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A simplified model of nitrogen flows from manure management

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Abstract

This report describes a model to simulate release processes of trace gases from manure into the atmosphere. This “manure handling model” (MHM) provides a mass-consistent scheme to follow nitrogen and carbon compounds along the typical stages of manure treatment in animal husbandry. In each of the model compartments, which reflect the respective stages, conversion between reactive and unreactive nitrogen or carbon species is possible, as well as the release of gaseous compounds from the reactive species. We use total ammoniacal nitrogen (TAN) as the reactive nitrogen species, and degradable volatile solid (VS_d) as the reactive carbon species. Conversion parameters, either derived from specific information, e.g. national data, or as default values, allow assessing transformation rates. As a result, the model generates emission factors for the release of nitrogen components (gaseous NH_3, N_2O, NO_x, N_2 and NO_3^- in runoff and the associated N_2O emission) and CH_4 for use in IIASA’s integrated assessment model GAINS.

Results of MHM have been compared with the German emission model GAS-EM for dairy cattle on liquid manure to demonstrate that the simplified model is able to reflect complex national information. With identical input parameters, the simplified model reproduces results of the more complex models within 1 % difference for the emission of all N components and emission of CH_4. MHM was also used with default input (excretion rates, emission coefficients and removal factors) to generate emission factors for all possible combinations of animals and control strategies for all European countries. However, a comparison with current GAINS emission factors reveals substantial differences due to country-specific information that is available in GAINS.

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Zbigniew Klimont graduated from Warsaw Technical University (Poland) in environmental engineering. He is a research scholar in the Atmospheric Pollution and Development Programme at the International Institute for Applied Systems Analysis (Laxenburg, Austria) where he works on assessment of regional (Europe, Asia) and global emissions of various air pollutants and leads development of models to estimate emissions and control costs of reducing emissions of ammonia, NMVOC, and carbonaceous aerosols. These models are part of the integrated assessment framework GAINS (http://gains.iiasa.ac.at).

Wilfried Winiwarter earned a doctoral degree in analytical chemistry from Vienna University of Technology, for work dealing with atmospheric trace compounds. During his employment with Austria's largest non-university research institution, AIT - Austrian Institute of Technology, he continued to developed his scientific interests on the release of trace constituents into the atmosphere, and their subsequent transformations. While maintaining an affiliation with AIT, he joined IIASA, where he is now employed as a Senior Research Scholar. Activities with IIASA's GAINS model, specifically on emissions of nitrous oxide, triggered his interest in nitrogen cycles in general and their interactions with agriculture. Dr Winiwarter holds the title of a "Universitätsdozent" in environmental chemistry, awarded by Vienna University of Technology, which provides him the full privileges in academic teaching.

A simplified model of nitrogen flows from manure management

Willem A.H. Asman, Zbigniew Klimont and Wilfried Winiwarter

1 Introduction

The GAINS model is a tool to evaluate the interactions between the control of air pollution emissions and greenhouse gases (Amann et al., 2009). Inter alia, GAINS includes emissions of ammonia (NH_3), nitrous oxide (N_2O) and methane (CH_4) from animal manure. While the respective GAINS modules have been developed a few years ago, knowledge about these substances has increased rapidly since then. Moreover, the current version of the GAINS model does not take full account of all interactions between the emission processes of the different component under all conditions. Therefore it was decided to develop a state-of-the-art manure handling model (MHM) that incorporates the new information and possibilities and generates revised emission factors (kg animal^{-1} yr^{-1}) for use in GAINS.

In the following the history of the development of emissions factors in general and for use in GAINS and its predecessor RAINS is described and it is indicated which recent information is now part of the MHM.

The first emission inventories of NH_3 emissions from livestock were made by multiplying the livestock numbers with emission factors for each animal category (Buijsman et al., 1987; Asman, 1992). In these inventories, emission factors (emission of NH_3 per animal and year) were given separately for different stages/situations: for housings, storage of manure, application of manure and for grazing. Such an emission factor for a particular stage is called a partial emission factor. In Buijsman et al. (1987) emission factors were mainly derived from measurements for each stage conducted in different experiments, which however did not necessarily describe the same situation. There was no relation between the losses in subsequent (housing-storage-application) stages.

The emission factors in Asman (1992) are based on calculations where there was a relation between the different stages using “the mass flow approach”. For instance, if there is a great loss of NH_3 from the housings, the subsequent loss of NH_3 from storage would be lower, because there is less nitrogen left.

For each step, emissions were calculated from the amount of total nitrogen (total N) present using the fraction of the total nitrogen that was emitted as NH_3. Such a model has been used in many countries, including the RAINS model, the predecessor of GAINS (Klimont and Brink, 2004). The last model also described emissions of N_2O and CH_4 from manure.

In recent years, an increasing number of NH_3 emission models distinguish between total ammoniacal nitrogen (TAN) and organic nitrogen (Norg). This distinction is important because the gaseous emissions as well as runoff of all N components are caused by the TAN. In those models emissions are calculated as the fraction of the TAN present, and they address the conversion of TAN to Norg and vice versa.

TAN based models have been applied in Germany (Haenel, 2010), the Netherlands (Velthof et al., 2009b), the UK (Misselbrook et al., 2009), Denmark (Hutchings, Department of Agroecology, University of Aarhus, Tjele, Denmark, personal communication, November 2010) and Switzerland (SHL, 2009). Moreover, international organisations, such as EMEP/EEA, have also come up with TAN based parameterizations (EMEP/EEA, 2009).

Recently a new model approach was developed for emissions of CH_4 from liquid manure (Sommer et al., 2004; Sommer et al., 2009), which makes it possible to model emissions for different climatic zones. The concept of this approach is similar to that of NH_3 emissions, as it differentiates between “degradable” and “non-degradable” volatile solids, which are organic components. Emissions are calculated as a fraction of the degradable volatile solids (VS_d), and exchange between the degradable and the non-degradable fraction (VS_{nd}) is possible and is modelled. Contrary to NH_3 emissions, also CH_4 emissions can occur from the non-degradable fraction, but at a much lower rate than of the degradable fraction.

The present version of GAINS handles emissions of NH_3, N_2O, NO_x and CH_4 from manure for housing, storage, application and grazing. However, emissions from some manure handling activities cannot be described well with the present GAINS approach, especially for yards, incineration of manure, direct spread of manure (daily transport of manure from the housing to the field without any storage), use of manure and additional waste for the production of biogas including storage before and after the biogas production. Furthermore, the present version of GAINS does not consider emissions of N_2 from the TAN in the manure, and does not address the leaching of NO_3^- from manure heaps and the runoff of NO_3^- from fields and its associated N_2O emissions (Asman and Klimont, 2010).

In order to obtain consistent parameters for GAINS, a manure handling model (MHM) has been developed to determine airborne partial emission factors for NH_3, N_2O, NO_x, N_2 and CH_4. In addition, it addresses NO_3^- emissions from the runoff of manure heaps and fields and the associated N_2O emission for a large number of manure management situations. The model derives partial emission factors, which then can be used in GAINS to calculate national emissions. The model is programmed in Fortran and nitrogen emissions are expressed as a fraction of the TAN present. MHM addresses emissions from manure handling, but does not quantify other agricultural emissions of the same components, such as the CH_4 emission from enteric fermentation, NO_3^- leaching in soils and related N_2O emissions.

In the following sections, the set-up of the model will be presented (Section 2). Model results are compared with the German GAS-EM model in Section 3. Section 4 presents results for all animals and control options for all European countries. Sources of information are discussed in Section 5, and conclusions are drawn in Section 6. A detailed description of MHM is given in Appendix 1. Appendices 2-6 present further details on processes and input parameters.

2 Methodology

2.1 The compartments

Figure 1 shows the set-up of MHM with regard to the processes taken into account. Each box in the figure denotes a compartment from which emissions can occur. The outlined arrows indicate the main input of material into the model (excretion). The model contains many more compartments and processes than normally would occur simultaneously. The philosophy behind the model is that the user can set flows or emission fractions to zero in the input file of the model, thereby excluding compartments and processes. This is the new and unique feature of the model. The model only contains flows; storage of components in any of the compartments is not considered.

The model uses information on excretion and fractions of components in manure that are emitted to calculate partial emission factors for each possible combination of housing, storage, application type for one animal category (e.g. in kg NH_3 animal^{-1} period^{-1} for housing) using information on the fraction of TAN (for N components) or VS (for CH_4 emission) that is emitted. Normally emissions are calculated for one year, but it is possible to let the model calculate emissions for any selected period for which partial emission factors are available. This allows the modelling of situations for summer and winter separately when large differences in the parameter values occur. Model inputs include manure, the amount of straw and litter, and the waste input to the biogas plant.

Figure 1 shows only the compartments, the flows and the emissions, not the components.

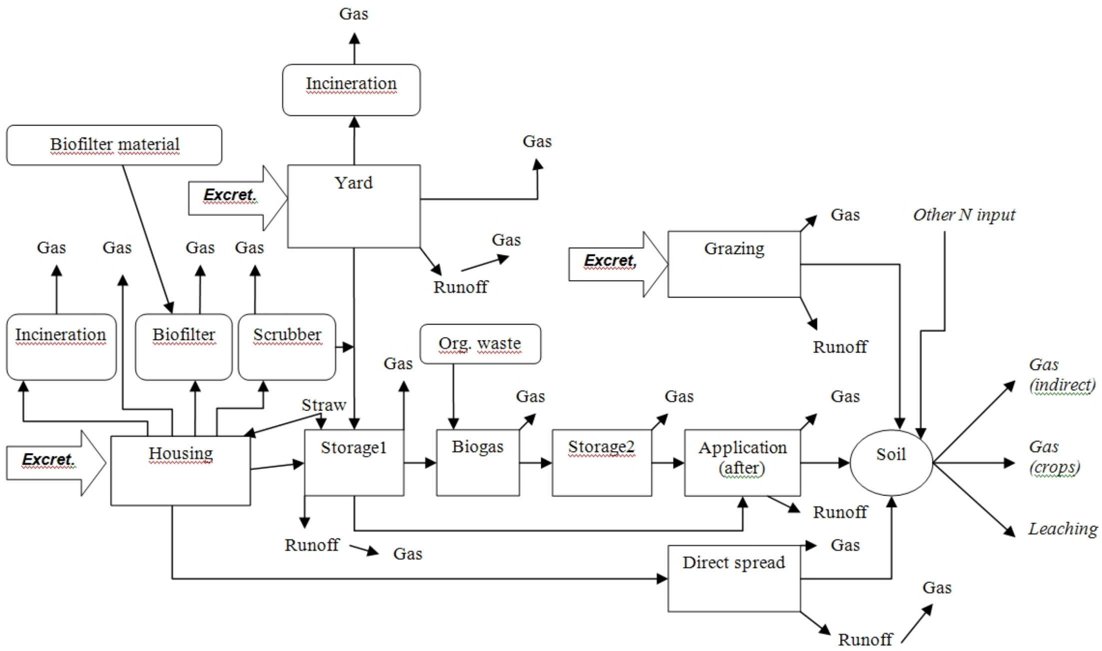

Figure 1. Set-up of the manure handling model. Excretion may include other animal material further processed. The figure indicates the maximum number of processes that can be described in the model. In practice fewer processes will be modeled. This situation can be handled by either setting some parameters to zero or by using by-pass switches. The processes at the right side of the figure described in italic font occur outside of the model. The excreted manure can enter the model in three different places: housing, yard and during grazing. The rectangles indicate compartments, where manure is input and output. The rounded rectangles indicate compartments, where this is not the case.

Excretion. Excretion can occur during housing, on the yard or while grazing, and can occur simultaneously at these places.

Housing. There is a possibility to add bedding material (e.g. straw) to the housing. In that case N and VS are added to the system. Manure from housing is either incinerated, transported directly to the field ("direct spread") or transported to a storage facility. Gaseous emissions are directly released into the atmosphere or processed in either a biofilter or in a scrubber. In case of a biofilter, biofilter material is added that also contains N and VS.

Yard. The manure excreted on the yard is either incinerated or transported to the storage facility storage1. Gaseous emissions occur from the yard and possibly runoff, but there are no facilities to reduce emissions.

Grazing. The manure excreted during grazing is transported into the soil. During grazing gaseous emissions and possibly runoff occur.

Storage1. This is the primary storage facility. Here the manure from the housing and possibly the yard are stored. It is possible to add straw containing N and VS to the storage facility, so that the manure can be covered, which reduces the loss of NH_3. Manure from storage1 is either applied or transferred to a biogas plant. During storage gaseous emissions and possibly runoff occur.

Biogas. There is a possibility to add organic waste (containing N and VS) to the biogas plant to increase the production of CH_4. A large part of the generated CH_4 is used for energy generation. The remaining part is released to the atmosphere. Other gases are mainly released into the atmosphere.

Storage2. This is the secondary storage facility, which in the model is only used in connection with the biogas plant. Gases can be released from the facility.

Application. The manure excreted is incorporated into the soil. After application gaseous emission and possibly runoff can occur.

Runoff. Runoff of NO_3^- (yard, storage1, grazing, direct spread, application) usually only occurs under special unfavourable conditions, which however do not always occur. It leads in the long run to indirect N_2O emissions (according to the IPCC).

Soil. The model calculates the input of manure to the soil, but does not estimate its fate in the soil, as there are other N inputs (e.g. *atmospheric* deposition). Moreover, a large fraction is removed with the crops (see Velthof et al., 2007; Velthof et al., 2009a, and Asman and Klimont, 2010, for a description of the soil processes).

2.2 The components

Figure 1 displays the main compartments, the flows and emissions. Figure 2 shows components in one compartment with input and output of manure and emissions. The amount of TAN, Norg, VS_d and VS_{nd} are both input to and output of the model.

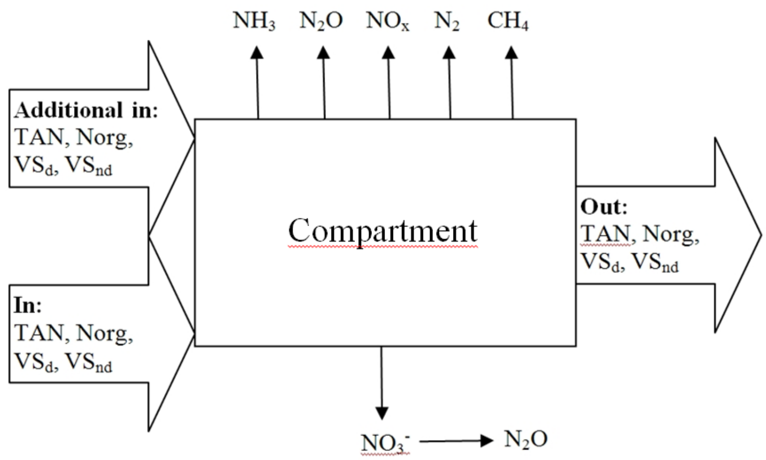

Figure 2. Set-up of one compartment, with input and output and emissions. The input called "In" comes from a previous step in the manure handling model, whereas the input called "Additional in" is fresh input (either bedding material or organic waste). The NO_3^- emission originating from leaching of manure heaps and runoff gives rise to N_2O emission.

Each of the compartments in the figure allows to treat each of the ten components of the model: TAN, Norg, NH_3, N_2O, NO_x, N_2, NO_3^- (N components) and VS_d (degradable volatile solids), VS_{nd} (non degradable or slowly degradable volatile solids), CH_4 (C components). Within these respective groups of components (N and C, respectively), emissions to different media and the transfers to other compartments are simulated. Also the conversion between TAN and Norg and vice versa, as well as between VS_d and VS_{nd} is possible. The full range of conversions as implemented in the model is described with equations in Appendix 1. The partial emission fractions in a compartment are calculated as a fraction of the TAN or VS (either VS_d, VS_{nd} or a combination of both).

There is no connection in the model itself between N and C components. An interaction between N and C components could be simulated by reducing or increasing conversion fractions or fractions emitted depending on the respective levels/concentrations. In principle this could be done automatically by a program producing the MHM input file, but this is not implemented as too little is yet known about such interactions.

In each of the compartments, conversions between the components occur. For N components, the sum of all N in components that are input to the system is equal to the sum of all N in components that are output. A complete N balance can therefore be derived.

The C components in the manure undergo conversion processes. The main gaseous carbon components formed are then CO_2 and CH_4 (see Appendix 3). A consistent treatment of organic material thus would consist of balancing C in manure. There is, however, not much information on CO_2 emissions. CO_2 emissions are normally not considered to be important compared to other CO_2 emissions, not at least since this CO_2 is part of the natural cycle and does not contribute to net emissions of greenhouse gases. Moreover, only part of the CO_2 formed will be released immediately, due to its high affinity with the aqueous phase.

As it seems impossible to maintain a carbon balance, the model performs book-keeping of VS instead. This is a new concept incorporated in the model. When applying the Sommer et al. (2004) parameterization, the model calculates how much VS_d and VS_{nd} is used for the production of C gases (CO_2 and CH_4) from the CH_4 production and the ratio $rm_{VS\text{-}CH4}$ (kg VS consumed per kg CH_4 produced). The VS balance is then calculated from the amount of VS remaining and the amount of VS used for the production of C gases. The ratio $rm_{VS\text{-}CH4}$ is different for different organic components and has to be specified by the user for each step where CH_4 is released.

Further to the model approach described above, MHM also allows for a simplified approach for CH_4 and N_2O taken from the IPCC (2006).

If the IPCC method is used for all CH_4 calculations (IPCC, 2006), no distinction is made between VS_d and VS_{nd}, and in the calculations all volatile solids (VS) are put into the VS_d reservoir while the VS_{nd} reservoir is not used at all. If the IPCC method is used for N_2O emission during storage, emissions are expressed as a fraction of the amount of total N excreted in the housing and not as a fraction of TAN as in the normal approach. The simplified options can be employed if no more detailed input data are available.

