manure and its fractions in Russia as documented in the "Guidelines for the Technological design of removal systems and preparation for the use of manure" (RD-APC 1.10.15.02-08).

Title	**Nutrient content in dry matter, %**		
	Total Nitrogen (N)	**Total Phosphorus (P)**	**Total Potassium (K)**
1. Pig manure:			
Total	6.0	1.42	2.08
- in liquid fraction	3.3	0.14	1.04
- in solid fraction	2.7	1.28	1.04
2. Cattle manure:			
Total	3.2	1.28	4.15
- in liquid fraction	1.28	0.80	3.53
- in solid fraction	1.92	0.02	0.62
3. Poultry manure with litter	6.2	0.78	1.74
4. Poultry manure without litter	3.6	1.56	1.66

Advantages and challenges of the existing systems at the national level in Russia

There are two most relevant problems of the Russian reference data in the "Guidelines for the Technological design of removal systems and preparation for the use of manure" (RD-APC 1.10.15.02-08): insufficient data updating and strong averaged data. Insufficient levels of mainstreaming means too rare updating of the documents - the latest version of the document was published in 2008, the previous version in 1999. Strong averaged data means that the actual data is often very different and have great variability caused by significant differences of climatic conditions at the location of agriculture and applied technologies, feeding, etc.

Table 7 presents data on the content of nutrients in the manure of cattle and pigs, and in poultry litter presented by the RD-APC 1.10.15.02-08 and received in the analytical laboratory IEEP. The samples for analysis were collected from farms of the Leningrad Region. The presented results demonstrate a significant difference in the content of nitrogen and phosphorus contained in RD-APC 1.10.15.02-08 and received from the agricultural enterprises of the Leningrad region.

Table 7. Comparative evaluation of the nutrient content of manure in the “Guidelines for the Technological design of removal systems and preparation for the use of manure" (RD-APC 1.10.15.02-08) and as sampled on farms in the Leningrad Region, Russia.

Type of manure	Information sources	Nutrients content in dry matter, %	
		Total Nitrogen (N)	Total Phosphorus (P)
Cattle manure	RD-APC 1.10.15.02-08	3.2	0.80
	Data of IEEP	2.9	0.77
Pig manure	RD-APC 1.10.15.02-08	6.0	1.42
	Data of IEEP	4.77	1.47
Poultry manure	RD-APC 1.10.15.02-08	6.3	1.56
	Data of IEEP	4.38	0.62

Table 8 presents a number of statistical characteristics of the sample based on the results of analyzes carried out in nitrogen and phosphorus in the cattle manure. Attention is drawn to the very high variability of nitrogen in manure. Although the average value of the index is close to the values given in RD-APC 1.10.15.02-08, the magnitude varying nitrogen content reaches 3.77%. The phosphorus content in the manure of cattle is a more stable figure, albeit in this case, the coefficient of variation is 19%.

Table 8. Statistical analysis of data on the nutrient content of cattle manure (% of dry matter) as sampled on cattle farms in the Leningrad Region, Russia.

Nutrient content in cattle manure	Average	Median	Scope of fluctuations	Dispersion
Nitrogen	2.93	3.30	1.41 – 5.18	1.50
Phosphorus	0.77	0.81	0.41 – 1.18	0.15

The reasons for the significant fluctuations in manure nutrient content are also varied. It is obvious that in recent years significant differences in the technologies of cattle production and their feeding in the agricultural enterprises have been noted. Also, a significant variability in the productivity of cows in the area has been noted. And all this, apparently, is reflected in the variability of the nutrient content in manure.

Also, to establish the on-farm control system over the treatment of such material as animal and poultry manure, the farms need to have special manure handling plans. According to the legislation of the Russian Federation such plans are developed and approved for particular farms; then they obtain the status of a regulatory legal act and are called “Enterprise Standard. Technological Regulations for Environmentally Sound Animal and Poultry Manure Processing and Fertilising Application”.
Regulations is a document, which describes the conditions and sequence of the Technological process of animal/poultry manure processing into an organic fertiliser, resulting in environmentally safe product with the quality indices, which comply with the requirements of approved standards or technical specifications. This document also describes how to secure the work safety and to achieve

the optimal technical and economic production indices on a particular farm. The main parts of Technological Regulations are as follows:

