SNAP CODES :	**10 09 01**	**10 09 08**
	10 09 02	**10 09 09**
	10 09 03	**10 09 10**
	10 09 04	**10 09 11**
	10 09 05	**10 09 12**
	10 09 06	**10 09 13**
	10 09 07	**10 09 14**
		10 09 15
SOURCE ACTIVITY TITLE :	**MANURE MANAGEMENT REGARDING NITROGEN COMPOUNDS**	
	Dairy cows	***Broilers***
	Other cattle	***Other poultry***
	Fattening pigs	***Fur animals***
	Sows	***Goats***
	Sheep	***Mules and asses***
	Horses	***Camels***
	Laying hens	***Buffalo***
		Any other animals
NOSE CODES :	**110.09.01**	**110.09.08**
	110.09.02	**110.09.09**
	110.09.03	**110.09.10**
	110.09.04	**110.09.11**
	110.09.05	**110.09.12**
	110.09.06	**110.09.13**
	110.09.07	**110.09.14**
		110.09.15
NFR CODES :	**4B1a**	**4B5**
	4B1b	**4B6**
	4B2	**4B7**
	4B3	**4B8**
	4B4	**4B9**
		4B13

1 ACTIVITIES INCLUDED

This chapter considers the emissions of ammonia (NH_3) and nitrous oxide (N_2O) from the excreta of agricultural animals deposited in buildings and collected as either liquid slurry or solid manure. This includes emissions from animal excreta at all stages: animal housing, manure storage and from land spreading of manures. Excreta deposited in fields by grazing animals are dealt with under SNAP codes 100100 (Cultures with fertilisers) and 100200 (Cultures without fertilisers) in this Guidebook. However, the calculation procedure is part of this chapter.

2 CONTRIBUTIONS TO TOTAL EMISSIONS

2.1 Ammonia

Approximately 80 - 90 % of the total ammonia emissions in Europe originates from agricultural practices, the remainder from industrial sources, households, pet animals and natural ecosystems. Only emissions from agricultural sources are included in this chapter.

Ammonia emissions from animal excreta contribute over 80 % and those from application of fertilisers less than 20 % to the total ammonia emissions of agricultural origin in Europe (The Netherlands: 1998: 92 and 8 %, Koch et al., 2001, see also table 2.1; Germany: 1996: 84 and 16 %, Döhler et al., 2002; Switzerland 1995: 89 and 11 %, Eidgenössische Forschungsanstalt, 1997; Spain 1996: 78 and 22 %, Spanish Ministry of Agriculture, 2001; UK 1997: 91 and 9 %, Pain et al., 1998). There is, however, a wide variation from country to country and within the main animal categories, cattle, sheep, pigs and poultry. This variation from country to country is partly explained by the different distribution of animals over the main categories, their respective nitrogen excretion and the emission factors reflecting differences in agricultural practices, and housing systems and climate.

Table 2.1 Percentage contributions of ammonia emissions of agricultural origin (Animal excreta and fertiliser application only)

	European average[1]	Range for individual countries[2]	The Nether-lands[3]	Germany[4]	Spain[5]	United Kingdom[6]
Year	1989	1989	1990	1996	1996	1996
Animal excreta	83 %	68 – 95 %	95 %	84 %	78 %	91 %
- cattle	55 %	21 – 83 %	54 %	55 %	35 %	55 %
- sheep and goats	5 %	0 – 35 %	2 %	0.4 %	9 %	6 %
- pigs	15 %	0 – 41 %	31 %	21 %	25 %	11 %
- poultry	6 %	0 – 10 %	8 %	6 %	7 %	19 %
Fertiliser application	17 %	5 – 32 %	5 %	16 %	21 %	9 %

[1,2] Asman, 1992
[3] Van Der Hoek, 1994
[4] Döhler et al., 2002
[5] Spanish Ministry of Agriculture, 2001
[6] Pain et al., 1998

2.2 Nitrous Oxide

IPCC estimates the global present-day emission of N2O-N at 14.7 (10 - 17) Tg a-1 N2O-N, of which 5.7 (3.7 - 7.7) Tg a-1 N2O-N is considered due to human activities (IPCC, 1995). Anthropogenic emissions result mainly from agricultural activities. Emissions from agricultural soils and livestock housing amount to 3.9 (2 - 5.8) Tg a-1 N2O-N.