Processes that do not need to be considered may simply be ignored by setting the appropriate switches. E.g., among the compartments displayed in Figure 1, some will need to consider both input and output of TAN, Norg, VS_d and VS_{nd}. These are visualized as rectangles (with corners). Other compartments will not have a specified input of these components (as they are the source), or they are end points, so that further fluxes need not be considered. We present these in rounded boxes.

Each subroutine in the model describes a compartment or a process related to a compartment (biofilter, scrubber) and checks the N and VS balances. Moreover, this is done for the whole model as well. These balances can be used to check for errors in the calculations. The individual steps in the model, in form of equations, are presented in Appendix 1.

Not all combinations of process and component occur in reality. Table 1 gives an overview of the processes that are taken into account in the MHM.

Table 1. Processes that can occur in different compartments.

Process	Housing	Storage1	Biogas	Storage2	Applic.	Direct	Yard	Grazing
Additional input	+	+	+	-	-	-	-	-
Conversion Norg to TAN	+	+	+	+	-	-	-	
Conversion TAN to Norg	+	+	-	-	-	-	-	-
Conversion VS_{nd} to VS_d	+	+	+	+	-	-	-	-
Conversion VS_d to VS_{nd}	+	-	-	-	-	-	-	-
N emissions to the air as a fraction of TAN (NH_3**,** N_2O**,** NO_x**,** N_2**,** CH_4**)**	+	+	+	+	+	+	+	+
NO_3^- emission	-	+	-	-	+	+	+	+
NH_3 emission from manure IPCC method	-	-	-	-	-	-	-	+
N_2O emission from manure IPCC method	-	+	-	-	-	-	-	-
CH_4 emission from VS_d	+	+	+	+	+	+	+	+
CH_4 emission from VS_{nd}	+	+	+	+	-	-	-	-
CH_4 emission IPCC type method	+	+	+	+	-	+	+	+

+ = does occur, **-** = does not occur

3 Comparison of MHM with the GAS-EM model

To test the performance of MHM, model runs were made for dairy cows and liquid manure systems in Germany. The idea of the comparison was to provide realistic data to MHM, and to demonstrate to which extent MHM is able to reproduce results from complex national models. Input data were either provided (for excretion: Claus Rösemann and Dieter Haenel, Johann Heinrich von Thünen-Institut, Braunschweig, November 2009) or taken from Haenel, 2010.

The analysis is conducted for dairy cows, because MHM and GAS-EM have this category in common, whereas GAS-EM has more detailed animal categories than MHM for the other animals.

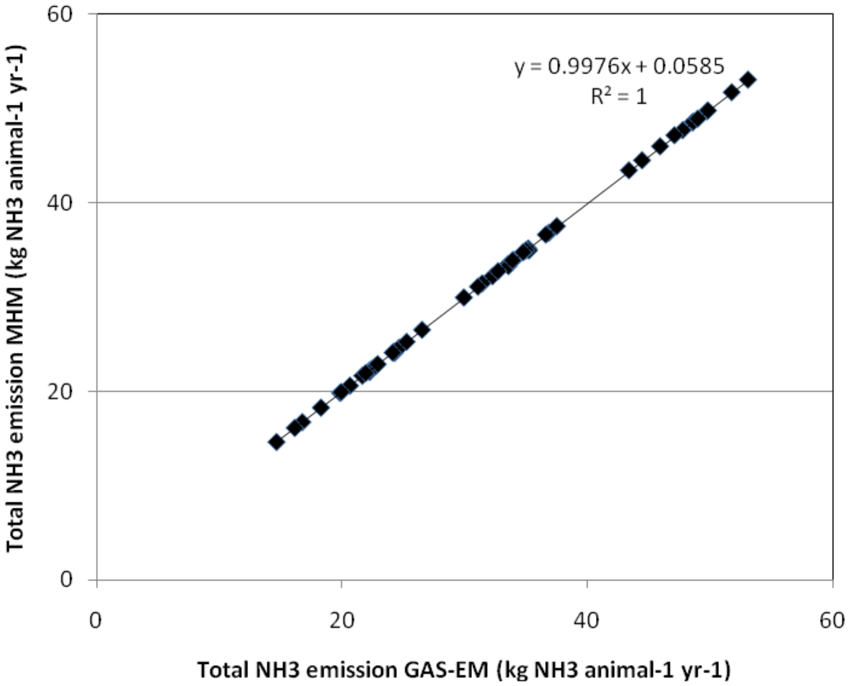

Figure 3. Total NH_3 emission (housing+storage+application+grazing) for dairy cows in liquid manure systems in Germany: results of MHM vs. GAS-EM.

The comparison was made for a mixture of tied housing systems and cubicle housings. The following parameters were varied: milk yield (5000/8000 kg animal^{-1} yr^{-1}) nitrogen feed (low/high), storage (natural crust/solid cover), application (low/medium/high emission), grazing (without grazing/120 days grazing. 48 runs were made and the following partial emission factors were calculated: NH_3 emission from housing, yard, storage, application and grazing; N_2O, NO_x, N_2 emission from storage and CH_4 emission from storage and grazing. N_2O emissions were calculated using the IPCC (2006) method as a fraction of N excreted in the housing and during grazing. Emissions of NO_x and N_2 are related to emission of N_2O. CH_4 emissions MHM were calculated using the IPCC method, just as in GAS-EM. Figure 3 shows a comparison for the sum of all NH_3 emissions, and Figure 4 provides a comparison for the sum of all CH_4 emissions. The comparison for the partial emission factors (e.g. for storage only) shows excellent agreement, with less than 1% differences, likely to be caused by rounding of input data.

This result demonstrates that MHM indeed is able to reproduce the national approach. The resolution of MHM reflects that of the national model. If national input data are fully available, the very high level of agreement is not too surprising as the MHM fully mimics the national data structure.

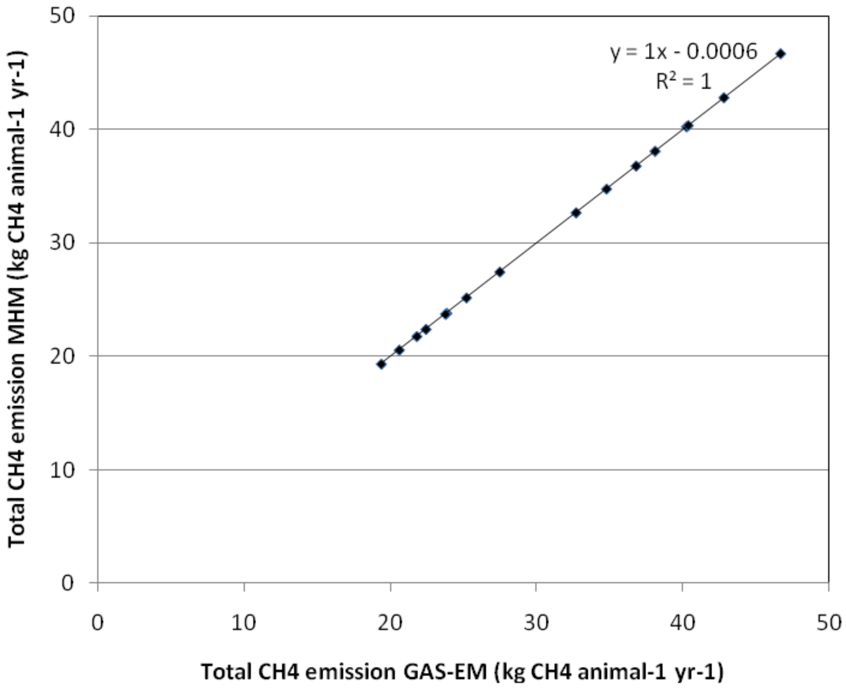

Figure 4. Total CH_4 emission (storage+grazing) for dairy cows in liquid manure systems in Germany: results of MHM vs. GAS-EM.

A comparison for dairy cows for solid manure appeared not to be possible, as in GAS-EM the solid manure is divided into farmyard manure (FYM) and leacheate (“Jauche”, which contains the liquid part), which are treated separately. If in the future information on solid manure is needed it is necessary to get some additional results from the GAS-EM model or to use default emission fractions.

4 Calculation of N fluxes over Europe with default parameters

The main reason for developing a model is its application to areas for which no data are available. In order to test the performance of MHM for the European countries, we gathered default input information from literature. Being aware that agricultural practices and climatic conditions can differ quite substantially across Europe, such a set of defaults could provide a first estimate. To understand the potential of MHM we compared emission factors (in kg N animal^{-1} yr^{-1}) with those of the GAINS model, which had been developed through intensive interaction with national experts.

A set of default emission fractions for N components for individual compartments of the overall process has been developed by the EAGER group. EAGER is a network of agricultural scientists from different countries (www.eager.ch) aiming for harmonizing emission modelling in Europe. Results of their work have been published in the EMEP/EEA emission inventory guidebook (EMEP/EEA, 2009). We understand that the emission fractions used for NH_3 (EMEP/EEA, 2009) are representative of a situation without abatement ("no control option").

In order to prepare this default information as an input file for MHM, a computer program (makeinp.f90) was developed as a pre-processing tool to combine the input information and put it into the right format. The respective default parameters are listed in Appendix 6.

Specifically, the following information is used by makeinp.f90 and combined into a file that MHM can use as an input directly.

- Animal categories (Table A6-1).
- Excretion rates for animals from GAINS (Table A6-2). Rates are specific for each country, even if for countries under similar conditions also the identical rates may be used.
- Information on straw from EMEP/EEA (2009). This information is the same for every country (Table A6-3).
- Information on the fraction of the N excretion that is present as TAN from EMEP/EEA (2009). This information is the same for every country (Table A6-4).
- Information on the fraction of TAN emitted as NH_3, N_2O, NO_x, and N_2 was taken from EMEP/EEA (2009). This information is the same for every country (Table A6-5 through Table A6-8).
- Information on a reduction of the NH_3 emission fractions in case of abatement. Reduction factors were taken from GAINS data (Table A6-9). The factors are to be applied to the emission fractions (non-abatement case) developed by EMEP/EEA (2009). This information is the same for every country.

- In case of liquid manure it was assumed that part of the Norg mineralizes during storage (a fraction 0.10 of Norg is assumed to convert to TAN, according to EMEP/EEA, 2009). In case of solid manure it was assumed that immobilization occurs during storage (a fraction 0.0067 of the TAN is assumed to convert to Norg) (EMEP/EEA, 2009). This information is the same for every country.

The only difference in input across countries is the amount of N excreted. All other parameters are the same for all countries. This means also that the ratio between the emission fractions for N components (expressed in kg N animal^{-1} yr^{-1}) and the excretion rate (kg N animal^{-1} yr^{-1}) are the same for every country for one control option.

The program makeinp.f90 provides its output in exactly the format required by MHM. This also means that all data are resolved by country, even if default data (from EMEP/EEA, 2009) are not. Once country-specific information becomes available, these can be taken advantage of fairly easily. In principle, the program would allow to also consider more complex interactions, like the possible influence of N components on the CH_4 emission rate (only as soon as parameters become available, of course).

We applied MHM for all of Europe selecting all different combinations of country, animal category, and control option, presently used in GAINS. A total of about 5500 different situations were modelled, and the resulting country-specific emission factors have been compared to those currently implemented in GAINS.

Some selected results are presented here. We focus on liquid manure systems and dairy cows as these have been used for the comparison with the German model. Data refer to systems without any abatement. Variation due to abatement in MHM and in the current GAINS implementation are identical, thus a comparison of the effects of abatement would be meaningless. Data points represent individual countries.

Figure 5 shows the relationship between the NH_3 emissions for housing for the two models. While the average emission factors are quite similar between the two models, there is a slightly larger spread in GAINS and a considerable scatter for the individual data points. Consequently the regression coefficient is rather low. The reason for this is that MHM uses the same default emissions fractions for housing for all countries, whereas GAINS uses country-specific emission factors.

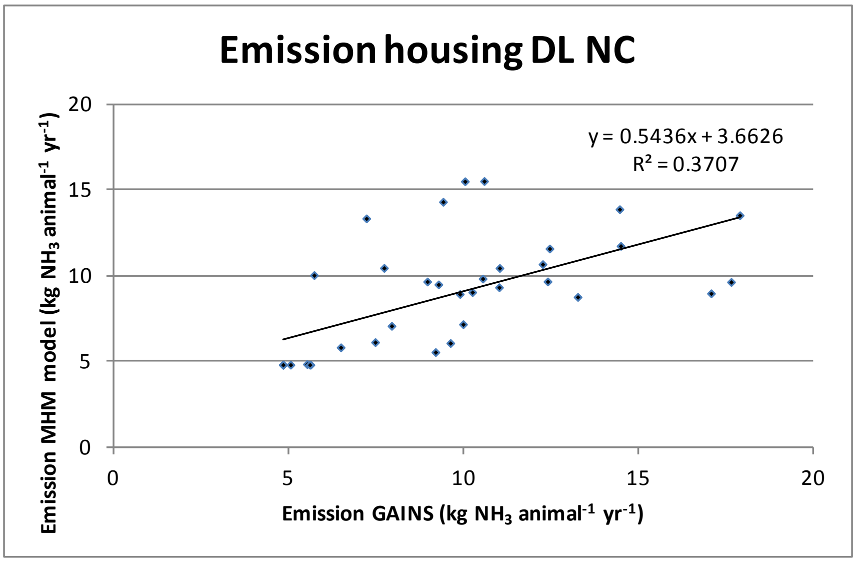

Figure 5. Emission factors of NH_3 from housing for dairy cows in a liquid manure system without any abatement: results of MHM vs. GAINS. Data points represent individual countries.

Due to the interdependence within the chain, differences in housing emissions also generate discrepancies in the other parts of the chain (storage and application). Still, as Figure 6 shows, emission factors for NH_3 emissionw during storage are somewhat better correlated between the models. The same holds for the emission after application (Figure 7). Also in these cases the spread is larger for GAINS than for MHM, even if in the case of storage this is all based on one outlier. It is also interesting to note that, except for this outlier, storage emission factors derived in MHM are all clearly larger than in GAINS.

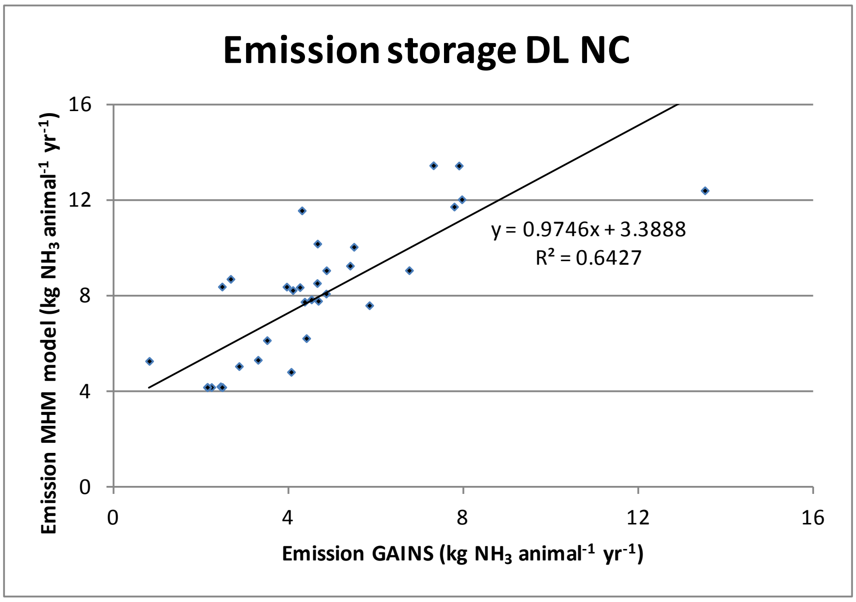

Figure 6. Emission factors of NH_3 from storage for dairy cows in a liquid manure system without any abatement: results of MHM vs. GAINS. Data points represent individual countries.

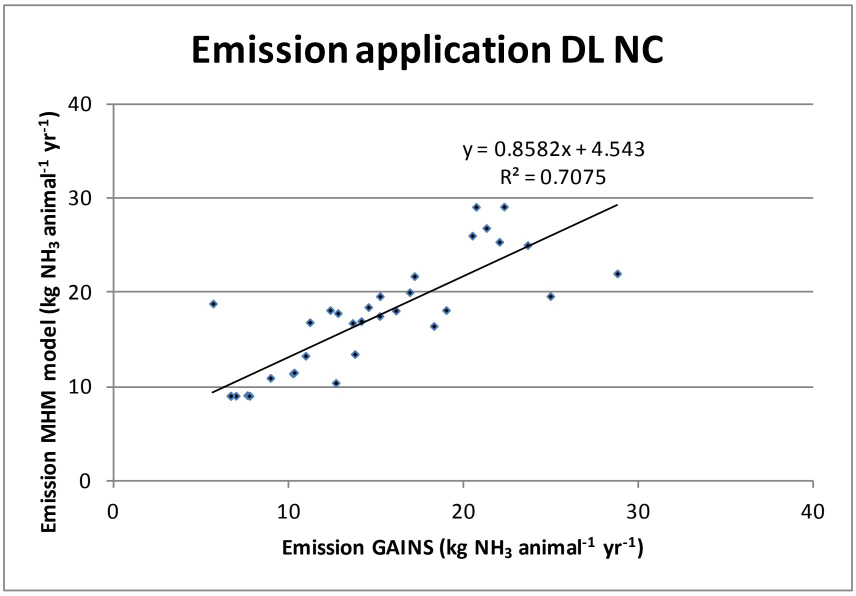

Figure 7. Emission factors of NH_3 after application housing for dairy cows in a liquid manure system without any abatement: results of MHM vs. GAINS. Data points represent individual countries.