- Introduction (The purpose and legal status of Technological Regulations),
- General description of production process,
- Background information on the farm: legal and location addresses, banking details, number of production sites and auxiliary facilities, principal and supporting activities, land area and its structure, available technical equipment,
- Description of raw materials and end products,
- Description of manure removal process,
- Description of manure processing,
- Description of Technological operations of animal/poultry manure processing into an organic fertiliser and production conditions,
- Standards (guidelines) of Technological process,
- The algorithm of engineering simulation of production, transportation, storing and application of organic fertilisers, required equipment and time profile,
- Ecological monitoring and control of the Technological process,
- Activities to perform ecological monitoring and control (list of registers, sampling places and procedures),
- Production safety,
- Requirements to work safety of the production process,
- Environmental requirements,
- Measures and requirements of environmental safety of the production process,
- List of regulatory and technical documents,
- Regulatory and technical documents, based on which the Technological Regulations were developed,
- Action Plan of farm environmental service to carry out ecological monitoring and compliance control of Technological Regulations, list of persons in charge and their responsibilities, control schedule on particular stages of animal/poultry manure processing.

Technological Regulations for animal/poultry manure utilisation take into account individually for each farm the amount and composition of initial raw material, availability and structure of arable land, the current crop rotation system, and available machine and tractor fleet.

Farm introduction of the above Technological Regulations means that the farm manager appoints by an administration order the persons who are responsible for the observance of these regulations and for establishing the permanent compliance control (Figure 12). As the farm manager approves Technological Regulations for his farm by signing this document, he bears personal liability to regulatory environmental authorities for compliance with its provisions.

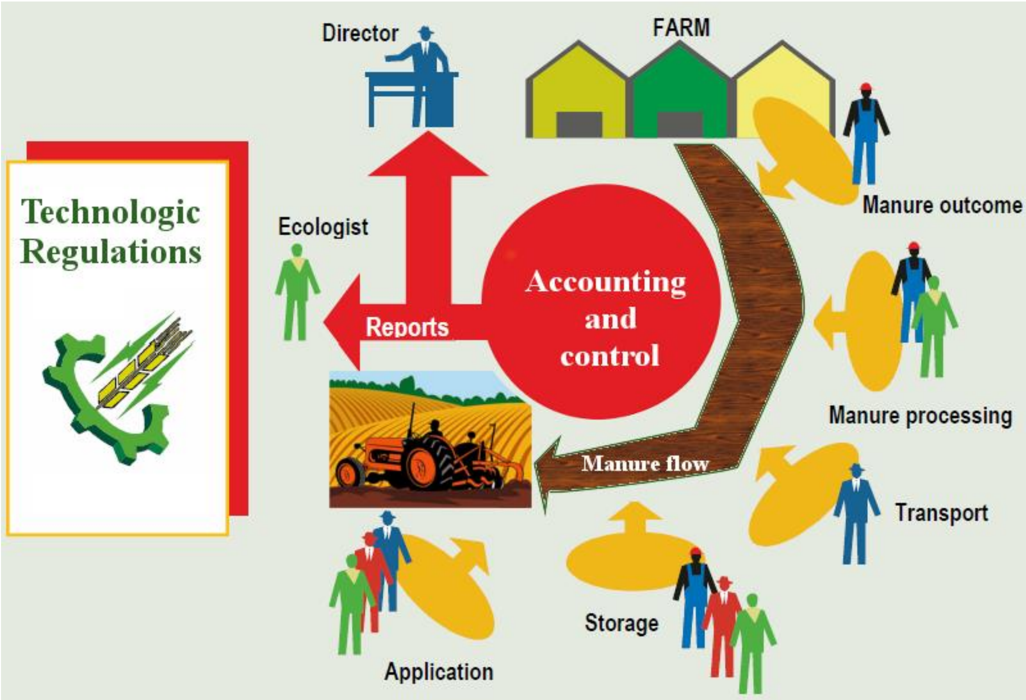

Figure 12. Setup diagram of the information flow within the framework of internal control over the observance of Technological Regulations in Russian animal manure handling.

Results of the project "Advanced manure standards for sustainable nutrient management and reduced emissions" allow to use in this document more accurate information about the volume and nutrient content of the manure output.

National needs for developing the existing system in Russia

Based on the results, we can conclude that for the improvement of the Russian system of evaluation of the nutrient content of manure, it is necessary to divide a shared document on geographical areas with similar soil and climatic conditions and more frequently updated data, and also to change the form of data. Also, it is advisable to introduce additional columns to display additional conditions related to feeding, housing, genetic features of animals. For the regular collection of this information the appropriate electronic database should be provided.