Combustion of fossil fuels, in particular for transportation, is another important source of N_2O, as well as biomass burning and industrial production of, for instance, nitric acid for synthetic fertilisers.

Table 2.2 Percentage contributions of nitrous oxide emissions of agricultural origin [1]

	Emission rates for EU 15 in Gg a^{-1}	Relative contribution EU 15 in %
Year	1995	1995
Mineral arable soils	190	46
Grassland soils	100	24
Farmed organic soils	38	9
Animal houses	23	6
Manure storage	9	2
Grazing	53	13
Total	413	100

[1] Freibauer & Kaltschmitt, 2001

In accordance with the revised IPCC Guidelines for National Greenhouse Gas Inventories (IPCC/OECD/IEA 1997), this Guidebook considers only animal manure management systems and soil emissions (both direct and indirect) as agricultural sources of N_2O. It is recognized that emissions from animal production are considerable on a global scale. Animal manure management systems alone account for about one-third of the agricultural emissions (Mosier et al., 1998).

3 GENERAL

3.1 Description

3.1.1 Ammonia

Ammonia emissions from animal husbandry occur during both the housing and grazing periods. This section deals primarily with emissions from the housed component of animal production. However, the results obtained for the grazing component are calculated in this chapter and are supplied for use in SNAP Code 100100.

In the case of housed animals, emissions may be divided into those occurring directly from animal houses and those associated with the subsequent storage and land spreading of animal manures.

Ammonia emissions from livestock depend on many factors including:

- the nitrogen content of the feed,
- the species, age and performance (e.g. milk yield, weight gain) of the animal,
- the conversion of nitrogen in feed to nitrogen in meat, milk and eggs and, hence, the amount of nitrogen in the animal excreta,
- the housing system of the animal, including storage of the manures inside the building,
- the storage system of the manure outside the building: open or covered slurry tank, loose or packed pile of solid manure,
- climatic conditions in the building and the storage system, e.g. temperature,
- the proportion of time spent by animals indoors and outside, e.g. at pasture or in yards.

Ammonia emissions from animal manures during and after spreading depend on:

- spreading techniques and the surface exposed of the respective manure,
- properties of the animal wastes including viscosity, ammoniacal nitrogen content and pH,
- soil properties such as pH, cation exchange capacity, calcium content, water content, buffer capacity and porosity,
- meteorological conditions including precipitation, temperature, humidity and wind-speed,
- the method and rate of application of animal manures, including, for arable land, the time between application and incorporation,
- the height and density of the crop or grassland.

In order to calculate ammonia emissions precisely, it is necessary to have quantitative data on all the factors noted above. In practice, results are summarized to provide 'average' emission factors per animal for each stage of emission for the main livestock classes and management types. Total ammonia emissions are then scaled by the numbers of animals in each country.

3.1.2 Nitrous Oxide

In 1995-1996 an IPCC/OECD/IEA working group developed a revised methodology for estimating N_2O emissions from agriculture (Mosier et al., 1998). The methodology was approved of by the Intergovernmental Panel on Climate Change (IPCC) and has been included in the IPCC Guidelines for National Greenhouse Gas Inventories (IPCC/OECD/IEA, 1997).

The IPCC Guidelines for National Greenhouse Gas Inventories provide default emission factors for direct and indirect soil emissions and different types of animal waste management systems (IPCC/OECD/IEA, 1997). The method aims at assessing the full nitrogen cycle, taking into account N_2O formation in agricultural soils (as a result of N inputs or soil cultivation), animal waste management systems, as well as indirect formation of N_2O after agricultural N is emitted as NH_3 or NO_x or leaches from the agricultural system to groundwater and surface waters.

Nitrous oxide emissions from agricultural activities are known to be regulated by many parameters. Specific characteristics of soils, crops, types of fertiliser, and climate largely influence biogenic N_2O formation in soils. As a result, the observed N_2O fluxes from agricultural fields show large spatial and regional variation. However, these factors were not included in the IPCC methodology for estimating direct N_2O emission from agricultural soils on a national scale, because the available data do not allow for identification of appropriate emission factors (Bouwman, 1996; Freibauer & Kaltschmitt, 2001). Instead, the IPCC Guidelines provide a methodology to estimate N_2O emissions as a percentage of N that is imported into the system as a result of human activity. The input data needed can all be obtained from FAO databases.