For grazing, emission factors of MHM and GAINS agree only on the low end of the range. In countries with higher emission factors, MHM factors are around two thirds of those of GAINS only (Figure 8). This is caused by different emission fractions/factors used by the models. The discrepancy is not so much evident from the regression coefficient but becomes visible in the low slope of the regression curve.

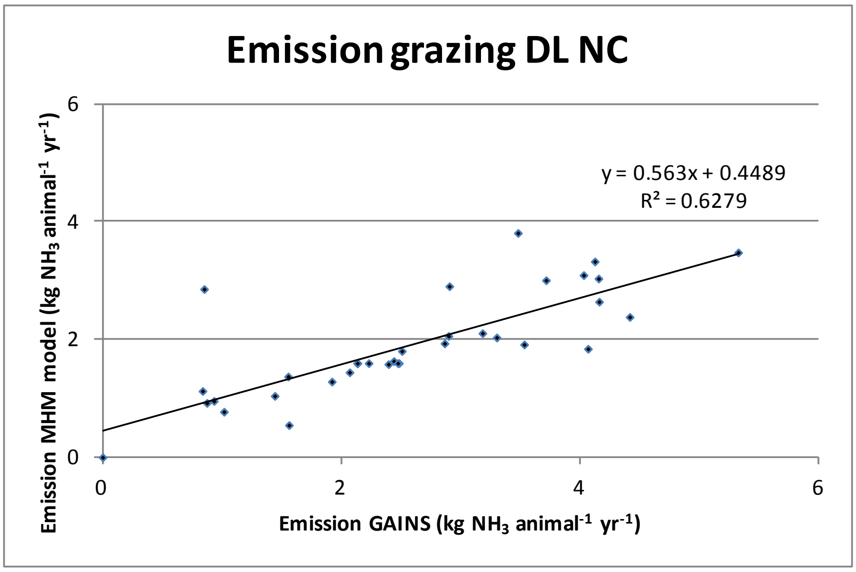

Figure 8. Emission factors of NH_3 during grazing for dairy cows without any abatement: results of MHM vs. GAINS. Data points represent individual countries.

The total of the individual emission stages is dominated by housing and the application stages. The result is presented in Figure 9 and shows both a reasonable agreement of the average emission factors and of the slopes, and the correlation between both models seems acceptable. The way the model works compensates a smaller release in one stage by increased emissions at the following stage. This seems to have affected the overall emission factors to become more similar than the individual stages, in addition to the more general effect of errors cancelling each other at a larger aggregation.

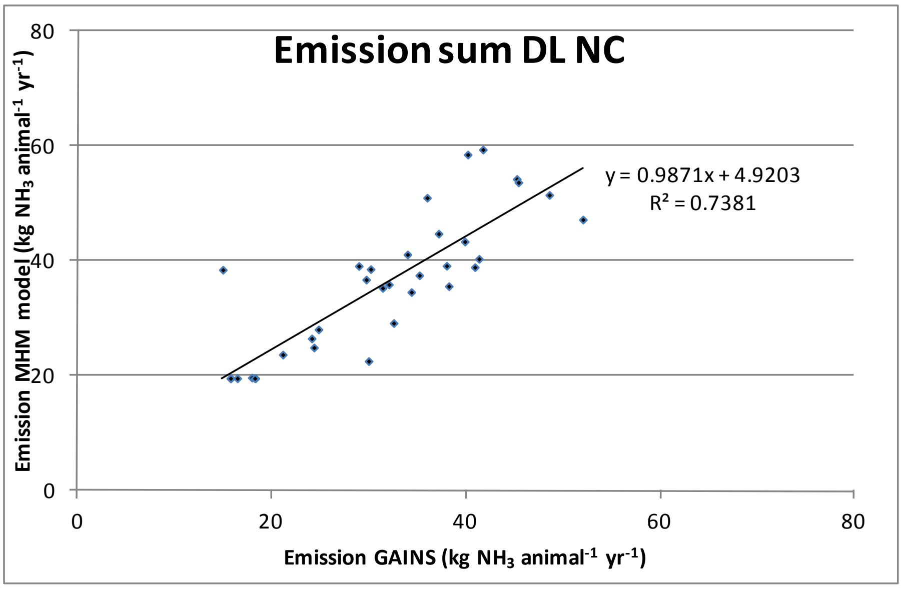

Figure 9. Total emission factors of NH_3 for dairy cows in a liquid manure system without any abatement (housing+storage+application+grazing): results of MHM vs. GAINS. Data points represent individual countries.

5 Obtaining country-specific information

The comparison between MHM and GAINS (which includes country-specific data), demonstrates the importance of using country-specific information when it comes to operating models on a high level of detail that are mimicking the information from national models. GAINS has successfully been extended with country-specific information over the years. Detailed national data, in principle, is available, but would not be fully compatible to MHM. Instead of trying to use data in MHM that are derived from GAINS we developed the idea to gather the information needed for MHM from the countries directly.

A questionnaire was developed and sent to the EAGER group of emission experts for comments and suggestions for improvements (Appendix 5). In getting MHM operational, we expect national experts to provide information, and use default emission fractions from EMEP/EEA (2009) for the remaining parts.

6 Discussion and conclusions

The MHM manure handling model uses information on emissions fractions to derive emission factors (kg N animal^{-1} yr^{-1}) for use in GAINS for nitrogen components (NH_3, N_2O, NO_x, N_2 emission to the air and NO_3^- emissions to water and the associated N_2O emission) and for CH_4. The model uses a mass flow approach, i.e. it follows the mass of manure N (and VS, respectively) through the different stages (compartments) of the manure handling process and takes into account the losses that have occurred in previous stages. The model differentiates between different nitrogen components (N_{org} and TAN) and different volatile solids (VS_d and VS_{nd})

The model makes it possible to derive emission factors for situations that GAINS could not handle in that detail so far: emission from yards, incineration of manure, direct spread of manure (directly transported from the housing to the field), NO_3^- from leakage of manure heaps and NO_3^- from runoff and the associated N_2O emissions. Moreover, the model can calculate emissions from biogas plants using mainly manure and includes the addition of organic waste material.

The model could use exactly the same information as the German model GAS-EM for N components for dairy cows in liquid manure systems. Perfect agreement (differences < 1%) was obtained for all components modelled: NH_3 emission from housing, yard, storage, application and grazing; N_2O, NO_x, N_2 emission from storage and CH_4 emission from storage and grazing.

MHM was used with the GAINS rates of manure excretion, GAINS emission reduction information and default EMEP/EEA (2009) emission fractions to generate emission factors for European countries. For that purpose, a pre-processing tool was developed that generates input files for the MHM model from tabulated input data.

Emission factors for NH_3 calculated by MHM were compared with the current GAINS emission factors. Differences between the model results were observed. One of the obvious reasons for these differences is that MHM uses the same information on emission fractions for all countries, whereas GAINS uses country-specific information obtained from direct interaction with country experts.

Given the importance of national information, there are in principle two ways to obtain data:

a. Extract information from GAINS that has originally been submitted by national experts. However, this information will not provide all input for MHM, and will deliver emission factors instead of emission fractions needed for the mass flow approach of MHM.

b. Obtain country-specific information for the mass-flow approach used in MHM, maintain full transparency about which information has been contributed by countries, and what data are being provided as default.

We conclude that possibility b) is by far preferable, as it also allows incorporating most recent information. A questionnaire was developed for national experts to collect the necessary information

In this way, MHM will be able to generate emission factors for the GAINS model for N components. Data incorporation into the MHM and further on into GAINS can be done in a transparent way, so that country experts can check and improve it.

Calculation of CH_4 emission from liquid manure was incorporated along the concept developed by Sommer et al. (2004), which differentiates between VS_d and VS_{nd}. The emission factor is then expressed as a fraction of the amount of VS_d and VS_{nd} and incorporated in MHM. Sommer et al. (2004) describe how this emission factor can be modelled as a function of temperature (see also Sommer et al., 2009). The parameterization of the temperature is not part of the MHM concept, but it could be dealt with by incorporating it in the MHM preprocessor. (In principle, it would be possible to obtain different emission factors for different climates and even to model the effect of climate change on the CH_4 emission.)

For CH_4 MHM gives excellent results for the alternative option when the IPCC parameterization is used as demonstrated in the comparison of the MHM with GAS-EM.

MHM can take into account organic waste added to a biogas plant. A point that needs further development is the parameterization of CH_4 emission from biogas plants for use in general models as GAINS. This needs further study of the literature and exploration of the possibilities of different parameterizations that make sense for both the generation of CH_4 emission from manure outside biogas plants as well as the generation of CH_4 in biogas plants.

MHM provides a consistent and transparent tool for delivering emission factors for components from animal manure for the GAINS model. The preprocessor makes it possible to generate input data for the MHM from different sources in an efficient way.

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Appendix 1. Detailed description of the MHM

General processes in compartments

Start of process chain (inputs)

The excretion of the animal in N and VS (volatile solids) is first split up into TAN and Norg (for N) or in VS_d and VS_{nd} (for VS). Here the split up of N is shown as an example:

$$m_{excr-TAN} = f_{TAN} * m_{excr-N} \qquad \text{(Equation 1)}$$

where:

$m_{excr-TAN}$ = amount of TAN (kg N animal^{-1} period^{-1}),

f_{TAN} = fraction of TAN in the N excretion,

m_{excr-N} = amount of total N excreted (kg N animal^{-1} period^{-1}),

The amount of Norg in the excretion m_{Norg} (kg animal^{-1} N period^{-1}) is then found from:

$$m_{excr-Norg} = m_{excr-N} - m_{excr-TAN} \qquad \text{(Equation 2)}$$

The amount of VS_d and VS_{nd} in the excretion (m_{VSd} *and* m_{VSnd}) is calculated in the same fashion as is done for N, using f_{VSd}, to find the fraction of VS that is VS_d. The other part of the VS is then VS_{nd}.

If the CH_4 emission is calculated with the IPCC method, which only uses VS (IPCC, 2006), this split up is not necessary and f_{VSd} is then set to 1 (all VS is then assumed to be VS_d and no VS_{nd} is present).

In the German emission model GAS-EM a small amount of Norg originating from skin and hair of cattle is also taken into account and is added to the amount of Norg from the excretion. As the MHM was to be compared with the German emission model GAS-EM, this source of Norg was also incorporated in MHM. Normally this amount is not of importance, compared to the uncertainty in the data.

$$m_{Norg} = m_{excr-Norg} + m_{skin-Norg} \qquad \text{(Equation 3)}$$

where:

$m_{skin\text{-}Norg}$ = amount of Norg originating from skin and hair.

In the following $m_{excr\text{-}TAN}$ is called m_{TAN}.

In the following step m_{TAN}, m_{Norg}, m_{VSd}, m_{VSnd} are distributed over the compartments where animals are present: housing, yard and grazing. It should be noted that not in all cases there are animals in these compartments.

An example of the calculation of the distribution for m_{TAN}:

$$m_{TAN-R} = f_R * m_{TAN} \qquad \text{(Equation 4)}$$

where:

$m_{TAN\text{-}R}$ = amount of TAN in compartment R (kg N animal^{-1} period^{-1}),
f_R = fraction of manure that goes to compartment R.

The amount of Norg, VS_d and VS_{nd} are distributed in the same way over the different compartments, using the distribution fractions so that for each compartment the amount of them is known ($m_{TAN\text{-}R}$, $m_{Norg\text{-}R}$, $m_{VSd\text{-}R}$, $m_{VSnd\text{-}R}$).

Additional input

As can be seen there is input into the compartment, which is coming from a previous step in the manure handling chain (“In”) and there is additional input (“Additional in”) that is e.g. from bedding material (straw, saw dust, wood chippings) added to a housing or to a manure storage facility or from organic waste added to a biogas installation.

The additional input is given by the equation below. In this equation $m_{y\text{-}R}$ on the right hand side is the amount of component y before adding the additional input, whereas $m_{y\text{-}R}$ on the left hand side is the amount after:

$$m_{y-R} = m_{y-R} + m_{y-Additonal} \qquad \text{(Equation 5)}$$

where:

$m_{y\text{-}R}$ = amount of component y in compartment R (kg N animal^{-1} period^{-1}),

$m_{y\text{-}Additional}$ = amount of component y added (kg N animal^{-1} period^{-1}).

In the above equations y = TAN, Norg, VS_d, VS_{nd}.

Conversion of N

In the compartment also conversion can occur, depending on the C/N ratio. If there is not much C present, mineralization will occur by which Norg is converted to TAN. If much C is present, e.g. due to added bedding material, TAN will be immobilized to Norg. The conversion in the model occurs before any emissions occur.

$$m_{Norg-R} = m_{Norg-R} * (1 - f_{Norg-TAN-R}) + m_{TAN-R} * f_{TAN-Norg-R}$$

(Equation 6)

and

$$m_{TAN-R} = m_{TAN-R} * (1 - f_{TAN-Norg-R}) + m_{Norg-R} * f_{Norg-TAN-R}$$

(Equation 7)

where:

$f_{Norg\text{-}TAN\text{-}R}$ = fraction of Norg converted to TAN in compartment R,
$f_{TAN\text{-}Norg\text{-}R}$ = fraction of TAN converted to Norg in compartment R.

Conversion of VS

VS_{nd} can be converted to VS_d and vice versa:

$$m_{VSnd-R} = m_{VSnd-R} * (1 - f_{VSnd-VSd-R}) + m_{VSd-R} * f_{VSd-VSnd-R}$$

(Equation 8)

and

$$m_{VSd-R} = m_{VSd-R} * (1 - f_{VSd-VSnd-R}) + m_{VSnd-R} * f_{VSnd-VSd-R}$$

(Equation 9)

where:

$m_{VSnd\text{-}R}$ = amount of VS_{nd} in compartment R (kg VS animal^{-1} period^{-1}),
$m_{VSd\text{-}R}$ = amount of VS_d in compartment R (kg VS animal^{-1} period^{-1}),
$f_{VSnd\text{-}VSd\text{-}R}$ = fraction of VS_{nd} converted to VS_d in compartment R,
$f_{TAN\text{-}Norg\text{-}R}$ = fraction of VS_d converted to VS_{nd} in compartment R.

N emissions

For the N emissions the following type of equation is used:

$$ef_{x-R} = f_{x-R} * m_{TAN-R} \qquad \text{(Equation 10)}$$

where:

$ef_{x\text{-}R}$ = emission factor for compartment R for nitrogen component x (kg N animal^{-1} period^{-1}),

$f_{x\text{-}R}$ = fraction of TAN lost from compartment R as component x.

In the above equations x is: NH_3, N_2O, NO, N_2, NO_3^-. The emission of all but the last components are to the air. The NO_3^- emission is due to leakage from manure heaps without a concrete floor.

The NO_3^- runoff/leakage from compartment R can also give rise to N_2O emission. A fraction of the NO_3^- lost is later converted to N_2O.

$$ef_{N2O-runoff-R} = f_{N2O-NO3-runoff-R} * ef_{NO3-R} \qquad \text{(Equation 11)}$$

where:

$ef_{N2O\text{-}runoff\text{-}R}$ = emission factor for N_2O due to NO_3^- runoff/leakage from compartment R (kg N animal^{-1} period^{-1}),

$f_{N2O\text{-}NO3\text{-}runoff\text{-}R}$ = fraction of N in NO_3^- in runoff/leakage from compartment R, which is lost as N_2O (kg N animal^{-1} period^{-1}).

The amount of N_2O generated in this way is then subtracted from the amount of NO_3^- originally calculated to find the remaining amount of NO_3^-. In the equation below $ef_{NO3\text{-}R}$ on the right hand side is the amount of NO_3^- prior to N_2O emission, whereas $ef_{NO3\text{-}R}$ on the left hand side is the amount of NO_3^- after:

$$ef_{NO3-R} = ef_{NO3-R} - ef_{N2O-runoff-R} \qquad \text{(Equation 12)}$$

Alternative option for NH_3 emission from grazing

There is a possibility in the model to calculate the emission of NH_3 from grazing in a different way: as a fraction of the amount of total N excreted while grazing. This method is e.g. used in Germany and is the method the IPCC (2006) uses. In order to make this calculation the amounts of TAN and Norg excreted have to be added:

$$ef_{NH3-Grazing} = f_{NH3-Ntot\_Grazing} * \left(m_{TAN-Grazing} + m_{Norg-Grazing}\right)$$

(Equation 13)

where:

$ef_{NH3\text{-}Grazing}$ = emission factor for grazing for NH_3 (kg N animal^{-1} period^{-1}),

$f_{NH3\text{-}Ntot\_Grazing}$ = fraction of total N lost as NH_3 during grazing.

Alternative option for N_2O emission from manure

There is an option in the model to calculate the N_2O emission from manure during storage (not from NO_3^- in runoff/leaching) with the IPCC (2006) method, where emission is expressed as a fraction of the N excretion in the housing (the IPCC does not describe what is happening on yards). The problem is, however, that then in some cases the emission of N-components from the housing and from storage can be so large that more TAN is used than is present (Dämmgen and Hutchings, 2008). If the sum of the fractions of TAN that is emitted as N components from the storage is larger than 1, all N emissions from the storage are reduced proportionally so that no TAN is left at all (which is not very realistic). In the MHM this includes also the NO_3^- leaked away, which was not taken into account in Dämmgen and Hutchings (2008).

$$sum_f = f_{NH3-Stor1} + f_{N2O-Stor1} + f_{NOx-Stor1} + f_{N2-Stor1} + f_{NO3-Stor1} \qquad \text{(Equation 14)}$$

where:

sum_f = sum of emission fractions for storage1,
$f_{x\text{-}Stor1}$ = fraction of N component x emitted from storage1.

If this sum is larger than 1, then the fractions $f_{x\text{-}Stor1}$ of all N components (expressed as a fraction of TAN) that are emitted are multiplied by $1/sum_f$.