Potential of developing and implementing a regional joint basis for an advanced nutrient standards system from the perspective of Russia

The natural conditions of the majority of the Baltic Sea region are similar, and in terms of livestock and poultry there are no big differences. It would be useful to establish a unified database of the Baltic nutrient content in manure. In parallel, it is necessary to conduct joint scientific work of the Baltic Sea region and to understand the processes of forming the nutrients in the manure. The results of all this work would prepare the Baltic guidelines for proper manure nutrient management, as well as the appropriate expert system.

Conclusions

1. The document RD-APC 1.10.15.02-08 "Guidelines for the Technological design of removal systems and preparation for the use of manure " to use in the design of newly constructed and reconstructed enterprises for cattle, pig and poultry farms is used in Russian Federation. The document contains information concerning nutrient content in manure in Russia.
2. To improve the management of animal manure, a similar document for the North-West region of the Russian Federation should be created including the information to predict the variability in the content of these elements.

3. Within the framework of the Baltic Sea Region, it is advisable to establish a common database of nutrient content in manure and conduct joint research concerning the processes of manure nutrients forming.
4. On the basis of research results and the information collected in the database it will be possible to prepare actualized Baltic guidelines for the manure nutrients management and the proper expert system.

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2.8. Sweden

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The existing systems and practices in Sweden

The calculation of nutrients in manure (faeces and urine) leaving the animal is based on Swedish research data and in agreement with the latest animal husbandry researcher. Animal categories included in the model are cattle, pig, poultry, sheep and horses.

Normative values for content of nutrients in manure are based on a "barn balance" in which standard feeding is used as the input data together with data on the livestock (Figure 13). As an output, animal products from the farm are used. This is combined with knowledge on nutrient concentrations in different products brought into and from the farm. The surplus is the estimated nutrient content in the manure. Feeding data has just been up-dated for dairy-cows and pigs. Next animal species to be updated are poultry and cattle.

Surplus = feeding + livestock animal – animal products

In the planning tool VERA (earlier Cofoten/STANK in Mind), managed by the Swedish Board of Agriculture through 'Greppa Näringen' (www.greppa.nu), the nutrients excreted in faeces and urine are calculated in two ways, either

a) based on the normative values described above for different animal species and production levels, or
b) based on actual feeding and production level on farm (nutrient balance of animal categories).

The mass of manure is based on the same standard feeding as used while calculating nutrient content. The digestibility of the different components of the feeding is used to calculate the excreted amount of manure

In the next step, the change in manure properties inside the barn (housing) is calculated as a result of manure management, water addition and ammonia losses. For instance, the data on addition of bedding material (amount and type), cleaning and waste water (default values) are taken into account, and if robotic milking is used, a higher water consumption is used in the calculations. Ammonia emissions in the barn are calculated with default values depending on animal species and manure handling system (liquid, solid, deep straw bed). The types of bedding and housing techniques also have an effect on ammonia emissions.

Changes during storage are calculated based on addition of precipitation in the region reduced with evaporation (default value) and storage dimensions. Other additions like effluents from silage storages, water from hard standings (area) or other sources are added to the total amount of manure from barn. The demand of storage capacity is calculated with extra safety margin, also given in a table form in the yearly guidelines (Jordbruksverket, 2014). The loss of nitrogen as ammonia from manure storage is calculated using default values (Karlsson & Rodhe, 2002) depending on animal species, type of bedding, type of manure and storage conditions, such as cover or not, manure handling system (slurry, solid, deep litter). In addition, turn-over losses are subtracted from the content in manure giving a new netto dry matter content also based on empirical values of dry matter content and weight by volume.