The IPCC Guidelines distinguish between emissions from domestic livestock (IPCC terminology: animal waste management) and agricultural soils. The IPCC source categories differ from the CORINAIR sub-sectors. This paper presents a guideline for estimating emissions for CORINAIR subcodes, using the IPCC Guidelines for National Greenhouse Gas Inventories (Table 3.1).

Nitrous oxide emissions from manure management according to EMEP/CORINAIR definitions include:

- emissions from livestock housing (6 “animal waste management” systems, but excluding grazing animals);
- direct soil emissions due to manure-N inputs when using manure as fertiliser (but excluding grazing animals);
- indirect emissions due to NH_3 and NO_x emissions from animal manure, excluding N excretion by grazing animals;
- indirect emissions due to N-leaching and runoff from animal manure, excluding N excretion by grazing animals.

Table 3.1 Summary of IPCC source categories (IPCC Guidelines for National Greenhouse Gas Inventories, Volume 2: Workbook, 1997) to be reported as CORINAIR sub-sectors for agriculture

CORINAIR SUB-SECTOR (SNAP code)	IPCC N_2O SOURCE (IPCC Workbook Worksheet)
Cultures with/without fertilisers (100100/100200)	- Direct soil emissions due to N-inputs excluding manure (worksheet 4-5, sheet 1, excluding animal waste F_{aw}) - Direct soil emissions due to histosol cultivation (worksheet 4-5, sheet 2) - Direct soil emissions from grazing animals; pasture, range & paddock (worksheet 4-5, sheet 3) - Indirect emissions due to NH_3 and NO_x emissions from synthetic fertiliser use and grazing animals (worksheet 4-5, sheet 4, excluding animal waste used as fertiliser) - Indirect emissions due to N leaching/runoff from synthetic fertiliser use and grazing animals (worksheet 4-5, sheet 5, excluding animal waste used as fertiliser)
Manure Management (100900)	- Manure management: 6 waste management systems (worksheet 4-1, sheet 2, excluding pasture, range & paddock) - Direct soil emissions due to manure N-inputs excluding grazing animals (worksheet 4-5, sheet 1, row for animal waste F_{aw} only) - Indirect emissions due to NH_3 and NO_x emissions from animal waste excluding grazing animals (worksheet 4-5, sheet 4, animal waste used as fertiliser only) - Indirect emissions due to N leaching/runoff from animal waste excluding grazing animals (worksheet 4-5, sheet 5, animal waste used as fertiliser only)

Both IPCC Guidelines and the EMEP/CORINAIR Guidebook give default values for nitrogen excretion by livestock in kg N per animal per year (Table 4.1 in this chapter of the EMEP/ CORINAIR Emission Inventory Guidebook, and Table 4-6 of Volume 2 of the IPCC Guidelines; IPCC/OECD/IEA, 1997). Countries are recommended to use the EMEP/ CORINAIR default values for nitrogen excretion by livestock in a consistent way.

3.1.3 Nitric oxide

Nitric oxide (NO) is primarily produced by nitrification; it should therefore be formed in the surface layers of stored manure. At present, no data are available describing NO emissions from manure management.

3.2 Controls

3.2.1 Ammonia

There are a number of potential methods for reducing ammonia emissions. With any of these methods, it is essential that due care is taken to ensure that any nitrogen conserved is made available as plant fertiliser and does not cause other environmental problems such as nitrate leaching or nitrous oxide emissions.

A wide range of control techniques are available for reducing ammonia emissions, depending on the source type and existing management practices (for details see Tables in Appendix B).

Feeding: Animal feeding strategies can also be used for reducing ammonia emissions. A better adjustment of protein supply in the feed to the protein requirement of the animal results in a lower nitrogen excretion. This approach is most effective with monogastric animals. For ruminants, the issue is complicated by the digestability of carbohydrates in the feed. The achievable reduction of ammonia emission is lower than with modification of the housing systems, but the associated costs are also much lower.

Housing: A reduction of the area polluted with urine and faeces and hence the emitting surface results in decreased emissions. However, means to improve animal welfare are likely to result in larger surface areas per animal and hence increased emission rates. Housing with out-door climate may reduce temperature and thus the vapour pressure of ammonia in excreta. An emission reduction may be obtained for pigs. Technical systems like grooved floors combined with an adequate scraping are likely to reduce emissions from cattle houses. For laying hens, manure drying and manure belts increase evaporation and by drying the excreta reduce the breakdown of uric acid to urea, hence reducing the formation of ammonia.