It should be noted, that in case no TAN is left at all, the N_2O emission in this case will be lower than is calculated by the IPCC (2006) method.

Emission of CH_4

For CH_4 emission the following equation is used:

$$ef_{CH4-VS*-R} = fact_{VS*-R} * m_{VS*-R} \qquad \text{(Equation 15)}$$

where:

$ef_{CH4\text{-}VS*\text{-}R}$ = emission factor for CH_4 for compartment R (kg CH_4 animal^{-1} period^{-1}),

$fact_{VS*\text{-}R}$ = factor by which $m_{VS*\text{-}R}$ has to be multiplied to find the loss of CH_4 from compartment R.

The loss of VS_d or VS_{nd} in the reservoir is then calculated from the CH_4 emission (it should be noted that part of this loss is due to the CO_2 emission occurring at the same time):

$$m_{loss-VS*-R} = ef_{CH4-VS*-R} * rm_{VS*-CH4-R} \qquad \text{(Equation 16)}$$

where:

$m_{loss-VS*-R}$ = loss of VS_d or VS_{nd} in compartment R lost due to the generation of CH_4 and CO_2 (kg VS $animal^{-1}$ $period^{-1}$)

$rm_{VS*-CH4-R}$ = amount VS_d or VS_{nd} lost per amount CH_4 produced in compartment R (kg VS*/kg CH4)

In the present version of the model the ratio $rm_{VS*-CH4-R}$ has to be given for every compartment in the model where CH_4 is generated. In theory one could think of giving the ratio $rm_{VS*-CH4-R}$ together with each input of VS to the model; but as also degradation might change that ratio, which would never be captured, adding further complexity did not seem warranted. The values of $fact_{VS*-R}$ and $rm_{VS*-CH4-R}$ for liquid manure can e.g. be retrieved from the model of Sommer et al. (2004) – see Appendix 2.

Finally the amount of VS_d or VS_{nd} present is given by:

$$m_{VS*-R} = m_{VS*-R} - m_{loss-VS-R} \qquad \text{(Equation 17)}$$

The model thus maintains the remaining matter available for methane production in the next stage as VS, without actually keeping a full carbon balance.

Alternative option emission of CH_4

As an alternative to the above calculation of the CH_4 emission the IPCC method can be used (IPCC, 2006). The IPCC only addresses the emission of CH_4 from manure storage and during grazing, using a method involving a maximum methane producing capacity B_0 and methane conversion factor *MCF*. In the MHM there is an option to use this type of approach also for some other compartments:

$$ef_{CH4-R} = B_0 * \rho_{CH4} * MCF_R * m_{VS-R} \qquad \text{(Equation 18)}$$

where:

ef_{CH4-R} = emission factor CH_4 for compartment R (kg CH_4 animal^{-1} period^{-1}),
m_{VS-R} = amount of volatile solid (kg VS animal^{-1} period^{-1}),
B_0 = maximum methane producing capacity (m^3 CH_4 kg^{-1} VS). This factor is a function of the climatic zone,
ρ_{CH4} = density of methane (0.67 kg m^{-3}),
MCF_R = methane conversion factor for compartment R: fraction of B_0, which is converted to CH_4. Note that the IPCC gives the MCF in %, whereas it here is given as a fraction.

The IPCC (2006) has no description of how to correct the amount of VS for the loss. This does not matter in this approach as there is no further VS loss after the first loss in a chain. The IPCC (2006) approach is modelled by using the VS_d compartment for all VS in the model. The VS_{nd} compartment is then empty in the model.

Also here the loss of VS is calculated using a ratio $rm_{VS*-CH4-R}$, which is different from the one used for VS_d and VS_{nd} for the same compartment in the model.

Compartment-specific processes

Housing: Air leaving the building

The emissions that have taken place in the housing can leave the building in three different ways:

a. The air leaves the building without any treatment,
b. The air leaves the building via a biofilter,
c. The air leaves the building via a scrubber.

In case the air leaves the building without any treatment the emission factor is equal to the calculated emission factor previously given.

In case of a biofilter or a scrubber the following procedure is followed:

$$ef_{x-Housing-a} = ef_{x-Housing} * f_{x-Housing-a} \qquad \text{(Equation 19)}$$

where:

$ef_{x-Housing-a}$ = emission factor for component x after passing the biofilter/scrubber (kg animal^{-1} period^{-1}),
$ef_{x-Housing}$ = emission factor for component x from housing prior to passing the biofilter/scrubber (kg animal^{-1} period^{-1}),
$f_{x-Housing-a}$ = fraction of the component that passes the biofilter/scrubber and is released into the atmosphere.

In the above equation the suffix x stands for NH_3, N_2O, NO, N_2 or CH_4 and the suffix a for biofilter or scrubber.

In case of a biofilter or a scrubber it is assumed that the captured component comes into the storage facility 1. For the time being is implicitly assumed that the material from the biofilter itself does not give rise to any emissions, but this may not be true. At the moment the material (TAN, Norg, VS_d, VS_{nd}) used for the biofilter is not input to the model. Moreover, at the moment no conversion of components is assumed and in biofilters there is conversion of components. This is not realistic, but the contribution is not likely to be large. A literature survey is needed before this situation can described satisfactorily.

Housing: Manure leaving the building

The manure from the housing can leave the building in three ways:

a. The manure is transported to the storage facility storage1.
b. The manure is spread directly on the field. This is e.g. practiced in the UK and reduces the CH_4 emission as there is no CH_4 emission from storage.
c. The manure is incinerated. This is practiced in the UK for dry poultry manure. At the moment it is assumed that no emissions occur during incineration in the MHM as these emissions should be taken into account in another part of the GAINS model.

Yard

The manure can leave the yard in two ways:

a. The manure is transported to the storage facility storage1.
b. The manure is incinerated. At the moment it is assumed that no emissions occur during incineration in the MHM as these emissions should be taken into account in another part of the GAINS model.

At the moment there is no option for direct spread of manure from the yard.

Storage1

Storage1 is a compartment in which manure and other material received from the housing, the yard, the biofilter and/or the scrubber is stored.

Bedding material containing TAN, Norg, VS_d and VS_{nd} can be added to the storage facility, just as described under “Housing”.

If manure is not stored on a concrete floor or in a sealed tank, some NO_3^- can leak away and and later give rise to N_2O emissions. This is modelled in the same way as runoff and N_2O emission under “Yard”.

Storage1: manure leaving the storage facility The IPCC (IPCC, 2006) addresses the emission of CH_4 from manure storage and during grazing, using a method involving a maximum methane producing capacity B_0 and methane conversion factor *MCF*. This alternative method can also be applied to calculate the emission of CH_4 during storage and the same as described under "Housing".

The manure from storage1 goes either to a biogas plant or is applied on the field. The model contains switches in the input file that do that.

Biogas plant: Added waste

Not only manure is entering the biogas plant, but also organic waste that is often used to enhance the production of CH_4. This organic waste can come from many different sources: spent crops and fruits, waste from animals (slaughterhouse waste, fat, blood, meat and bone meal, stomach content of pigs, rumen content of cattle), but also ordinary crops and waste products (silage, grass, leaves of sugar beet), waste from the food and fodder industry, wastes from households and gastronomy and wastes from the pharmaceutical and other industries (e.g. glycerine) (Deublin and Steinhauser, 2008). The organic waste cannot only enhance the production of CH_4, but in some cases, toxic substances can be present, which reduce the production. Moreover, liquid pig manure can contain so much copper that the biogas production is reduced.

The model contains the possibility of additional input of TAN, Norg, VS_d, VS_{nd} from organic waste. Here an example is given for VS_d.

$$m_{VSd-Biogasplant} = m_{VSd-Stor1} + m_{VSd-Waste} \qquad \text{(Equation 20)}$$

where:

$m_{VSd\text{-}Biogasplant}$ = amount of VSd in the biogasplant (kg animal^{-1} period^{-1}),
$m_{VSd\text{-}Stor1}$ = amount of VSd from storage1 (kg animal^{-1} period^{-1}),
$m_{VSd\text{-}Waste}$ = amount of VSd in the waste (kg animal^{-1} period^{-1}).

As can be seen the amount of added waste per animal and per period needs to be known. If most of the VS in the biogas plant does not come from animal manure, there is of course no good relation between the production of CH_4 and the amount of VS in manure. In that case it is not so useful to use the MHM.

Biogas plant: Emissions to the air and use for energy

The production of all gases is calculated in the same way as for emission factors for all compartments. The difference is that the produced amount stays in the biogas plant and only a fraction will be emitted to the atmosphere.

So far, emissions have been calculated for the gases produced in the biogas plant. These gases are not yet emitted to the atmosphere. In this step the emission of the gases from the biogas plant as well as the amount of all gases that is used for energy production is calculated from:

$$ef_{z-Biogasplant} = f_{z-Biogasplant} * ef_{z-Biogasplant\_previous} \qquad \text{(Equation 21)}$$

$$m_{z-Energy-Biogasplant} = ef_{z-Biogasplant\_previous} - ef_{z-Biogasplant} \qquad \text{(Equation 22)}$$

where:

$ef_{z\text{-}Biogasplant\_previous}$ = production of gas z in biogas plant (kg N or CH_4 animal^{-1} period^{-1}) calculate in the same way as normal emission factors in the model,
$ef_{z\text{-}Biogasplant}$ = emission factor for gas z from biogas plant to the air (kg N or CH_4 animal^{-1} period^{-1}),
$f_{z\text{-}Biogasplant}$ = fraction of the produced gas z that is emitted from the biogas plant,
$m_{z\text{-}Energy\text{-}Biogasplant}$ = amount of gas z used for energy production (kg N or CH_4 animal^{-1} period^{-1}).
In the above equations z stands for NH_3, N_2O, NO_x, N_2 or CH_4.

It should be noted that the present version of the model does not address any treatment of the gases.

Storage2

Storage2 is a compartment that is only used to store the manure and waste (digestate) that remains after the treatment in the biogas plant. The reason for a separate compartment is that the properties of the digestate are different from those of the manure that was input to the biogas plant and for that reason also the associated emissions.

Appendix 2. Calculation of the CH_4 emission by Sommer et al.

Sommer et al. (2004) made a model for CH_4 emission from liquid manure stored in housings and in outside stores. This model has also been used to estimate the production of biogas after addition of organic waste to the manure (Sommer, personal communication, University of Southern Denmark, Odense, Denmark, 2010). In their model they split up VS (volatile solids) into VS_d (degradable VS) and VS_{nd} (non-degradable VS, also called slowly degradable VS). VS_d consists of lipids, proteins, volatile fatty acids (mainly acetic acid) and carbohydrates and constitutes about 80% of the VS in liquid manure from fatteners and about 70% of the VS in liquid manure from dairy cows (Sommer et al., 2009).

The fraction of VS_d in slurry to be used in the equation of Sommer et al. (2004) can be estimated from:

$$\frac{c_{VSd}}{c_{VS}} = \frac{B_0^{'}}{yield_{max}} \qquad \text{(equation A2-1)}$$

where:

c_{VSd}	= concentration of VS_d in slurry (kg VS kg^{-1} slurry),
c_{VS}	= concentration of VS, i.e. the sum of the concentrations of VS_d and VS_{nd} (kg VS kg^{-1} slurry),
$B_0^{'}$	= maximum methane producing capacity during anaerobic batch digestion in the laboratory (kg CH_4 kg^{-1} VS),
$yield_{max}^{'}$	= potential yield (kg CH_4 kg^{-1} VS)

Sommer et al. (2004) and Sommer (personal communication, University of Southern Denmark, Odense, Denmark) calculate the emission rate with the following Arrhenius type of equation, which gives the emission rate as a function of temperature:

$$F(T) = c_{VSd} b_{VSd} \exp[\ln(A) - (E/RT)] + c_{VSnd} b_{VSnd} \exp[\ln(A) - (E/RT)] \qquad \text{(Equation A2-2)}$$

where:

$F(T)$	= emission rate (g CH_4 kg^{-1} slurry h^{-1}),
c_{VSd}	= concentration of VS_d in slurry (kg VS kg^{-1} slurry),
c_{VSnd}	= concentration of VSn_d in slurry (kg VS kg^{-1} slurry),
b_{VSd}, b_{VSnd}	= correcting factors (no dimensions),
A	= Arrhenius parameter (g CH_4 kg^{-1} VS h^{-1}),
E	= apparent activation energy (J mol^{-1}),
R	= gas constant (8.314 J K^{-1} mol^{-1}),

T = temperature (K).

Sommer et al. (2004) give the following values for the parameters in the above equation:

Table A2-1. Parameter values in the Sommer et al. (2004) equation.

Parameter	**Value for cattle**	**Value for pigs**
ln(A), store in-house	44.29	44.22
ln(A), store outside	43.33	43.21
E	1.127×10^5	1.127×10^5
b_{VSd}	1	1
b_{VSnd}	0.01	0.01

The Sommer et al. (2004) equation can be used to calculate the CH_4 emission rate for different seasons and for different climatic zones, using different time-dependent slurry removal procedures (see Sommer et al., 2009). Information on the amounts of manure stored indoors and outside are needed, as well as on storage times and temperature variation over the year. The typical time step for modelling is one day. As emissions are presented as a function of temperature, this equation can also be used to predict the change in CH_4 emission due to climate change.

It should be noted that Sommer et al. (2004) calculate the amount of CH_4 produced as function of the amounts of different types of VS present. They do not provide information on the amount of VS consumed to produce the amount of CH_4 that is produced.

Appendix 3. Potential production of CH_4

The maximum possible (= potential) production of CH_4 follows the following equation (Deublin and Steinhauser, 2008, p. 89):

$C_cH_hO_oN_nS_s + y\ H_2O \rightarrow x\ CH_4 + n\ NH_3 + s\ H_2S + (c - x)\ CO_2$

where:

x = (1/8)*(4c + h – 2o – 3n – 2s)

y = (1/4)*(4c – h – 2o + 3n + 2s)

(In this book the equation for y contains the term +3s, this does not give the right balance between number of moles before and after the reaction. It is concluded that there is apparently an error and this term should be +2s, which was confirmed by the author Prof. Deublin).

The mass (kg) of an organic component that is part of the VS and is used to produce 1 kg CH_4 is given by:

$$rm_{VS-CH4} = \frac{mol_{VS}\ M_{VS}}{mol_{CH4}\ M_{CH4}}$$

where:

mol_{VS} = mole VS component used in the reaction,

M_{VS} = molecular mass of the VS component,

mol_{CH4} = mole CH_4 generated in the reaction,

M_{CH4} = molecular mass of CH_4.

Deublin and Steinhauser (2008) give the following reactions for formation of CH_4 from specific components. This information can be derived from the above equations. The calculated rm_{VS-CH4} is given in parentheses (kg VS/kg CH_4) :

Carbohydrates: $C_6H_{12}O_6 \rightarrow 3\ CO_2 + 3\ CH_4$ (3.74)

Fats: $C_{12}H_{24}O_6 + 3\ H_2O \rightarrow 4.5\ CO_2 + 7.5\ CH_4$ (2.20)

Proteins: $C_{13}H_{25}O_7N_3S + 6\ H_2O \rightarrow 6.5\ CO_2 + 6.5\ CH_4 + 3\ NH_3 + H_2S$ (3.52)

Sommer et al. (2009) present formulas for the organic components making up $\mathbf{VS_d}$ in fattening pig slurry and dairy cow slurry and using the above equations the reaction products are found as well as rm_{VS-CH4}, which is given in parentheses:

Lipids:	$C_{57}H_{104}O_6 + 28\ H_2O \rightarrow 40\ CH_4 + 17\ CO_2$	(1.38)
Protein:	$C_5H_7O_2N + 3\ H_2O \rightarrow 2.5\ CH_4 + NH_3 + 2.5\ CO_2$	(2.82)
VFA (acetic acid):	$C_2H_4O_2 \rightarrow CH_4 + CO_2$	(3.74)
Carbohydrate:	$C_6H_{10}O_5 + H_2O \rightarrow 3\ CH_4 + 3\ CO_2$	(3.37)

Sommer et al. (2009) give also the fraction of the above components as well as carbohydrates that are VS_{nd}. From those values an average value of $rm_{VS\text{-}CH4}$ for VS_d of 2.81 for fattening pig slurry is obtained and a value of 3.04 for dairy cows.

A rough estimate for $rm_{VS\text{-}CH4}$ for liquid manure is 2.9 kg VS/kg CH_4 according to Sommer (personal communication, University of Southern Denmark, Odense, Denmark, 2010).

It should be noted that the value of $rm_{VS\text{-}CH4}$ can be different for other types of manure or for organic waste or agricultural products. Moreover, the real production is less than the maximal (potential) production. This could have some influence on the value of $r_{VS\text{-}CH4}$.

With regard to biogas production Deublin and Steinhauser (2008, p. 89) mention that S remains in the residue and part of the CO_2 binds to NH_3. One may assume that their water solubility decreases their volatility such that these components also stay in the residue. CH_4 is hardly soluble in water, thus is enriched in the produced gas such that the produced gas consists preferentially of CH_4 (71 vol% as reported by Deublin and Steinhauser).