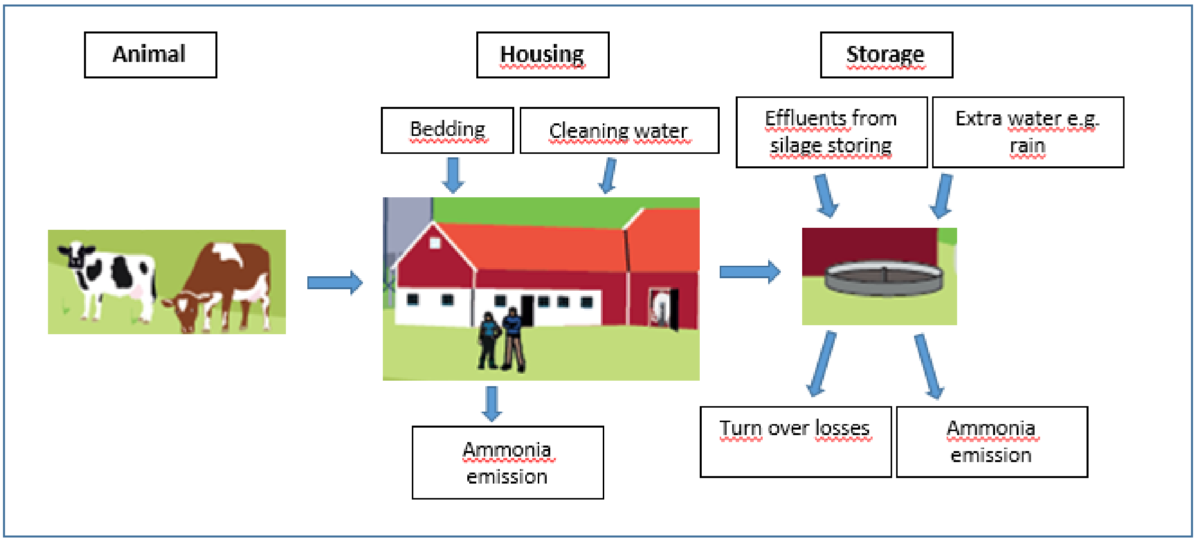

Figure 13. The "barn balance" of the Swedish calculation of manure quantity and quality.

Data concerning content of micro-nutrients and trace elements are taken from an empirical study, where the manure in storage were sampled and analysed from 130 farms with different animal production in different regions of Sweden (Steineck et al., 2000).

In the project Baltic Manure (2010-2013) financed by Baltic Sea Region Programme, the calculated nutrient amounts excreted from dairy cows (ex animal) were compared with analysed manure leaving the animal barn (ex housing; Sindhöj et al., 2013). There was no clear correlation between calculated amount of nutrients excreted by animals and the sampled and analysed concentrations in manure leaving the barn. Also, there were considerable differences in the calculated ex animal nutrient excretion between dairy farms in Sweden and Estonia, as well as measured nutrient in manure leaving the barns. It means that manure handling in the housing system has a large effect on manure properties.

The decrease in manure P concentrations between ex animal and ex housing suggested that on average, dilution doubled the volume of manure generated in the housing system. Measurements showed that cleaning water and wastewater added to the slurry in the housing system accounted for the largest percentage of observed dilution, but still about 50% of the dilution could not be related to any certain source. Therefore, it is important when using data from the model to be careful when comparing dry matter content between calculated values and the actual manure.

How the Swedish manure data is used

The calculated amounts of manure and nutrients in storage are used when planning manure application strategy, including allocation of manure to fields, crops and doses in order to get high efficiency in plant uptake. In VERA, the ammonia losses at spreading are calculated depending on manure type, spreading time, crop, spreading technique and time between spreading and incorporation based on default values (Karlsson & Rodhe, 2002). From this, the need of supplementary mineral fertilisers on farm can be estimated. The model is also used as a way for the farmer to estimate if his/her spreading area is sufficient for the limit of 22 kg of phosphorus per ha and in nitrate vulnerable zones the limit of 170 kg N per ha. The calculated mass of manure is used for determining if there is enough storage capacity on the farm. Further, the model is used when applying for approval at large poultry and pig farms. Amount of manure, nutrient content and ammonia emissions need to be accounted for in the approval procedure.

According to Swedish regulation it is not permitted to use analysis of manure as basis for manure fertilisation when having supervision from the regulatory authority. However, it should be mentioned that in order to apply the optimum amounts of nutrients for minimising the risk of nutrient leaching, it is recommended to analyse the manure for nutrient content at spreading**.** There are simple technologies for determining the ammonium nitrogen content of slurry, but also more advanced techniques are developed like on-line sensors for precision agriculture.

The manure data is used by farmers and advisory services in order to show that regulations are followed when having supervision and when planning the spreading of manure in an effective way on the farm. Advisory services often use the tool VERA (earlier Cofoten/Stank in Mind) for manure calculations but there are also tables in the Swedish fertiliser recommendations and in the common advice connected to the Swedish regulation over nutrient content in manure. The values in these tables are based on the same normative values that are used in VERA.

Municipalities, county administrative boards and other supervisory bodies use the data as well, when performing supervision.

VERA is furthermore used in educational context – both at upper secondary school level and at university level.