Slurry and manure treatment systems: Anaerobic digestion of slurry results in an increased share of TAN. However, the treated slurry has a reduced viscosity and thus penetrates the soil surface more easily. Anaerobic digestion is likely to reduce ammonia emissions from spreading slightly. Slurry separation leads to considerably reduced ammonia emissions due to increased penetration rates of the slurry. The emissions from the solid separate are comparatively small. Composting of solid manure increases ammonia emissions during the composting process and storage drastically; overall losses were much greater from composted than from uncomposted manure despite the fact that there are no subsequent losses during spreading (Amon et al., 1998).

Storage: Covering the slurry storage tank outside the building with a tight roof decreases the emission of ammonia by about 80 %. Often cattle slurry generates a floating crust, which is less effective in reducing the emission of ammonia (about 50 % reduction of emission). Other control options also require modified housing conditions. Examples are immediate removal of urine in cubicle houses for cattle, keeping the temperature of stored pig manure in pig housing below 15 °C. These techniques can give 50 % or more emission reduction but they are quite expensive and as yet no legislation has been applied to encourage these approaches, which require careful management to be effective.

Spreading: Emissions from manure and slurry spreading can be reduced efficiently using technical systems which reduce the effective emitting surface and thus the gaseous exchange between slurry and air. Low emission land spreading techniques include bandspreading and injection of slurries and directly ploughing in or harrowing after application to arable land. In several countries legislation already exists for land spreading of animal wastes (The Netherlands: Besluit Gebruik Dierlijke Meststoffen, 1991; England: see Brewer and Davidson, 1999; Germany: Düngeverordnung, 1996; Sweden: see Jakobsson, 1999).

Where applicable, low emission techniques such as injection can give up to 80 % reduction in ammonia emission on grassland, compared to surface spreading of animal manures. However, injection techniques are not suitable for stony or sloping fields, or in all weather conditions.

For arable land, 80 % reduction in ammonia emission is achievable when the wastes are harrowed or ploughed in within 4-6 hours after application of the wastes to the soil.

The vapour pressure of ammonia is significantly influenced by temperature. Hence spreading during cooler seasons or periods leads to reduced emissions. In some countries the Meteorological Service provides estimates of ammonia losses as a function of time of the respective day.

However, any technique that reduces emissions and thus increases nitrogen inputs into soils has the potential to increase nitrate leaching, stimulate N_2O formation etc.

3.2.2 Nitrous Oxide

As described earlier, manure management may lead to N_2O emissions

- from animal manure management systems,
- from agricultural soils due to use of manure as fertiliser and
- indirectly, following NH_3 and NO_x emissions or N leaching and runoff.

Emissions from animal housing (animal manure management systems) could be reduced by shifting towards systems having low emissions of N_2O. Storage of manure at aerobic conditions is known to result in more N_2O formation than anaerobic storage of manure, as reflected in the emission factors. It should be noted, however, that systems with low N_2O emissions may have relatively high emissions of NH_3 and CH_4.

The amount of N_2O formation in agricultural soils following some amount of N input is difficult to reduce. Some studies show that, under specific circumstances, certain types of fertilisers give rise to higher emissions than others. However, it is as yet not possible to formulate general rules for fertiliser use leading to a reduction in N_2O emissions. The use of chemical inhibitors (e.g. nitrification inhibitors) has been shown to decrease N_2O formation for some time. However, it is as yet not known what the side-effects and long-term effects of inhibitors are on agricultural and surrounding natural soils. Inhibitors are therefore not recommended.

Any reduction in emissions of NH_3 and NO_x will reduce *indirect* N_2O formation.

However, some techniques for reducing NH_3 emissions may lead to increased N_2O emissions from soils and animal housing. For instance, injection of manure into soils instead of surface spreading may reduce NH_3 emissions and related indirect N_2O emissions, but increase N_2O formation in agricultural soils. Similarly, some methods for reducing NH_3 emissions from animal housing may increase N_2O emissions.