Appendix 4. Example of a MHM input file

```
Used for man4.f90, version November 2010
After addition of rm_VS*_CH4


*****
1           ! ioutput_conversion, 1 = N/C are converted to NH3, N2O, CH4 to C etc., 0 = N/ are not converted
1           ! nregion
1           ! nactiv
1           ! nyear The input parameters below have to be repeated for each period (iperiod gets then different
        values); ##### after each period!
ALBA
NC
2000
1           ! nperiod                         = total number of actual periods (parts of a year, or a whole year)
1           ! iperiod                         = actual period
    55.000  ! 01    fl_excr_n                 = excretion flux of N  (kg N period-1)
1400.       ! 01    fl_excr_vs                = excretion flux of VS (volatile solids)  (kg VS period-1)
2.0         ! 01    fl_skin_n                 = loss of N from skin and hair (kg N period-1)
 0.60000    ! 01    frac_excr_tan             = fraction of the excretion that is in the form of TAN
 1.         ! 01    frac_excr_vsd             = fraction of the excretion that is in the form of VSd (volatile solid
        degradable)
 0.60000    ! 02    frac_excr_house           = fraction of the excretion that occurs in house
 0.10000    ! 02    frac_excr_yard            = fraction of the excretion that occurs in yard
 0.30000    ! 02    frac_excr_graz            = fraction of the excretion that occurs during grazing
 1.         ! 03    f_straw_house(itan)       = flux of TAN from straw to house  (kg N period-1 or kg VS period-1)
 2.         ! 03    f_straw_house(inorg)      = flux of Norg from straw to house  (kg N period-1 or kg VS period-1)
 3.         ! 03    f_straw_house(ivsd)       = flux of VSd  from straw to house  (kg N period-1 or kg VS period-1)
 4.         ! 03    f_straw_house(ivsnd)      = flux of VSnd from straw to house  (kg N period-1 or kg VS period-1)
 0.11       ! 03    frac_house_norg_tan       = fraction of Norg that is converted to TAN in house
 0.12       ! 03    frac_house_tan_norg       = fraction of TAN that is converted to Norg in house box
 0.1        ! 03    frac_house_vsnd_vsd       = fraction of VSnd that is converted to VSd
 0.200      ! 03    frac_house_tan_nh3        = fraction of TAN that is lost as NH3 in house
 0.01       ! 03    frac_house_tan_n2o        = fraction of TAN that is lost as N2O in house
 0.02       ! 03    frac_house_tan_nox        = fraction of TAN that is lost as NOx in house
 0.03       ! 03    frac_house_tan_n2         = fraction of TAN that is lost as N2 in house
 1          ! 03    imanure_house_ch4         = indicator: 1 = Sven Sommer s method, 2 = IPCC s method
 0.1        ! 03    fact_house_vsd_ch4        = factor by which amount of VSd (kg period-1) has to be multiplied to
        find CH4 emission (kg CH4 period-1) in house
 2.8        ! 03    rm_house_vsd_ch4          = kg VSd lost per kg CH4 produced
 0.12       ! 03    fact_house_vsnd_ch4       = factor by which amount of VSnd (kg period-1) has to be multiplied to
        find CH4 emission (kg CH4 period-1)
 3.0        ! 03    rm_house_vsnd_ch4         = kg VSnd lost per kg CH4 produced
 0.1        ! 03    B0_house                  = maximum methane producing capacity (m3 CH4 kg-1 VS) IPCC method
 0.01       ! 03    MCF_house                 = methane conversion factor (fraction) IPCC method
 2.9        ! 03    rm_house_vs_ch4           = kg VS lost per kg CH4 produced
1           ! 03    iair_house_out            = indicator: indicates in which way the air leaves the house. Possible
        values: 1 = without any treatment, 2 = via biofilter, 3 = via scrubber
2           ! 03    imanure_house_out         = indicator: indicates in which way the manure leaves the house.
        Possible values: 1 = to stor1, 2 = : to direct, 3 = to incin
 0.         ! 04    frac_scrub_air(inh3)      = fraction of NH3 in the scrubber that is RELEASED to the air
 0.         ! 04    frac_scrub_air(in2o)      = fraction of N2O in the scrubber that is RELEASED to the air
 0.         ! 04    frac_scrub_air(inox)      = fraction of NOx in the scrubber that is RELEASED to the air
 0.         ! 04    frac_scrub_air(in2)       = fraction of N2  in the scrubber that is RELEASED to the air
 0.         ! 04    frac_scrub_air(ich4)      = fraction of CH4 in the scrubber that is RELEASED to the air
 0.         ! 05    frac_biof_air(inh3)       = fraction of the flux of NH3 that is emitted from the biofilter to the
        air
 0.         ! 05    frac_biof_air(in2o)       = fraction of the flux of N2O that is emitted from the biofilter to the
        air
 0.         ! 05    frac_biof_air(inox)       = fraction of the flux of NOx that is emitted from the biofilter to the
        air
 0.         ! 05    frac_biof_air(in2)        = fraction of the flux of N2  that is emitted from the biofilter to the
        air
 0.         ! 05    frac_biof_air(ich4)       = fraction of the flux of CH4  that is emitted from the biofilter to
        the air
 1.         ! 06    f_straw_stor1(itan)       = flux of TAN  from straw to stor1  (kg N period-1 or kg VS period-1)
 2.         ! 06    f_straw_stor1(inorg)      = flux of Norg from straw to stor1  (kg N period-1 or kg VS period-1)
 3.         ! 06    f_straw_stor1(ivsd)       = flux of VSd  from straw to stor1  (kg N period-1 or kg VS period-1)
 4.         ! 06    f_straw_stor1(ivsnd)      = flux of VSnd from straw to stor1  (kg N period-1 or kg VS period-1)
 0.1        ! 06    frac_stor1_norg_tan       = fraction of Norg converted to TAN
 0.11       ! 06    frac_stor1_tan_norg       = fraction of TAN that is converted to Norg in stor1
 0.         ! 06    frac_stor1_vsnd_vsd       = fraction of VSnd that is converted to VSd in stor1
 0.200      ! 06    frac_stor1_tan_nh3        = fraction of TAN that is lost as NH3 in stor1
1           ! 06    imanure_stor1_n2O         = indicator: indicates har frac_stor1_tan_n2o is calculated: 1 = just
        normally from TAN; 2 = from N excretion animal (IPCC, 2006)
 0.010      ! 06    frac_stor1_tan_n2o        = fraction of TAN (option 1) or N excreted (option 2) that is lost as
        N2O in stor1
 0.001      ! 06    frac_stor1_tan_nox        = fraction of TAN that is lost as NOx (option 1) in stor1 box, or
        number by which N2O emission has to be multiplied to get NOX emission (option 2)
 0.003      ! 06    frac_stor1_tan_n2         = fraction of TAN that is lost as N2 (option 1)in stor1 box, or number
        by which N2O emission has to be multiplied to get N2 emission (option 2)
 1          ! 06    imanure_stor1_ch4         = indicator: 1 = Sven Sommer s method, 2 = IPCC s method
 0.1        ! 06    fact_stor1_vsd_ch4        = factor by which amount of VSd (kg period-1) has to be multiplied to
        find CH4 emission (kg CH4 period-1) in stor1
 2.8        ! 06    rm_stor1_vsd_ch4          = kg VSd lost per kg CH4 produced in stor1
 0.12       ! 06    fact_stor1_vsnd_ch4       = factor by which amount of VSnd (kg period-1) has to be multiplied to
        find CH4 emission (kg CH4 period-1) in stor1
 3.0        ! 06    rm_stor1_vsnd_ch4         = kg VSnd lost per kg CH4 produced in stor1
 0.24       ! 06    B0_stor1                  = maximum methane producing capacity (m3 CH4 kg-1 VS) IPCC method
 0.10       ! 06    MCF_stor1                 = methane conversion factor (fraction) IPCC method
 2.9        ! 06    rm_stor1_vs_ch4           = kg VS lost per kg CH4 produced
 0.02       ! 06    frac_stor1_runoff_tan_no3  = fraction of TAN that is lost due to NO3- runoff in stor1
 0.01       ! 06    frac_stor1_runoff_no3_n2o  = fraction of NO3- of runoff that is lost as n2o in stor1
```

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2          ! 06    imanure_stor1_out          = indicator: indicates in which way the manure leaves stor1 possible
       values: 1 = to appl, 2 = to biogas
 0.        ! 07    f_waste_biogas             = flux of TAN  from waste to biogas  (kg N period-1 or kg VS period-1)
 0.        ! 07    f_waste_biogas             = flux of Norg from waste to biogas  (kg N period-1 or kg VS period-1)
 0.        ! 07    f_waste_biogas             = flux of VSd  from waste to biogas  (kg N period-1 or kg VS period-1)
 0.        ! 07    f_waste_biogas(ivsnd)      = flux of VSnd from waste to biogas  (kg N period-1 or kg VS period-1)
 0.        ! 07    frac_biogas_norg_tan       = fraction of Norg that is converted to TAN
 0.        ! 07    frac_biogas_vsnd_vsd       = fraction of VSnd that is converted to VSd
 0.        ! 07    frac2_biogas_tan_nh3       = fraction of TAN that is converted to NH3
 0.        ! 07    frac2_biogas_tan_n2o       = fraction of TAN that is converted to N2O
 0.        ! 07    frac2_biogas_tan_nox       = fraction of TAN that is converted to NOx
 0.        ! 07    frac2_biogas_tan_n2        = fraction of TAN that is converted to N2
 1         ! 07    imanure_biogas_ch4         = indicator: 1 = Sven Sommer s method, 2 = IPCC s method
 0.1       ! 07    fact2_biogas_vsd_ch4       = factor by which amount of VSd (kg period-1) has to be multiplied to
       find CH4 production (kg CH4 period-1) in biogas
 2.8       ! 07    rm_biogas_vsd_ch4          = kg VSd lost per kg CH4 produced in biogas
 0.12      ! 07    fact2_biogas_vsnd_ch4      = factor by which amount of VSnd (kg period-1) has to be multiplied to
       find CH4 emission (kg CH4 period-1) in biogas
 3.0       ! 07    rm_biogas_vsnd_ch4         = kg VSnd lost per kg CH4 produced in biogas
 0.1       ! 07    B0_biogas                  = maximum methane producing capacity (m3 CH4 kg-1 VS) IPCC method
 0.1       ! 07    MCF_biogas                 = methane conversion factor (fraction) IPCC method
 2.9       ! 07    rm_biogas_vs_ch4           = kg VS lost per kg CH4 produced in biogas
 0.        ! 07    frac2_biogas_air_nh3       = fraction of NH3 in box biogas that is emitted to the air
 0.        ! 07    frac2_biogas_air_n2o       = fraction of N2O in box biogas that is emitted to the air
 0.        ! 07    frac2_biogas_air_nox       = fraction of NOx in box biogas that is emitted to the air
 0.        ! 07    frac2_biogas_air_n2        = fraction of N2 in box biogas that is emitted to the air
 0.        ! 07    frac2_biogas_air_ch4       = fraction of CH4 in box biogas that is emitted to the air
 0.        ! 08    frac_stor2_norg_tan        = fraction of Norg converted to TAN
 0.        ! 08    frac_stor2_vsnd_vsd        = fraction of VSnd that is converted to VSd in stor2
 0.        ! 08    frac_stor2_tan_nh3         = fraction of TAN that is lost as NH3 in stor2
 0.        ! 08    frac_stor2_tan_n2o         = fraction of TAN that is lost as N2O in stor2
 0.        ! 08    frac_stor2_tan_nox         = fraction of TAN that is lost as NOx in stor2
 0.        ! 08    frac_stor2_tan_n2          = fraction of TAN that is lost as N2 in stor2
 1         ! 08    imanure_stor2_ch4          = indicator: 1 = Sven Sommer s method, 2 = IPCC s method
 0.1       ! 08    fact_stor2_vsd_ch4         = factor by which amount of VSd (kg period-1) has to be multiplied to
       find CH4 emission (kg CH4 period-1) in stor2
 2.8       ! 08    rm_stor2_vsd_ch4           = kg VSd lost per kg CH4 produced in stor2
 0.12      ! 08    fact_stor2_vsnd_ch4        = factor by which amount of VSnd (kg period-1) has to be multiplied to
       find CH4 emission (kg CH4 period-1) in stor2
 3.0       ! 08    rm_stor2_vsnd_ch4          = kg VSnd lost per kg CH4 produced in stor2
 0.1       ! 08    B0_stor2                   = maximum methane producing capacity (m3 CH4 kg-1 VS) IPCC method
 0.01      ! 08    MCF_stor2                  = methane conversion factor (fraction) IPCC method
 2.9       ! 08    rm_stor2_vs_ch4            = kg VS lost per kg CH4 produced in stor2
 0.550     ! 09    frac_appl_tan_nh3          = fraction of TAN in appl box that is lost as NH3 (dimensionless)
 0.001     ! 09    frac_appl_tan_n2o          = fraction of TAN in appl box that is lost as N2O (dimensionless)
 0.002     ! 09    frac_appl_tan_nox          = fraction of TAN in appl box that is lost as NOx (dimensionless)
 0.003     ! 09    frac_appl_tan_n2           = fraction of TAN in appl box that is lost as N2 (dimensionless)
 0.004     ! 09    fact_appl_vsd_ch4          = factor by which amount of VSd (kg period-1) has to be multiplied to
       find CH4 emission (kg CH4 period-1) in appl
 2.8       ! 09    rm_appl_vsd_ch4            = kg VSd lost per kg CH4 produced in appl
 0.005     ! 09    frac_appl_runoff_tan_no3   = fraction of TAN in appl box that is lost as runoff of NO3-
       (dimensionless)
 0.004     ! 09    frac_appl_runoff_no3_n2o   = fraction of NO3- from runoff in appl box that is lost as N2O
       (dimensionless)
 0.001     ! 10    frac_direct_tan_nh3        = fraction of TAN in direct box that is lost as NH3 (dimensionless)
 0.002     ! 10    frac_direct_tan_n2o        = fraction of TAN in direct box that is lost as N2O (dimensionless)
 0.003     ! 10    frac_direct_tan_nox        = fraction of TAN in direct box that is lost as NOx (dimensionless)
 0.004     ! 10    frac_direct_tan_n2         = fraction of TAN in direct box that is lost as N2 (dimensionless)
 1         ! 10    imanure_direct_ch4         = indicator: 1 = Sven Sommer s method, 2 = IPCC s method
 0.11      ! 10    fact_direct_vsd_ch4        = factor by which amount of VSd (kg period-1) has to be multiplied to
       find CH4 emission (kg CH4 period-1) in direct
 2.8       ! 10    rm_direct_vsd_ch4          = kg VSd lost per kg CH4 produced in direct
 0.1       ! 10    B0_direct                  = maximum methane producing capacity (m3 CH4 kg-1 VS) IPCC method
 0.1       ! 10    MCF_direct                 = methan conversion factor (fraction) IPCC method
 2.9       ! 10    rm_direct_vs_ch4           = kg VS lost per kg CH4 produced in direct
 0.05      ! 10    frac_direct_runoff_tan_no3 = fraction of TAN in direct box that is lost as runoff of NO3-
       (dimensionless)
 0.04      ! 10    frac_direct_runoff_no3_n2o = fraction of NO3- in runoff in direct box that is lost as N2O
       (dimensionless)
 0.001     ! 11    frac_yard_tan_nh3          = fraction of TAN in yard box that is lost as NH3 (dimensionless)
 0.002     ! 11    frac_yard_tan_n2o          = fraction of TAN in yard box that is lost as N2O (dimensionless)
 0.003     ! 11    frac_yard_tan_nox          = fraction of TAN in yard box that is lost as NOx (dimensionless)
 0.004     ! 11    frac_yard_tan_n2           = fraction of TAN in yard box that is lost as N2 (dimensionless)
 1         ! 11    imanure_yard_ch4           = indicator: 1 = Sven Sommer s method, 2 = IPCC s method
 0.11      ! 11    fact_yard_vsd_ch4          = factor by which amount of VSd (kg period-1) has to be multiplied to
       find CH4 emission (kg CH4 period-1) in yard
 2.8       ! 11    rm_yard_vsd_ch4            = kg VSd lost per kg CH4 produced in yard
 0.1       ! 11    B0_yard                    = maximum methane producing capacity (m3 CH4 kg-1 VS) IPCC method
 0.01      ! 11    MCF_yard                   = methan conversion factor (fraction) IPCC method
 2.9       ! 11    rm_yard_vs_ch4             = kg VS lost per kg CH4 produced in yard
 0.03      ! 11    frac_yard_runoff_tan_no3   = fraction of TAN in yard box that is lost as runoff of NO3-
       (dimensionless)
 0.07      ! 11    frac_yard_runoff_no3_n2o   = fraction of NO3- in runoff in yard box that is lost as N2O
       (dimensionless)
1          ! 11    imanure_yard_out           = indicator: indicates in which way the manure leaves the yard.
       Possible values: 1 = to stor1, 2= to incin2
1          ! 12    imanure_graz_nh3           = indicator: indicates in which way the NH3 emission is calculated: 1 =
       just normally from TAN ; 2 = from total N excretion grazing (Germany)
 0.100     ! 12    frac_graz_tan_nh3          = fraction of TAN in graz box that is lost as NH3 (dimensionless)
 0.        ! 12    frac_graz_tan_n2o          = fraction of TAN in graz box that is lost as N2O (dimensionless)
 0.        ! 12    frac_graz_tan_nox          = fraction of TAN in graz box that is lost as NOx (dimensionless)
 0.        ! 12    frac_graz_tan_n2           = fraction of TAN in graz box that is lost as N2 (dimensionless)
 1         ! 12    imanure_graz_ch4           = indicator: 1 = Sven Sommer s method, 2 = IPCC s method
 0.11      ! 12    fact_graz_vsd_ch4          = factor by which amount of VSd (kg period-1) has to be multiplied to
       find CH4 emission (kg CH4 period-1) in graz
 2.8       ! 12    rm_graz_vsd_ch4            = kg VSd lost per kg CH4 produced in graz
 0.24      ! 12    B0_graz                    = maximum methane producing capacity (m3 CH4 kg-1 VS) IPCC method
 0.01      ! 12    MCF_graz                   = methane conversion factor (fraction) IPCC method
```