Statistics Sweden makes every second year an inventory among a selected number of farmers to determine the use of fertilisers including manure (Statistics Sweden, 2014). For calculating the amount of N, P and K in manure, they use the same default values as in VERA together with animal production data. The statistics are shown for eight different regions of Sweden. From the inventory, additional information is collected concerning storage and spreading of manure. For example, data are shown concerning handling methods of manure (solid, slurry, semisolid, deep litter), storage capacity (months) and techniques for filling storages and type of cover or no cover. For spreading, information, such as time of spreading, which crops, application rates, spreading techniques and the time between spreading and incorporation are collected. The result is used when calculating the ammonia emissions from Swedish agriculture inventory report.

Advantages and challenges of the existing systems at the national level in Sweden

The advantages identified with the Swedish system are for example:

- Default values of nutrient content of manure are used by many stakeholders.
- The default values are good for fertiliser planning on farms, like amount of N, P and K on farm, and the need of supplementary mineral fertilisers.
- A good help for calculating the need of storage capacity, used both by consultant and authorities.
- A help when planning in which fields to place the manure based on content of P and K together with soil analysis and at which doses =>
  more efficient use of P and K on farm level, better economy, reduced risks for eutrophication.

Challenges are for example:

- To update feeding ratios continuously (can change rather fast), as well as emission factors for ammonia, reflecting barn design, handling methods and technologies of today.
- The changes of manure properties in stables depending on barn design, water dilution, management routines, need to be investigated additionally.
- The advisory service can see a potential of improvement of the formula for calculating needed storage capacity.
- High risk of pollution, if the fertilisation is not based on actual content of nutrients, in the first hand nitrogen.

National needs for developing the existing system in Sweden
The calculations could be improved by:

- More frequent updating of the normative excreted nutrients according to changes in diets.
- Validation and identification of errors when calculating nutrients in manure and amounts like errors in dosage of feed components, in feed declaration, in feed sampling for analysis etc.
- Dilution of manure in barns and outdoor sources.

Potential of developing and implementing a regional joint basis for an advanced nutrient standards system from the perspective of Sweden
An implemented nutrient standard system for manure makes it easier to compare manure calculations done in other countries in the region.

Also, while developing a joint basis for advanced nutrient standards we have the possibility to learn from each other and perhaps find solutions for some of the challenges each country in the region face. It could, for example, give us a better understanding on how barn design and management inside the barns influence nutrient content and mass of manure leaving the housing. Also improvement of the calculation of storage capacity is necessary for environmentally friendly use of manure. Since the Swedish system is recently rewieved, we would gladly share our method in the work with the regional standards.

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3. Conclusions

Manure standards in the Baltic Sea countries – current state

All Baltic Sea countries taking part in this report – Estonia, Denmark, Finland, Germany, Latvia, Poland, Russia and Sweden – currently have own national methods for determining manure nutrient content. This data is then utilised as the national basis for manure utilisation.

However, *the methods for manure data provision vary significantly*. Some are based on manure sampling and analysis, some on modelled calculations and some on both. Most calculation systems are based on mass balances / mass flows, but there are no joint protocols how these should be calculated and what kind of national background data to use.

There are also *differences between the countries in how the manure data is used in fertilisation plans*. The officially calcaluted and published data may be regarded as the only acceptable method or they may be used more as an advisory tool. For example in Denmark, the standards are used for regulatory purposes e.g. to determine the farm nitrogen quotas. Also in Latvia the standard values are used e.g. in the nitrates vulnerable zones to calculate the allowed 170 kg/ha of nitrogen from manure. In Finland, the farmer can choose between the table values or taking manure samples to determine manure nutrient content. And in Russia, farms are not required to determine manure nutrient content but there are reference manuals available.

General aspects of developing joint Baltic guidelines for advancing national manure standards

The relevant Baltic research organisations and ministries concluded that there *could be significant benefits from such joint guidelines*, while preparing this report and in discussions (incl. November 2015 workshop in Finland) towards the possibility of determining joint guidelines for manure data provision in the Baltic Sea Region.

The ultimate target of enhancing manure fertiliser use and simultaneously reducing emissions into air and water could be reached if manure management and use was based on more equal and precise manure nutrient data and thorough nutrient balances, including manure fertilisation plans using this data. Such a system was also seen as a way to ensure resource and consequently national food security. In addition to environmental benefits, it was recognised that more advanced and transparent systems on determination of manure nutrient content provide for a level playing field for agricultural producers and are a good basis for environmental branding of national agricultural production.