The most effective way to avoid N_2O formation in agriculture is, therefore, by improving the efficiency of nitrogen use (Kroeze, 1996). This may result in a reduced N input to agricultural soils and, as a result, reduce formation of N_2O. In addition, it may reduce nitrogen leaching and runoff, thus reducing indirect emissions of N_2O.

4 SIMPLER METHODOLOGY

4.1 Ammonia

The simpler approach for estimating ammonia emissions from animal husbandry is to use an average emission factor per animal for each class of animal and to multiply this factor by the number of animals counted in the annual agricultural census. Table 4.1 presents the recommended ammonia emission factors for the different classes of animals. The ammonia emission factors are calculated for the average European farming situation, starting with an average nitrogen excretion per animal and using a volatilization percentage for ammonia losses in the housing and also volatilization factors for the remaining nitrogen entering the storage outside the building and for the nitrogen available for landspreading. Appendix A gives more details and also instructions how to account for emission control techniques.

The emission factors are calculated for one average animal which is present 365 days a year. Due to empty housing between two production cycles in practical farming situations, the number of animal places on a farm is greater than the average number of animals which are present on a yearly base at a farm. The average numbers of the different animal categories are counted by the annual agricultural census.

The ammonia emission caused by agricultural sources can be calculated by multiplying the average number of animals by the emission factor (Table 4.2). The default ammonia emission factors are given in Table 4.1. Every country can also use country specific factors; this can be the situation when more precise data are available on e.g. the nitrogen excretion per animal or the volatilisation percentages for ammonia losses. Appendix A (Table 3A) explains the derivation of the default ammonia emission factors, which can be helpful for calculating country specific factors.

Table 4.1: Ammonia emission factors for the simpler methodology to calculate the NH_3 emission from manure management. Annually averaged emission in kg NH_3 per animal, as counted in the annual agricultural census[1]

	Activity	N excreted	Animal housing	Storage outside the housing	Surface spreading of waste	Sum housing and manage-ment	Grazing	Total emissions
100901	Dairy cows	100	8.7	3.8	12.1	24.6	3.9	28.5
100902	Other cattle (including young cattle, beef cattle and suckling cows)	50	4.4	1.9	6.0	12.3	2.0	14.3
100903	Fattening pigs	14	2.89	0.85	2.65	6.39	0.0	6.39
100904	Sows[2]	36	7.43	2.18	6.82	16.43	0.0	16.43
100905 (+100911)	Sheep (and goats)[2]	20	0.24		0.22	0.46	0.88	1.34
100906 (+100912)	Horses (and mules, asses)	50	2.9		2.2	5.1	2.9	8.0
100907	Laying hens (laying hens and parents)	0.8	0.19	0.03	0.15	0.37	0.0	0.37
100908	Broilers (broilers and parents)	0.6	0.15	0.02	0.11	0.28	0.0	0.28
100909	Other poultry (ducks, geese, turkeys)	2.0	0.48	0.06	0.38	0.92	0.0	0.92
100910	Fur animals[2]	4.1	0.60		1.09	1.69	0.0	1.69
100913	Camels[3]	55				5.0	5.5	10.5
100914	Buffalo[3]	45				4.2	4.5	8.7

[1] This means explicitly not per animal place or per delivered animal.
[2] The emission factors are calculated for female adult animals; the emissions of the young animals are included in the given values.
[3] Preliminary data given in Bouwman et al. 1997

Table 4.2: Total ammonia emissions based on ammonia emission factors and animal class numbers, for manure management. Emission factors in kg NH_3 per animal, as counted in the annual agricultural census.

	Activity	Ammonia emission factor				Number of Animals	Total ammonia emission D * E
		Housing	Storage	Application	Total A+B+C		
		A	B	C	D	E	F
100901	Dairy cows						
100902	Other cattle (including young cattle, beef cattle and suckling cows)						
100903	Fattening pigs						
100904	Sows (only female adult animals)						
100905	Sheep (only female adult sheep and goats)						
100906	Horses (horses, mules and asses)						
100907	Laying hens (laying hens and parents)						
100908	Broilers (broilers and parents)						
100909	Other poultry (ducks, geese, turkeys)						
100910	Fur animals (only female adult animals)						
	TOTAL						

4.2 Nitrous Oxide

Nitrous oxide emissions from manure management include (Table 2.2)

- emissions from manure management systems,
- direct soil emissions due to manure N-inputs, excluding manure,
- indirect emissions due to manure N-inputs.