```
 2.9        ! 12    rm_graz_vs_ch4             = kg VS lost per kg CH4 produced in graz
 0.         ! 12    frac_graz_runoff_tan_no3   = fraction of TAN in graz box that is lost as runoff of NO3-
        (dimensionless)
 0.         ! 12    frac_graz_runoff_no3_n2o   = fraction of NO3- in runoff in graz box that is lost as N2O
        (dimensionless)
#####
```

Appendix 5. Questionnaire to collect country information

The information on emission fractions is focused on NH_3.

5	**Separate sheets for each animal category:**		**The light blue colour means that a default value can be given**
6	Dairy cows		
7	Other cattle (incl. young cattle, beef cattle and suckling cows)		
8	Fattening pigs (give appr. weight)		
9	Sows		
10	Sheep and goats		
11	Horses incl. mules and asses		
12	Laying hens (incl. parents)		
13	Broilers (incl. parents)		
14	Ducks		
15	Geese		
16	Turkeys		
17	Fur animals		
18	Camels		
19	Buffalo		
20			

21	**Parameter**		**Value**	**Units**		
22						
23	***Animal and farm characteristics***					
24	**Production indicators**					
25	Production of amount of milk (only for dairy cows)			kg place-1 year-1		
26	Production of N in milk (only for dairy cows)			kg N place-1 year-1		
27	Production of N in eggs (laying hens only)			kg N place-1 year-1		
28	Production of N in offspring			kg N place-1 year-1		
29	Production cycles			number year-1		
30	Weight at time of slaughter			kg		
31						
32	**Excretion**					
33	N-excretion	- total		kg place-1year-1 N		
34		- of which TAN		%		
35	VS-excretion (volatile solids)	- total		kg place-1year-1		
36						
37	Percentage of excretion in housing			%		
38	Percentage of excretion on feeding yards			%		
39	Percentage of excretion on exercise yards			%		
40	Percentage of excretion while grazing			%		
41						
42						
43	**IPCC farm indicators**					
44	Percentage of animals on IPPC farms			%		
45	Percentage of animals on other farms			%		
46						
47	Average size of IPPC farms			places		
48	Average size of other farms			places		
49						
50	***Housing***					
51	a. Percentage of animals kept on liquid manure system			%		
52	b. Percentage of animals kept on solid manure system			%		
53	c. Percentage kept on separated system consisting of a liquid part leacheate ("Jauche" = leacheate) and a solid part			%		
54						
55	Housing types	*Of which (if available). Give as many*				
56	*(Percentage of animals kept in different housing types)*	Housing a. Type 1 (Give name):		% of animals of this category		% of TAN in housing emitted
57		Housing a.Type 2:		% of animals of this category		% of TAN in housing emitted
58		....		% of animals of this category		% of TAN in housing emitted
59		Housing b. Type 1:		% of animals of this category		% of TAN in housing emitted
60		....		% of animals of this category		% of TAN in housing emitted
61		Housing c. Type 1		% of animals of this category		% of TAN in housing emitted
62		....		% of animals of this category		% of TAN in housing emitted
63						
64						
65						
66	Percentage of animals in mechanically ventilated housings			%		
67	Percentage of animals in housings with scrubbers/biofilters			%		
68						
69	*Liquid manure system*					
70	Liquid manure volume per animal (including flush water)			m3 place-1 year-1		
71	Flush water volume per animal			m3 place-1 year-1		
72						
73	*Solid manure system*					
74	Solid manure volume produced per animal (including straw)			m3 place-1 year-1		
75	Dry matter content FYM			%		
76						
77						

78	*Bedding properties solid manure*					
79	Type of bedding (straw, etc.)					
80	Bedding added per animal place			kg place-1year-1		
81	Dry matter content bedding			%		
82	VS content in bedding			kg VS place-1 year-1		
83	N in dry matter in bedding			%		% TAN in N
84						
85						
86	Direct spread (Percentage of liquid manure spread directly on land)			%		
87	Direct spread (Percentage of solid manure spread directly on land)			%		
88	Direct spread (Percentage of separated manure spread directly on land)			%		
89						
90	Incineration (Percentage of solid manure)			%		
91						
92	***Yards***					
93	Feeding yards					% of TAN on yards emitted
94	Excercise yards					% of TAN on yards emitted
95						
96						
97	***Storage and manure management***					
98	Type (L - liquid manure; S - solid manure; SEP - manure separated in a solid and a liquid fraction ("Jauche"))			Green fields add up to 100%		
99						
100		**Liquid manure**		**% of manure that is liquid manure**		
101		(L) Lagoons				
102		*- of which covered*		% of liquid manure		% of TAN in storage emitted
103		*- of which crusted*		% of liquid manure		% of TAN in storage emitted
104		*- no cover and no crust*		% of liquid manure		% of TAN in storage emitted
105		(L) Tanks				
106		*- of which covered with a "tight" lid, roof or tent*		% of liquid manure		% of TAN in storage emitted
107		*- of which covered by floating plastic cover*		% of liquid manure		% of TAN in storage emitted
108		*- of which have a "low technology" cover (chopped straw,peat, bark, LECA balls etc.)*		% of liquid manure		% of TAN in storage emitted
109		*- of which covered by a natural crust*		% of liquid manure		% of TAN in storage emitted
110		*- of which have no cover and no crust*		% of liquid manure		% of TAN in storage emitted
111		(L) Under housing		% of liquid manure		% of TAN in storage emitted
112		(L) Other (specify)		% of liquid manure		% of TAN in storage emitted
113						
114						
115		Percentage of organic N (Norg) that mineralizes to TAN during storage				% of Norg
116		Storage time for liquid manure (usually minimum set by legislation)				months
117		Percentage of liquid manure used for anaerobic digestion				%
118						
119		Percentage of liquid manure kept in tanks/lagoons with an impermeable bottom				%
120						
121		*Digested manure*				
122		Percentage of liquid manure that is used in biogas plant		%		
123		Amount of N added from waste etc.		t N added / t N in manure		
124		Percentage of N that is TAN		%		% of TAN emitted from the li
125		Amount of VS added from waste etc.		t VS added / t VS in manure		
126		Maximum methane producing capacity B0		B0: maximum methane producing capacity m3 CH4 generated/kg VS		
127		Percentage of CH4 produced that is recovered		%		
128						
129						
130						
131						
132		**Solid manure**		**% of manure that is solid manure and is stored**		
133		(S) Solid storage and dry lot				
134		*- of which covered*		% of solid manure		% of TAN in storage emitted
135		*- other (uncovered)*		% of solid manure		% of TAN in storage emitted
136		(S) Other (specify)		% of solid manure		% of TAN in storage emitted
137						
138		Percentage of TAN that immobilizes to organic N during storage				% of TAN
139						
140		Percentage of solid manure kept on impermeable material				%
141						
142						
143						
144		**Separated manure**		**% of manure that is separated manure**		
145						
146		Percentage of TAN excreted found in liquid fraction of the separated manure		%		
147		Percentage of Norg excreted found in liquid part of the separated manure		%		
148		Percentage of VS excreted found in liquid fraction of the separated manure		%		
149						

	(SEP-L) Liquid fraction separated manure ("Jauche")		**% of the liquid fraction**		
	(SEP-L) Tanks				
	- of which covered with a "tight" lid, roof or tent		% of liquid fraction		% of TAN in storage emitted
	- of which covered by floating plastic cover		% of liquid fraction		% of TAN in storage emitted
	- of which have a "low technology" cover (chopped straw,peat, bark, LECA balls etc.)		% of liquid fraction		% of TAN in storage emitted
	- of which covered by a natural crust		% of liquid fraction		% of TAN in storage emitted
	- of which have no cover and no crust		% of liquid fraction		% of TAN in storage emitted
	(SEP-L) Under housing		% of liquid fraction		% of TAN that immobilizes to
	(SEP-L) Other (specify)		% of liquid fraction		% of TAN in storage emitted
	Percentage of organic N (Norg) that mineralizes to TAN during storage				%
	(SEP-S) Solid fraction separated manure		**% of the solid fraction**		
	- of which covered		% of solid fraction		% of TAN in storage emitted
	- other (uncovered)		% of solid fraction		% of TAN in storage emitted
	(SEP-S) Other (specify)		% of solid fraction		% of TAN in storage emitted
	Percentage of TAN that immobilizes to organic N during storage				% of TAN
			%		
Percentage of the liquid fraction of separated manure kept on impermeable material			%		
Percentage of the solid fraction of separated manure kept on impermeable material			%		

Application

Application technique ***(currently practiced)***	**liquid manure**	% of the liquid	manure		
	Broadcast and incorporation after more than 12 h		% of the liquid manure		% of TAN present in applied
	Broadcast and incorporation within 12 h, but not immediate		% of the liquid manure		% of TAN present in applied
	Broadcast and immediate incorporation		% of the liquid manure		% of TAN present in applied
	Immediate incorporation by disc		% of the liquid manure		% of TAN present in applied
	Trailing hose		% of the liquid manure		% of TAN present in applied
	Trailing shoe		% of the liquid manure		% of TAN present in applied
	Shallow injection		% of the liquid manure		% of TAN present in applied
	Deep injection		% of the liquid manure		% of TAN present in applied
	Solid manure	% of the solid	manure		
	Broadcast and incorporation after more than 24 h		% of the solid manure		% of TAN present in applied
	Broadcast and incorporation between 12 and 24 h		% of the solid manure		% of TAN present in applied
	Broadcast and incorporation within 12 h, but not immediate		% of the solid manure		% of TAN present in applied
	Broadcast and immediate incorporation		% of the solid manure		% of TAN present in applied
	Separated manure				
	Liquid fraction separated manure	% of the liquid	fraction		
	Broadcast and incorporation after more than 12 h		% of the liquid fraction		% of TAN present in applied
	Broadcast and incorporation within 12 h, but not immediate		% of the liquid fraction		% of TAN present in applied
	Broadcast and immediate incorporation		% of the liquid fraction		% of TAN present in applied
	Immediate incorporation by disc		% of the liquid fraction		% of TAN present in applied
	Trailing hose		% of the liquid fraction		% of TAN present in applied
	Trailing shoe		% of the liquid fraction		% of TAN present in applied
	Shallow injection		% of the liquid fraction		% of TAN present in applied
	Deep injection		% of the liquid fraction		% of TAN present in applied

	Solid fraction separated manure	% of the solid	fraction		
	Broadcast and incorporation after more than 24 h		% of the solid fraction		% of TAN present in applied r
	Broadcast and incorporation between 12 and 24 h		% of the solid fraction		% of TAN present in applied r
	Broadcast and incorporation within 12 h, but not immediate		% of the solid fraction		% of TAN present in applied r
	Broadcast and immediate incorporation		% of the solid fraction		% of TAN present in applied r
Application technique ***(technically feasable)***	**Liquid manure**	% of the liquid	manure		
	Broadcast and incorporation after more than 12 h		% of the liquid manure		
	Broadcast and incorporation within 12 h, but not immediate		% of the liquid manure		
	Broadcast and immediate incorporation		% of the liquid manure		
	Immediate incorporation by disc		% of the liquid manure		
	Trailing hose		% of the liquid manure		
	Trailing shoe		% of the liquid manure		
	Shallow injection		% of the liquid manure		
	Deep injection		% of the liquid manure		
	Solid manure	% of the solid	manure		
	Broadcast and incorporation after more than 24 h		% of the solid manure		
	Broadcast and incorporation between 12 and 24 h		% of the solid manure		
	Broadcast and incorporation within 12 h, but not immediate		% of the solid manure		
	Broadcast and immediate incorporation		% of the solid manure		

235		**Separated manure**					
236		*Liquid fraction separated manure*	% of the liquid fraction				
237		Broadcast and incorporation after more than 12 h		% of the liquid fraction			
238		Broadcast and incorporation within 12 h, but not immediate		% of the liquid fraction			
239		Broadcast and immediate incorporation		% of the liquid fraction			
240		Immediate incorporation by disc		% of the liquid fraction			
241		Trailing hose		% of the liquid fraction			
242		Trailing shoe		% of the liquid fraction			
243		Shallow injection		% of the liquid fraction			
244		Deep injection		% of the liquid fraction			
245							
246		*Solid fraction separated manure*	% of the solid fraction				