Advanced systems for manure data provision together with effective data exchange *also facilitate cooperation between the Baltic Sea countries to ensure transparency of the assessment of environmental impacts and equal efforts in protecting the environment*. In addition, better compliance of the national environmental policies to international commitments could be achieved. Nationally the system could also be used for other purposes, in particular, improving land resource management through better access to information.

The challenge is to find wide acceptance to the joint guidelines in all Baltic Sea countries. However, this can be solved if the guidelines are created in dialogue with all the relevant stakeholders in all countries. They all should feel confident that the resulting manure standards are indeed taking all national conditions into account even if the procedure to determine them is based on joint Baltic guidelines. With manure sampling and analysis this is simple to ensure, as the sampling and analysis procedures are performed on national manure samples. With modelled calculation systems, the result also becomes thoroughly national as all the background data on animal feeding, breeds and manure management are collected from national sources. There may be a need to develop data collection, but this too could be planned and tested together and added into the guidelines. The quality of the manure data obtained relies heavily on high quality background data from the animal farms.

More specific challenges may include issues, such as i) unsupportive legal framework for promoting the development of a more advanced manure data based on joint guidelines, ii) the requirement of training and education to ensure sufficient competence in the practical use of the advanced system of manure data (applies to all stakeholders), and iii) changes in the results of emissions inventories due to novel manure data.

These issues can be solved with training and effective communication, plans to update regulations and discussion with all relevant stakeholders. In fact, *the guidelines should be firstly created and tested for their impact on farming practices, including choices of manure management and farm economy, and environmental impacts. Only with this information the means to make national plans for implementing the use of the new manure data can be achieved.*

Thus, the introduction of a new advanced system of manure data requires not only expertise and time, but also funding, which in many countries could hinder the development.

The next steps to advance joint guidelines for national manure standards

During the time of writing this report, the relevant research organisations (co-authoring also this report), HELCOM and the relevant ministries in the Baltic Sea Region (via HELCOM Agri group) have been *planning a project* in which

- The Baltic guidelines for determining manure quantity and quality as a tool for enhanced manure utilisation are developed,
- The impact of implementating this tool in each country and in the Baltic Sea Region is assessed for farm economy and the environment, and
- The steps towards their implementation are planned in dialogue with the relevant stakeholders.

The stakeholders, i.e. policymakers, authorities, advisory organisations and the farming community, are seen to be taking integral part in all tasks via intensive dialogue both on national and BSR level. The guidelines are seen to entail joint instructions for both proper and unified manure sampling and analysis, and for modelled calculations as mass balances. The guidelines for sampling and analysis will be tested on pilot farms and in cooperation with commercial laboratories in all BSR countries. These results will be used in validating the model calculations. The resulting manure data, i.e. the new tool for enhanced manure use, will then be subjected to impact assessment on farm economy and the environment on national and BSR level as compared to the currently existing systems in each country. Finally, all data will be used for planning the potential national implementation of the tool e.g. in farming practices and policy instruments. Open public discussion is an integral part of the planned project in order to reach national and regional political agreement on the integration of the updated methodology to the national legal frameworks.

Final conclusion

In the light of the discussions held and the project planned, the Baltic Sea countries agree that there is a *need for enhancing manure utilisation* in the BSR and this could be reached via more precise nutrient balances. In order to make them more precise, *improved manure data* is seen integral. Moreover*, to ensure a level playing field for all Baltic Sea countries, unifying the procedures* of collecting manure data is seen a way forward.

All countries have national systems for manure data provision and they are mostly based on sampling and analysis or modelled calculations. All countries report needs for improving and updating their systems and the resulting manure data. Many also refer to similar challenges in data provision, such as how to consider the variability of housing solutions, additives (bedding, water) and losses (water, nitrogen) from different manure types.

There is a *great chance of learning from one another during the development of the suggested joint guidelines for manure data provision*. Instead of all countries trying to solve the same challenges individually, the solutions could be reached in close cooperation. The resulting tool, the more precise manure data, would become more effective and give all its users, farmers, advisory, authorities, policymakers, research and also companies developing and providing technologies for manure management and processing, a more solid database from which to plan the most effective ways to make the most of manure and its valuable nutrients (and energy). This is foreseen to also decrease the risk for environmentally harmful impacts from agriculture.

We hope the project will be successful and the joint Baltic guidelines for manure nutrient standards and generally data on manure quantity and quality can be developed into more useful and equal tools for all stakeholders in the Baltic Sea Region.

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