In the following paragraph reference is made to several worksheets included in the IPCC-guidelines for National Greenhouse Gas Inventories. Worksheets 4-1 to 4-5 can be found in Volume 2 of the Workbook of the Revised 1996 IPCC Guidelines[1] (IPCC/OECD/IEA, 1997).

4.2.1 Emissions from manure management systems

These emissions are calculated in IPCC Worksheet 4-1, sheet 2 for 6 Animal Waste Management Systems (AWMS). The EMEP/CORINAIR sub-sector, however, is subdivided into 10 animal categories.

Recommended methodology (IPCC default methodology)

$$N\text{ex}_{(\text{AWMS})} = \sum\nolimits_{(\text{T})} [n_{(\text{T})} \cdot N\text{ex}_{(\text{T})} \cdot AWMS_{(\text{T})}]$$

where

$N\text{ex}_{(\text{AWMS})}$ nitrogen excretion rate per AWMS (kg a^{-1} N)

$n_{(\text{T})}$ number of animals of type T in the country

$N\text{ex}_{(\text{T})}$ N excretion rate of animals of type T in the country (kg $animal^{-1}$ a^{-1} N); it is recommended to use national data rather than EMEP/CORINAIR default values given in Table 4.1 rather than the excretion rates given in Table 4-6 of the IPCC Workbook..

$AWMS_{(\text{T})}$ fraction of $N\text{ex}_{(\text{T})}$ that is managed in one of the different distinguished animal waste management systems for animals of type T in the country; it is recommended to use national data rather than the default values given in the IPCC Workbook, Table 4-7.

From this the total N_2O emission rate can be obtained as sum of the emission rates for each animal waste management system according to

[1] The simpler methodology to assess nitrous oxide emissions was extracted in detail from the IPCC Guidelines and uses the IPCC terminology, symbols and units as far as possible. The terminology in the Good Practice Guidance (IPCC, 2000) Chapter 4.4, differs slightly from the Worksheet.

$$N_2O_{(\mathrm{AMWS})} = \sum [Nex_{\mathrm{AWMS}} \cdot EF_{3(\mathrm{AWMS})}]$$

$N_2O_{(\mathrm{AWMS})}$	N_2O-N emission rate from all animal waste management systems in the country (in kg a^{-1} N)
$EF_{3(\mathrm{AWMS})}$	N_2O-N emission factor for a single AWMS (in kg kg^{-1} N, i.e. kg N_2O-N per kg *N*ex in the system). For $EF_{3(\mathrm{AWMS})}$, default values are listed in Table 4.3.

For N_2O emission rates the N_2O-N emission rates have to be multiplied by 44/28.

Table 4.3. IPCC default emission factors for N_2O emissions from manure management

Animal Waste Management System	Emission Factor $EF_{3(\mathrm{AWMS})}$ (kg N_2O-N per kg N excreted) [1]
Anaerobic lagoon	0.001 (< 0.002)
Liquid system	0.001 (< 0.001)
Daily spread	0.0
Solid storage & drylot	0.02 (0.005 - 0.03)
Pasture range & paddock[2]	0.02 (0.005 - 0.03)
Other	0.005

[1] see IPCC/OECD/IEA (1997) for default method to estimate N excretion per Animal Waste Management System
[2] to be included in SNAP CODE 100100/100200 (cultures with/without fertiliser)

4.2.2 Direct soil emissions due to manure N-inputs

Direct soil emissions induced by animal manure include emissions following use of manure as fertiliser. Emissions induced by grazing animals are included in SNAP Codes 100100 and 100200 (cultures with and without fertiliser).
Emission rates resulting from use of manure as fertiliser can be assessed as

$$N_2O_{\mathrm{AW,spread}} = EF_1 \cdot \sum_{(\mathrm{T})} [n_{(\mathrm{T})} \cdot N_{\mathrm{AW,spread,(T)}}]$$

where

$N_2O_{\mathrm{AW,\,spread}}$	N_2O-N emission rate for the application of animal waste (kg a^{-1} N_2O-N)
EF_1	emission factor for direct emissions due to manure application (kg kg^{-1} N), as listed in Table 4.4
$n_{(\mathrm{T})}$	number of animals of type T in the country
$N_{\mathrm{AW,\,spread,\,(T)}}$	amount of N in excreta left for spreading (in kg $animal^{-1}$ a^{-1} N) according to

$$N_{\text{AW,spread,(T)}} = Nex_{\text{housing,(T)}} - NH_{3(\text{T})} \cdot \frac{14}{17}$$

where

$Nex_{\text{housing, (T)}}$	amount of N excreted in animal houses for an animal category T (in kg $animal^{-1}$ a^{-1} N)
NH_3	NH_3 emission rate for an animal category T

For default values of $Nex_{\text{housing (T)}}$ and NH_3 use Appendix A, Table 3A.