247		Broadcast and incorporation after more than 24 h		% of the solid fraction			
248		Broadcast and incorporation between 12 and 24 h		% of the solid fraction			
249		Broadcast and incorporation within 12 h, but not immediate		% of the solid fraction			
250		Broadcast and immediate incorporation		% of the solid fraction			
251							
252	***Grazing***						
253							
254	Emission factor					% of TAN emitted	

Appendix 6. Suggested default parameters

Table A6-1. GAINS animal categories.

Code	**Description**
DL	Dairy cows, liquid manure
DS	Dairy cows, solid manure
OL	Other cattle, liquid manure
OS	Other cattle, solid manure
PL	Pigs, liquid manure
PS	Pigs, solid manure
LH	Laying hens
OP	Other poultry
SH	Sheep and goats
HO	Horses
FU	Fur animals
BS	Buffaloes
CM	Camels

Table A6-2. Excretion of GAINS animal types for European countries: total excretion, exretion in housing and excretion during grazing (kg N animal^{-1} yr^{-1}).

Country	Animal	Excr. total	Excr. housing	Excr. grazing
ALBA	DL	55.000	33.060	21.940
ALBA	DS	55.000	33.060	21.940
ALBA	OL	40.000	21.808	18.192
ALBA	OS	40.000	21.808	18.192
ALBA	PL	12.375	12.375	0.000
ALBA	PS	12.375	12.375	0.000
ALBA	LH	0.800	0.800	0.000
ALBA	OP	0.703	0.703	0.000
ALBA	SH	12.000	1.644	10.356
ALBA	HO	50.000	20.548	29.452
ALBA	BS	0.000	0.000	0.000
ALBA	CM	0.000	0.000	0.000
ALBA	FU	4.100	4.100	0.000
AUST	DL	89.390	71.757	17.633
AUST	DS	89.390	71.757	17.633
AUST	OL	45.845	23.236	22.609
AUST	OS	45.845	23.236	22.609
AUST	PL	9.032	9.032	0.000
AUST	PS	9.032	9.032	0.000
AUST	LH	0.730	0.730	0.000
AUST	OP	0.403	0.403	0.000
AUST	SH	13.000	7.800	5.200
AUST	HO	47.900	19.685	28.215
AUST	BS	0.000	0.000	0.000
AUST	CM	0.000	0.000	0.000
AUST	FU	4.100	4.100	0.000
BELA	DL	55.000	33.060	21.940
BELA	DS	55.000	33.060	21.940
BELA	OL	45.000	27.740	17.260
BELA	OS	45.000	27.740	17.260
BELA	PL	12.375	12.375	0.000
BELA	PS	12.375	12.375	0.000
BELA	LH	0.800	0.800	0.000
BELA	OP	0.703	0.703	0.000
BELA	SH	12.000	3.288	8.712
BELA	HO	50.000	20.548	29.452
BELA	BS	0.000	0.000	0.000
BELA	CM	0.000	0.000	0.000
BELA	FU	1.500	1.500	0.000
BELG	DL	108.000	66.339	41.661
BELG	DS	108.000	66.339	41.661
BELG	OL	50.000	27.123	22.877
BELG	OS	50.000	27.123	22.877
BELG	PL	11.050	11.050	0.000
BELG	PS	11.050	11.050	0.000
BELG	LH	0.700	0.700	0.000
BELG	OP	0.460	0.460	0.000
BELG	SH	7.400	2.027	5.373
BELG	HO	50.000	20.548	29.452
BELG	BS	0.000	0.000	0.000
BELG	CM	0.000	0.000	0.000

Country	Animal	Excr. total	Excr. housing	Excr. grazing
BELG	FU	4.100	4.100	0.000
BOHE	DL	55.000	33.060	21.940
BOHE	DS	55.000	33.060	21.940
BOHE	OL	40.000	21.808	18.192
BOHE	OS	40.000	21.808	18.192
BOHE	PL	12.375	12.375	0.000
BOHE	PS	12.375	12.375	0.000
BOHE	LH	0.800	0.800	0.000
BOHE	OP	0.703	0.703	0.000
BOHE	SH	12.000	1.644	10.356
BOHE	HO	50.000	20.548	29.452
BOHE	BS	0.000	0.000	0.000
BOHE	CM	0.000	0.000	0.000
BOHE	FU	4.100	4.100	0.000
BULG	DL	66.544	39.999	26.545
BULG	DS	66.544	39.999	26.545
BULG	OL	45.000	24.534	20.466
BULG	OS	45.000	24.534	20.466
BULG	PL	12.375	12.375	0.000
BULG	PS	12.375	12.375	0.000
BULG	LH	0.800	0.800	0.000
BULG	OP	0.703	0.703	0.000
BULG	SH	12.000	3.288	8.712
BULG	HO	50.000	20.548	29.452
BULG	BS	0.000	0.000	0.000
BULG	CM	0.000	0.000	0.000
BULG	FU	1.500	1.500	0.000
CROA	DL	55.000	33.060	21.940
CROA	DS	55.000	33.060	21.940
CROA	OL	45.000	24.534	20.466
CROA	OS	45.000	24.534	20.466
CROA	PL	12.375	12.375	0.000
CROA	PS	12.375	12.375	0.000
CROA	LH	0.800	0.800	0.000
CROA	OP	0.703	0.703	0.000
CROA	SH	12.000	1.644	10.356
CROA	HO	50.000	20.548	29.452
CROA	BS	0.000	0.000	0.000
CROA	CM	0.000	0.000	0.000
CROA	FU	4.100	4.100	0.000
CYPR	DL	107.621	65.162	42.459
CYPR	DS	107.621	65.162	42.459
CYPR	OL	40.000	21.918	18.082
CYPR	OS	40.000	21.918	18.082
CYPR	PL	12.375	12.375	0.000
CYPR	PS	12.375	12.375	0.000
CYPR	LH	0.800	0.800	0.000
CYPR	OP	0.703	0.703	0.000
CYPR	SH	12.000	1.644	10.356
CYPR	HO	50.000	20.548	29.452
CYPR	BS	0.000	0.000	0.000
CYPR	CM	0.000	0.000	0.000
CYPR	FU	4.100	4.100	0.000
CZRE	DL	100.284	64.017	36.267

Country	Animal	Excr. total	Excr. housing	Excr. grazing
CZRE	DS	100.284	64.017	36.267
CZRE	OL	45.000	31.438	13.562
CZRE	OS	45.000	31.438	13.562
CZRE	PL	12.375	12.375	0.000
CZRE	PS	12.375	12.375	0.000
CZRE	LH	0.800	0.800	0.000
CZRE	OP	0.608	0.608	0.000
CZRE	SH	12.000	3.288	8.712
CZRE	HO	50.000	20.548	29.452
CZRE	BS	0.000	0.000	0.000
CZRE	CM	0.000	0.000	0.000
CZRE	FU	1.500	1.500	0.000
DENM	DL	125.310	106.496	18.814
DENM	DS	125.310	106.496	18.814
DENM	OL	37.150	23.613	13.537
DENM	OS	37.150	23.613	13.537
DENM	PL	9.633	9.554	0.079
DENM	PS	9.633	9.554	0.079
DENM	LH	0.710	0.710	0.000
DENM	OP	0.510	0.510	0.000
DENM	SH	16.950	4.644	12.306
DENM	HO	43.310	21.714	21.596
DENM	BS	0.000	0.000	0.000
DENM	CM	0.000	0.000	0.000
DENM	FU	4.630	4.630	0.000
ESTO	DL	91.004	62.082	28.922
ESTO	DS	91.004	62.082	28.922
ESTO	OL	45.000	26.753	18.247
ESTO	OS	45.000	26.753	18.247
ESTO	PL	12.375	12.375	0.000
ESTO	PS	12.375	12.375	0.000
ESTO	LH	0.800	0.800	0.000
ESTO	OP	0.497	0.497	0.000
ESTO	SH	14.000	3.836	10.164
ESTO	HO	50.000	20.548	29.452
ESTO	BS	0.000	0.000	0.000
ESTO	CM	0.000	0.000	0.000
ESTO	FU	4.100	4.100	0.000
FINL	DL	99.324	79.513	19.811
FINL	DS	99.324	79.513	19.811
FINL	OL	53.000	34.414	18.586
FINL	OS	53.000	34.414	18.586
FINL	PL	10.137	10.137	0.000
FINL	PS	10.137	10.137	0.000
FINL	LH	0.800	0.800	0.000
FINL	OP	0.400	0.400	0.000
FINL	SH	16.000	7.890	8.110
FINL	HO	50.000	20.548	29.452
FINL	BS	0.000	0.000	0.000
FINL	CM	0.000	0.000	0.000
FINL	FU	1.900	1.900	0.000
FRAN	DL	100.000	71.726	28.274
FRAN	DS	100.000	71.726	28.274
FRAN	OL	50.000	19.041	30.959

Country	Animal	Excr. total	Excr. housing	Excr. grazing
FRAN	OS	50.000	19.041	30.959
FRAN	PL	12.168	12.168	0.000
FRAN	PS	12.168	12.168	0.000
FRAN	LH	0.800	0.800	0.000
FRAN	OP	0.880	0.880	0.000
FRAN	SH	12.000	3.616	8.384
FRAN	HO	50.000	19.041	30.959
FRAN	BS	0.000	0.000	0.000
FRAN	CM	0.000	0.000	0.000
FRAN	FU	4.100	4.100	0.000
GERM	DL	113.900	106.410	7.490
GERM	DS	113.900	106.410	7.490
GERM	OL	39.900	34.320	5.580
GERM	OS	39.900	34.320	5.580
GERM	PL	14.800	14.800	0.000
GERM	PS	14.800	14.800	0.000
GERM	LH	0.840	0.840	0.000
GERM	OP	0.550	0.550	0.000
GERM	SH	7.500	2.140	5.360
GERM	HO	47.900	32.680	15.220
GERM	BS	0.000	0.000	0.000
GERM	CM	0.000	0.000	0.000
GERM	FU	4.100	4.100	0.000
GREE	DL	63.376	38.095	25.281
GREE	DS	63.376	38.095	25.281
GREE	OL	45.000	24.534	20.466
GREE	OS	45.000	24.534	20.466
GREE	PL	11.506	11.506	0.000
GREE	PS	11.506	11.506	0.000
GREE	LH	0.800	0.800	0.000
GREE	OP	0.703	0.703	0.000
GREE	SH	12.000	1.644	10.356
GREE	HO	50.000	20.548	29.452
GREE	BS	0.000	0.000	0.000
GREE	CM	0.000	0.000	0.000
GREE	FU	4.100	4.100	0.000
HUNG	DL	121.000	73.263	47.737
HUNG	DS	121.000	73.263	47.737
HUNG	OL	45.000	22.808	22.192
HUNG	OS	45.000	22.808	22.192
HUNG	PL	8.943	8.943	0.000
HUNG	PS	8.943	8.943	0.000
HUNG	LH	1.500	1.500	0.000
HUNG	OP	1.450	1.450	0.000
HUNG	SH	12.000	4.110	7.890
HUNG	HO	50.000	20.548	29.452
HUNG	BS	0.000	0.000	0.000
HUNG	CM	0.000	0.000	0.000
HUNG	FU	4.100	4.100	0.000
IREL	DL	94.000	41.721	52.279
IREL	DS	94.000	41.721	52.279
IREL	OL	68.850	26.974	41.876
IREL	OS	68.850	26.974	41.876
IREL	PL	12.436	12.436	0.000

Country	Animal	Excr. total	Excr. housing	Excr. grazing
IREL	PS	12.436	12.436	0.000
IREL	LH	0.840	0.840	0.000
IREL	OP	0.508	0.508	0.000
IREL	SH	8.000	1.403	6.597
IREL	HO	50.000	25.068	24.932
IREL	BS	0.000	0.000	0.000
IREL	CM	0.000	0.000	0.000
IREL	FU	4.100	4.100	0.000
ITAL	DL	108.814	98.201	10.613
ITAL	DS	108.814	98.201	10.613
ITAL	OL	46.885	44.316	2.569
ITAL	OS	46.885	44.316	2.569
ITAL	PL	11.516	11.516	0.000
ITAL	PS	11.516	11.516	0.000
ITAL	LH	0.660	0.660	0.000
ITAL	OP	0.510	0.510	0.000
ITAL	SH	16.200	1.553	14.647
ITAL	HO	50.000	20.000	30.000
ITAL	BS	0.000	0.000	0.000
ITAL	CM	0.000	0.000	0.000
ITAL	FU	4.100	4.100	0.000
LATV	DL	71.000	48.591	22.409
LATV	DS	71.000	48.591	22.409
LATV	OL	51.000	25.151	25.849
LATV	OS	51.000	25.151	25.849
LATV	PL	10.010	10.010	0.000
LATV	PS	10.010	10.010	0.000
LATV	LH	0.900	0.900	0.000
LATV	OP	0.900	0.900	0.000
LATV	SH	6.950	3.999	2.951
LATV	HO	51.000	25.151	25.849
LATV	BS	0.000	0.000	0.000
LATV	CM	0.000	0.000	0.000
LATV	FU	4.100	4.100	0.000
LITH	DL	70.000	42.077	27.923
LITH	DS	70.000	42.077	27.923
LITH	OL	50.000	27.260	22.740
LITH	OS	50.000	27.260	22.740
LITH	PL	12.375	12.375	0.000
LITH	PS	12.375	12.375	0.000
LITH	LH	0.800	0.800	0.000
LITH	OP	0.500	0.500	0.000
LITH	SH	12.000	3.288	8.712
LITH	HO	50.000	20.548	29.452
LITH	BS	0.000	0.000	0.000
LITH	CM	0.000	0.000	0.000
LITH	FU	4.100	4.100	0.000
LUXE	DL	107.583	66.318	41.265
LUXE	DS	107.583	66.318	41.265
LUXE	OL	42.000	22.899	19.101
LUXE	OS	42.000	22.899	19.101
LUXE	PL	9.908	9.908	0.000
LUXE	PS	9.908	9.908	0.000
LUXE	LH	0.800	0.800	0.000

Country	Animal	Excr. total	Excr. housing	Excr. grazing
LUXE	OP	0.703	0.703	0.000
LUXE	SH	12.000	3.288	8.712
LUXE	HO	50.000	20.548	29.452
LUXE	BS	0.000	0.000	0.000
LUXE	CM	0.000	0.000	0.000
LUXE	FU	4.100	4.100	0.000
MACE	DL	55.000	33.060	21.940
MACE	DS	55.000	33.060	21.940
MACE	OL	40.000	21.808	18.192
MACE	OS	40.000	21.808	18.192
MACE	PL	12.375	12.375	0.000
MACE	PS	12.375	12.375	0.000
MACE	LH	0.800	0.800	0.000
MACE	OP	0.703	0.703	0.000
MACE	SH	12.000	1.644	10.356
MACE	HO	50.000	20.548	29.452
MACE	BS	0.000	0.000	0.000
MACE	CM	0.000	0.000	0.000
MACE	FU	4.100	4.100	0.000
MALT	DL	99.346	60.152	39.194
MALT	DS	99.346	60.152	39.194
MALT	OL	40.000	21.918	18.082
MALT	OS	40.000	21.918	18.082
MALT	PL	12.375	12.375	0.000
MALT	PS	12.375	12.375	0.000
MALT	LH	0.800	0.800	0.000
MALT	OP	0.703	0.703	0.000
MALT	SH	12.000	1.644	10.356
MALT	HO	50.000	20.548	29.452
MALT	BS	0.000	0.000	0.000
MALT	CM	0.000	0.000	0.000
MALT	FU	0.700	0.700	0.000
NETH	DL	126.200	80.561	45.639
NETH	DS	126.200	80.561	45.639
NETH	OL	40.000	25.644	14.356
NETH	OS	40.000	25.644	14.356
NETH	PL	9.177	9.177	0.000
NETH	PS	9.177	9.177	0.000
NETH	LH	0.670	0.670	0.000
NETH	OP	0.618	0.618	0.000
NETH	SH	11.539	3.161	8.378
NETH	HO	50.000	19.863	30.137
NETH	BS	0.000	0.000	0.000
NETH	CM	0.000	0.000	0.000
NETH	FU	2.200	2.200	0.000
NORW	DL	82.000	68.880	13.120
NORW	DS	82.000	68.880	13.120
NORW	OL	38.000	30.400	7.600
NORW	OS	38.000	30.400	7.600
NORW	PL	10.681	10.681	0.000
NORW	PS	10.681	10.681	0.000
NORW	LH	0.700	0.700	0.000
NORW	OP	0.494	0.494	0.000
NORW	SH	14.702	7.250	7.452

Country	Animal	Excr. total	Excr. housing	Excr. grazing
NORW	HO	50.000	20.548	29.452
NORW	BS	0.000	0.000	0.000
NORW	CM	0.000	0.000	0.000
NORW	FU	4.100	4.100	0.000
POLA	DL	75.900	61.604	14.296
POLA	DS	75.900	61.604	14.296
POLA	OL	35.000	28.408	6.592
POLA	OS	35.000	28.408	6.592
POLA	PL	11.130	11.130	0.000
POLA	PS	11.130	11.130	0.000
POLA	LH	0.700	0.700	0.000
POLA	OP	0.630	0.630	0.000
POLA	SH	13.734	3.763	9.971
POLA	HO	50.000	20.548	29.452
POLA	BS	0.000	0.000	0.000
POLA	CM	0.000	0.000	0.000
POLA	FU	4.100	4.100	0.000
PORT	DL	87.600	61.320	26.280
PORT	DS	87.600	61.320	26.280
PORT	OL	49.930	21.910	28.020
PORT	OS	49.930	21.910	28.020
PORT	PL	9.150	8.970	0.180
PORT	PS	9.150	8.970	0.180
PORT	LH	0.600	0.600	0.000
PORT	OP	0.940	0.940	0.000
PORT	SH	7.000	1.400	5.600
PORT	HO	39.350	25.580	13.770
PORT	BS	0.000	0.000	0.000
PORT	CM	0.000	0.000	0.000
PORT	FU	0.700	0.700	0.000
MOLD	DL	55.000	33.060	21.940
MOLD	DS	55.000	33.060	21.940
MOLD	OL	40.000	21.808	18.192
MOLD	OS	40.000	21.808	18.192
MOLD	PL	12.375	12.375	0.000
MOLD	PS	12.375	12.375	0.000
MOLD	LH	0.800	0.800	0.000
MOLD	OP	0.703	0.703	0.000
MOLD	SH	12.000	3.288	8.712
MOLD	HO	50.000	20.548	29.452
MOLD	BS	0.000	0.000	0.000
MOLD	CM	0.000	0.000	0.000
MOLD	FU	4.100	4.100	0.000
ROMA	DL	55.000	33.301	21.699
ROMA	DS	55.000	33.301	21.699
ROMA	OL	45.000	24.534	20.466
ROMA	OS	45.000	24.534	20.466
ROMA	PL	12.375	12.375	0.000
ROMA	PS	12.375	12.375	0.000
ROMA	LH	0.800	0.800	0.000
ROMA	OP	0.703	0.703	0.000
ROMA	SH	12.000	3.288	8.712
ROMA	HO	50.000	20.548	29.452
ROMA	BS	0.000	0.000	0.000

Country	Animal	Excr. total	Excr. housing	Excr. grazing
ROMA	CM	0.000	0.000	0.000
ROMA	FU	4.100	4.100	0.000
RUSS	DL	55.000	33.060	21.940
RUSS	DS	55.000	33.060	21.940
RUSS	OL	40.000	23.014	16.986
RUSS	OS	40.000	23.014	16.986
RUSS	PL	12.375	12.375	0.000
RUSS	PS	12.375	12.375	0.000
RUSS	LH	0.800	0.800	0.000
RUSS	OP	0.703	0.703	0.000
RUSS	SH	12.000	3.288	8.712
RUSS	HO	50.000	20.548	29.452
RUSS	BS	0.000	0.000	0.000
RUSS	CM	0.000	0.000	0.000
RUSS	FU	4.100	4.100	0.000
SEMO	DL	55.000	33.060	21.940
SEMO	DS	55.000	33.060	21.940
SEMO	OL	40.000	21.808	18.192
SEMO	OS	40.000	21.808	18.192
SEMO	PL	12.375	12.375	0.000
SEMO	PS	12.375	12.375	0.000
SEMO	LH	0.800	0.800	0.000
SEMO	OP	0.703	0.703	0.000
SEMO	SH	12.000	1.644	10.356
SEMO	HO	50.000	20.548	29.452
SEMO	BS	0.000	0.000	0.000
SEMO	CM	0.000	0.000	0.000
SEMO	FU	4.100	4.100	0.000
SKRE	DL	81.944	49.256	32.688
SKRE	DS	81.944	49.256	32.688
SKRE	OL	45.000	24.534	20.466
SKRE	OS	45.000	24.534	20.466
SKRE	PL	12.375	12.375	0.000
SKRE	PS	12.375	12.375	0.000
SKRE	LH	0.800	0.800	0.000
SKRE	OP	0.703	0.703	0.000
SKRE	SH	12.000	3.288	8.712
SKRE	HO	50.000	20.548	29.452
SKRE	BS	0.000	0.000	0.000
SKRE	CM	0.000	0.000	0.000
SKRE	FU	4.100	4.100	0.000
SLOV	DL	105.500	92.828	12.672
SLOV	DS	105.500	92.828	12.672
SLOV	OL	40.100	34.080	6.020
SLOV	OS	40.100	34.080	6.020
SLOV	PL	11.942	11.942	0.000
SLOV	PS	11.942	11.942	0.000
SLOV	LH	0.710	0.710	0.000
SLOV	OP	0.520	0.520	0.000
SLOV	SH	11.300	4.068	7.232
SLOV	HO	50.000	35.616	14.384
SLOV	BS	0.000	0.000	0.000
SLOV	CM	0.000	0.000	0.000
SLOV	FU	4.100	4.100	0.000

Country	Animal	Excr. total	Excr. housing	Excr. grazing
SPAI	DL	67.495	67.495	0.000
SPAI	DS	67.495	67.495	0.000
SPAI	OL	52.490	52.490	0.000
SPAI	OS	52.490	52.490	0.000
SPAI	PL	9.385	9.385	0.000
SPAI	PS	9.385	9.385	0.000
SPAI	LH	0.775	0.775	0.000
SPAI	OP	0.585	0.585	0.000
SPAI	SH	5.244	0.474	4.770
SPAI	HO	40.000	20.000	20.000
SPAI	BS	0.000	0.000	0.000
SPAI	CM	0.000	0.000	0.000
SPAI	FU	4.100	4.100	0.000
SWED	DL	120.000	95.237	24.763
SWED	DS	120.000	95.237	24.763
SWED	OL	39.000	21.477	17.523
SWED	OS	39.000	21.477	17.523
SWED	PL	11.000	11.000	0.000
SWED	PS	11.000	11.000	0.000
SWED	LH	0.640	0.640	0.000
SWED	OP	0.326	0.326	0.000
SWED	SH	6.099	3.049	3.050
SWED	HO	50.000	25.000	25.000
SWED	BS	0.000	0.000	0.000
SWED	CM	0.000	0.000	0.000
SWED	FU	4.100	4.100	0.000
SWIT	DL	107.000	91.561	15.439
SWIT	DS	107.000	91.561	15.439
SWIT	OL	36.000	27.185	8.815
SWIT	OS	36.000	27.185	8.815
SWIT	PL	11.715	11.715	0.000
SWIT	PS	11.715	11.715	0.000
SWIT	LH	0.710	0.710	0.000
SWIT	OP	0.420	0.420	0.000
SWIT	SH	8.200	3.851	4.349
SWIT	HO	44.000	35.682	8.318
SWIT	BS	0.000	0.000	0.000
SWIT	CM	0.000	0.000	0.000
SWIT	FU	4.100	4.100	0.000
TURK	DL	66.544	39.999	26.545
TURK	DS	66.544	39.999	26.545
TURK	OL	45.000	24.534	20.466
TURK	OS	45.000	24.534	20.466
TURK	PL	12.375	12.375	0.000
TURK	PS	12.375	12.375	0.000
TURK	LH	0.800	0.800	0.000
TURK	OP	0.703	0.703	0.000
TURK	SH	12.000	3.288	8.712
TURK	HO	50.000	20.548	29.452
TURK	BS	0.000	0.000	0.000
TURK	CM	0.000	0.000	0.000
TURK	FU	1.500	1.500	0.000
UKRA	DL	55.000	33.060	21.940
UKRA	DS	55.000	33.060	21.940

Country	Animal	Excr. total	Excr. housing	Excr. grazing
UKRA	OL	45.000	24.534	20.466
UKRA	OS	45.000	24.534	20.466
UKRA	PL	12.375	12.375	0.000
UKRA	PS	12.375	12.375	0.000
UKRA	LH	0.800	0.800	0.000
UKRA	OP	0.703	0.703	0.000
UKRA	SH	12.000	3.288	8.712
UKRA	HO	50.000	20.548	29.452
UKRA	BS	0.000	0.000	0.000
UKRA	CM	0.000	0.000	0.000
UKRA	FU	1.500	1.500	0.000
UNKI	DL	106.000	66.141	39.859
UNKI	DS	106.000	66.141	39.859
UNKI	OL	49.000	24.433	24.567
UNKI	OS	49.000	24.433	24.567
UNKI	PL	12.408	12.000	0.408
UNKI	PS	12.408	12.000	0.408
UNKI	LH	0.850	0.850	0.000
UNKI	OP	0.746	0.746	0.000
UNKI	SH	6.420	0.264	6.156
UNKI	HO	50.000	10.274	39.726
UNKI	BS	0.000	0.000	0.000
UNKI	CM	0.000	0.000	0.000
UNKI	FU	4.100	4.100	0.000

Table A6-3. Default values for length of housing period and annual straw use and amount of N added with straw (EMEP/EEA, 2009).

Animal	Housing period (days)	Straw (kg AAP^{-1} yr^{-1})	N added with straw (kg N AAP yr^{-1})
DL	0	0	0.00
DS	180	1500	6.00
OL	0	0	0.00
OS	180	500	2.00
PL	0	0	0.00
PS	365	200	0.80
LH	0	0	0.00
OP	0	0	0.00
SH	30	20	0.08
HO	180	500	2.00
FU	0	0	0.00
BS	225	1500	6.00
CM	0	0	0.00

Notes:

- AAP = average animal present.
- For the amount of N added with straw gives EMEP/EEA(2009) different separate values for finishing pigs (0.80 kg N AAP yr^{-1}) and for sows (2.40 kg N AAP yr^{-1}). GAINS does not know these categories and for that reason a value of 0.80 kg N AAP yr^{-1} was adopted for PS.

Table A6-4. Default values for the fraction of N in manure that is TAN (EMEP/EEA, 2009).

Animal	**Fraction**
DL	0.60
DS	0.60
OL	0.60
OS	0.60
PL	0.70
PS	0.70
LH	0.70
OP	0.70
SH	0.50
HO	0.60
FU	0.60
BS	0.50
CM	-

Table A6-5. Default fraction of TAN that is emitted as NH_3 in housing, from yard and during grazing and after application (minimum and maximum fraction is indicated as well) for the case where there are no abatement measures (EMEP/EEA, 2009).

Animal	**Source type**	**Fraction**	**Fraction, minimum**	**Fraction, maximum**
DL	Housing	0.20	0.10	0.40
DL	Yard	0.30	0.15	0.60
DL	Storage	0.20	0.10	0.40
DL	Application	0.55	0.28	0.75
DL	Grazing	0.10	0.05	0.20
DS	Housing	0.19	0.10	0.38
DS	Yard	0.30	0.15	0.60
DS	Storage	0.27	0.14	0.54
DS	Application	0.79	0.40	0.85
DS	Grazing	0.10	0.05	0.20
OL	Housing	0.20	0.10	0.40
OL	Yard	0.53	0.27	0.75
OL	Storage	0.20	0.10	0.40
OL	Application	0.55	0.28	0.75
OL	Grazing	0.06	0.03	0.12
OS	Housing	0.19	0.10	0.38
OS	Yard	0.53	0.27	0.75
OS	Storage	0.27	0.14	0.54
OS	Application	0.79	0.40	0.90
OS	Grazing	0.06	0.03	0.12
BS	Housing	0.20	0.10	0.40
BS	Yard	0.00	0.00	0.00
BS	Storage	0.17	0.09	0.34
BS	Application	0.55	0.28	0.75
BS	Grazing	0.13	0.06	0.25
SH	Housing	0.22	0.11	0.44
SH	Yard	0.75	0.38	0.90
SH	Storage	0.28	0.14	0.56
SH	Application	0.90	0.45	0.95
SH	Grazing	0.09	0.05	0.18
HO	Housing	0.22	0.11	0.44
HO	Yard	0.00	0.00	0.00
HO	Storage	0.35	0.18	0.70
HO	Application	0.90	0.45	0.95
HO	Grazing	0.35	0.18	0.70
PL	Housing	0.27	0.14	0.54
PL	Yard	0.53	0.27	0.75
PL	Storage	0.14	0.07	0.28
PL	Application	0.38	0.19	0.77
PL	Grazing	0.00	0.00	0.00
PS	Housing	0.27	0.14	0.53
PS	Yard	0.53	0.27	0.75
PS	Storage	0.45	0.23	0.90
PS	Application	0.81	0.41	0.90
PS	Grazing	0.00	0.00	0.00
LH	Housing	0.41	0.21	0.82
LH	Yard	0.00	0.00	0.00
LH	Storage	0.14	0.07	0.28
LH	Application	0.69	0.35	0.80

Animal	Source type	Fraction	Fraction, minimum	Fraction, maximum
LH	Grazing	0.00	0.00	0.00
OP	Housing	0.28	0.14	0.56
OP	Yard	0.00	0.00	0.00
OP	Storage	0.17	0.09	0.34
OP	Application	0.66	0.33	0.75
OP	Grazing	0.00	0.00	0.00
FU	Housing	0.27	0.14	0.54
FU	Yard	0.00	0.00	0.00
FU	Storage	0.09	0.05	0.18
FU	Application	0.27	-	-
FU	Grazing	0.00	0.00	0.00

Notes:

- EMEP/EEA (2009) gives separate values for fatteners and sows . GAINS does not know these categories and for that reason a weighted average of the results for fatteners and sows is taken for pigs.
- The values for broilers from EMEP/EEA (2009) are taken for the category OP (other poultry) in GAINS.
- For fur animals no data for application were given. Instead data from the draft publication of Haenel et al. (2010) were taken.

Table A6-6. Default fraction of TAN that is emitted as N_2O from storage (EMEP/EEA, 2009).

Animal	Type of storage	Fraction
DL	Cattle slurry with natural crust	0.01
DS	Cattle manure heaps, solid	0.08
OL	Cattle slurry with natural crust	0.01
OS	Cattle manure heaps, solid	0.08
PL	Pig slurry without natural crust	0.00
PS	Pig manure heaps, solid	0.05
LH	Layer manure heaps, solid	0.04
OP	Broiler, turkey, duck, goose manure heaps, solid	0.03
SH	Sheep and goat manure heaps, solid	0.07
HO	Horse (mules and asses) manure heaps, solid	0.08
BS	buffalo manure heaps, solid	0.08

Table A6-7. Default fraction of TAN that is emitted as NO from storage (EMEP/EEA, 2009).

Animal	Fraction
DL	0.0001
DS	0.0100
OL	0.0001
OS	0.0100
PL	0.0001
PS	0.0100
LH	0.0100
OP	0.0100
SH	0.0100
HO	0.0100
FU	0.0100
BS	0.0100
CM	0.0100

Table A6-8. Default fraction of TAN that is emitted as N_2 from storage (EMEP/EEA, 2009).

Animal	Fraction
DL	0.0030
DS	0.3000
OL	0.0030
OS	0.3000
PL	0.0030
PS	0.3000
LH	0.3000
OP	0.3000
SH	0.3000
HO	0.3000
FU	0.3000
BS	0.3000
CM	0.3000

Table A6-9. Fractions by which the NH_3 emissions are reduced for different animal-control option combinations. These fractions are currently taken the same for all countries.

Animal	Control option	Reduction factors Housing	Reduction factors Storage	Reduction factors Application	Reduction factors Grazing
DL	NC	0.0000	0.0000	0.0000	0.0000
DL	LNF	0.1500	0.1500	0.1500	0.2000
DL	SA	0.2500	0.8000	0.0000	0.0000
DL	CS_high	0.0000	0.8000	0.0000	0.0000
DL	CS_low	0.0000	0.4000	0.0000	0.0000
DL	CS	0.0000	0.8000	0.0000	0.0000
DL	LNA_high	0.0000	0.0000	0.8000	0.0000
DL	LNA_low	0.0000	0.0000	0.4000	0.0000
DL	LNA	0.0000	0.0000	0.8000	0.0000
DL	LNF_SA	0.3600	0.8300	0.1500	0.2000
DL	LNF_CS	0.1500	0.8300	0.1500	0.2000
DL	LNF_LNA	0.1500	0.1500	0.8300	0.2000
DL	SA_LNA	0.2500	0.8000	0.8000	0.0000
DL	CS_LNA	0.0000	0.8000	0.8000	0.0000
DL	LNF_SA_LNA	0.3600	0.8300	0.8300	0.2000
DL	LNF_CS_LNA	0.1500	0.8300	0.8300	0.2000
DS	NC	0.0000	0.0000	0.0000	0.0000
DS	LNF	0.1500	0.1500	0.1500	0.2000
DS	LNA_high	0.0000	0.0000	0.8000	0.0000
DS	LNA_low	0.0000	0.0000	0.2000	0.0000
DS	LNF_LNA_high	0.1500	0.1500	0.8300	0.2000
DS	LNF_LNA_low	0.1500	0.1500	0.3200	0.2000
OL	NC	0.0000	0.0000	0.0000	0.0000
OL	SA	0.2500	0.8000	0.0000	0.0000
OL	CS_high	0.0000	0.8000	0.0000	0.0000
OL	CS_low	0.0000	0.4000	0.0000	0.0000
OL	CS	0.0000	0.8000	0.0000	0.0000
OL	LNA_high	0.0000	0.0000	0.8000	0.0000
OL	LNA_low	0.0000	0.0000	0.4000	0.0000
OL	LNA	0.0000	0.0000	0.8000	0.0000
OL	SA_LNA	0.2500	0.8000	0.8000	0.0000
OL	CS_LNA	0.0000	0.8000	0.8000	0.0000
OS	NC	0.0000	0.0000	0.0000	0.0000
OS	LNA_high	0.0000	0.0000	0.8000	0.0000
OS	LNA_low	0.0000	0.0000	0.2000	0.0000
PL	NC	0.0000	0.0000	0.0000	0.0000
PL	LNF	0.2000	0.2000	0.2000	0.0000
PL	SA	0.4000	0.8000	0.0000	0.0000
PL	BF	0.8000	0.0000	0.0000	0.0000
PL	CS_high	0.0000	0.8000	0.0000	0.0000
PL	CS_low	0.0000	0.4000	0.0000	0.0000
PL	CS	0.0000	0.8000	0.0000	0.0000
PL	LNA_high	0.0000	0.0000	0.8000	0.0000
PL	LNA_low	0.0000	0.0000	0.4000	0.0000
PL	LNA	0.0000	0.0000	0.8000	0.0000
PL	LNF_SA	0.5200	0.8400	0.2000	0.0000
PL	LNF_BF	0.8400	0.2000	0.2000	0.0000
PL	LNF_CS	0.2000	0.8400	0.2000	0.0000

Animal	Control option	Reduction factors Housing	Reduction factors Storage	Reduction factors Application	Reduction factors Grazing
PL	LNF_LNA	0.2000	0.2000	0.8400	0.0000
PL	SA_LNA	0.4000	0.8000	0.8000	0.0000
PL	BF_CS	0.8000	0.8000	0.0000	0.0000
PL	BF_LNA	0.8000	0.0000	0.8000	0.0000
PL	LNF_SA_LNA	0.5200	0.8400	0.8400	0.0000
PL	LNF_BF_CS	0.8400	0.8400	0.2000	0.0000
PL	LNF_BF_LNA	0.8400	0.2000	0.8400	0.0000
PL	LNF_CS_LNA	0.2000	0.8400	0.8400	0.0000
PL	BF_CS_LNA	0.8000	0.8000	0.8000	0.0000
PL	LNF_BF_CS_LNA	0.8400	0.8400	0.8400	0.0000
PS	NC	0.0000	0.0000	0.0000	0.0000
PS	LNF	0.2000	0.2000	0.2000	0.0000
PS	BF	0.8000	0.0000	0.0000	0.0000
PS	LNA_high	0.0000	0.0000	0.8000	0.0000
PS	LNA_low	0.0000	0.0000	0.2000	0.0000
PS	LNF_BF	0.8400	0.2000	0.2000	0.0000
PS	LNF_LNA_high	0.2000	0.2000	0.8400	0.0000
PS	LNF_LNA_low	0.2000	0.2000	0.3600	0.0000
PS	BF_LNA_high	0.8000	0.0000	0.8000	0.0000
PS	BF_LNA_low	0.8000	0.0000	0.2000	0.0000
PS	LNF_BF_LNA_high	0.8400	0.2000	0.8400	0.0000
PS	LNF_BF_LNA_low	0.8400	0.2000	0.3600	0.0000
LH	NC	0.0000	0.0000	0.0000	0.0000
LH	LNF	0.2000	0.2000	0.2000	0.0000
LH	SA	0.6500	0.8000	0.0000	0.0000
LH	BF	0.8000	0.0000	0.0000	0.0000
LH	CS_high	0.0000	0.8000	0.0000	0.0000
LH	CS_low	0.0000	0.0000	0.0000	0.0000
LH	CS	0.0000	0.8000	0.0000	0.0000
LH	LNA_high	0.0000	0.0000	0.8000	0.0000
LH	LNA_low	0.0000	0.0000	0.2000	0.0000
LH	LNA	0.0000	0.0000	0.8000	0.0000
LH	LNF_SA	0.7200	0.8400	0.2000	0.0000
LH	LNF_BF	0.8400	0.2000	0.2000	0.0000
LH	LNF_CS	0.2000	0.8400	0.2000	0.0000
LH	LNF_LNA	0.2000	0.2000	0.8400	0.0000
LH	SA_LNA	0.6500	0.8000	0.8000	0.0000
LH	BF_CS	0.8000	0.8000	0.0000	0.0000
LH	BF_LNA	0.8000	0.0000	0.8000	0.0000
LH	LNF_SA_LNA	0.7200	0.8400	0.8400	0.0000
LH	LNF_BF_CS	0.8400	0.8400	0.2000	0.0000
LH	LNF_BF_LNA	0.8400	0.2000	0.8400	0.0000
LH	LNF_CS_LNA	0.2000	0.8400	0.8400	0.0000
LH	BF_CS_LNA	0.8000	0.8000	0.8000	0.0000
LH	LNF_BF_CS_LNA	0.8400	0.8400	0.8400	0.0000
OP	NC	0.0000	0.0000	0.0000	0.0000
OP	LNF	0.1000	0.1000	0.1000	0.0000
OP	SA	0.8500	0.8000	0.0000	0.0000
OP	BF	0.8000	0.0000	0.0000	0.0000
OP	CS_high	0.0000	0.8000	0.0000	0.0000
OP	CS_low	0.0000	0.0000	0.0000	0.0000
OP	CS	0.0000	0.8000	0.0000	0.0000
OP	LNA_high	0.0000	0.0000	0.8000	0.0000

Animal	Control option	Reduction factors Housing	Reduction factors Storage	Reduction factors Application	Reduction factors Grazing
OP	LNA_low	0.0000	0.0000	0.2000	0.0000
OP	LNA	0.0000	0.0000	0.8000	0.0000
OP	LNF_SA	0.8600	0.8200	0.1000	0.0000
OP	LNF_BF	0.8200	0.1000	0.1000	0.0000
OP	LNF_CS	0.1000	0.8200	0.1000	0.0000
OP	LNF_LNA	0.1000	0.1000	0.8200	0.0000
OP	SA_LNA	0.8500	0.8000	0.8000	0.0000
OP	BF_CS	0.8000	0.8000	0.0000	0.0000
OP	BF_LNA	0.8000	0.0000	0.8000	0.0000
OP	LNF_SA_LNA	0.8600	0.8200	0.8200	0.0000
OP	LNF_BF_CS	0.8200	0.8200	0.1000	0.0000
OP	LNF_BF_LNA	0.8200	0.1000	0.8200	0.0000
OP	LNF_CS_LNA	0.1000	0.8200	0.8200	0.0000
OP	BF_CS_LNA	0.8000	0.8000	0.8000	0.0000
OP	LNF_BF_CS_LNA	0.8200	0.8200	0.8200	0.0000
SH	NC	0.0000	0.0000	0.0000	0.0000
SH	LNA_high	0.0000	0.0000	0.8000	0.0000
SH	LNA_low	0.0000	0.0000	0.2000	0.0000
SH	LNA	0.0000	0.0000	0.8000	0.0000
HO	NC	0.0000	0.0000	0.0000	0.0000
FU	NC	0.0000	0.0000	0.0000	0.0000

For an explanation of the control options see the GAINS website.