4.2.3 Indirect emissions due to manure N-inputs

Indirect emissions due to manure N-inputs result from

- atmospheric emission and consecutive deposition of NH_3 and NO_x, and
- leaching of manure-N from soils to ground- and surface waters where N_2O formation takes place.

hence

$$N_2O_{\text{indirect}} = N_2O_{\text{G}} + N_2O_{\text{L}}$$

where

N_2O_{indirect}	N_2O-N emission rates in the respective country due to NH_3 and NO_x losses from manure and mineral fertiliser application (kg a^{-1} N) [for kg a^{-1} N_2O multiply by 44/28]
N_2O_{G}	indirect emission rates due to deposition of reactive N species following agricultural emissions of NH_3 and NO (kg a^{-1} N)
N_2O_{L}	indirect emission rates due to leaching and runoff of reactive N species following application of manure and mineral fertiliser (kg a^{-1} N)

In the IPCC Workbook, ***indirect emissions due to NH_3 and NO_x emissions*** are calculated in IPCC Worksheet 4-5, sheet 4. Only indirect emissions due to manure spreading (excluding grazing animals) should be reported in this CORINAIR subsection. Table 4.4 summarises default emission factors.

Recommended methodology:

$$N_2O_{\text{indirect}} = (NH_3 + NO) \cdot EF_4$$

where

NH_3	NH_3-N emission rates from manure and mineral fertiliser application (kg a^{-1} N). Emissions to be used from results obtained according to chapters 100900 – 5.1 or 4.1 and chapter 100100 – 4.1 of this Guidebook.
NO	NO-N emission rates from fertiliser application (kg a-1 N). Emissions to be used from results obtained according to chapter 100100 – 4.3 of this Guidebook.
EF_4	emission factor for indirect emissions due to manure and mineral fertiliser application (kg kg^{-1} N), as listed in Table 4.4

Indirect emissions due to leaching are calculated in IPCC Worksheet 4-5, sheet 5, and the manure-related part of this source can be estimated in a similar way.

Recommended methodology:

$$N_2O_\mathrm{L} = \left(N_\mathrm{Fert} + N\mathrm{ex}_\mathrm{spread}\right) \cdot Frac_\mathrm{Leach} \cdot EF_5$$

where

N_fert	total use of mineral fertiliser N in a country (see 100100)
$Frac_\mathrm{Leach}$	fraction of nitrogen input to soils that is lost through leaching and runoff (kg kg^{-1} N); default value $Frac_\mathrm{Leach}$ = 0.3 kg kg^{-1}, see IPCC Workbook, Table 4-19.
EF_5	emission factor for indirect emissions due to leaching and runoff of fertilisers applied (kg kg^{-1} N), as listed in Table 4.4

Table 4.4. IPCC default emission factors EF_1 for N_2O emissions from agricultural soils to be reported under SNAP CODE 100900 (manure management)

	Emission Factor
Direct soil emissions - due to N input	EF_1 = 0.0125 (0.0025 - 0.0225) kg N_2O-N per kg N input[1]
Indirect emissions - NH_3 and NO_x deposition	EF_4 = 0.01 (0.002 - 0.02) kg N_2O-N per kg NH_3-N and NO_x-N emitted
- N leaching and runoff	EF_5 = 0.025 (0.002 - 0.12) kg N_2O-N per kg N leaching/runoff

[1] manure (excl. NH_3 emissions); see IPCC/OECD/IEA (1997) for default method to estimate N input

5 DETAILED METHODOLOGY

5.1 Ammonia

5.1.1 Introduction

It is anticipated that within the next two decades, ammonia from livestock manure will contribute over a quarter of all acidifying, and half of all eutrophying, emissions of atmospheric pollutants in Europe (Amann et al., 1996). International protocols therefore aim at a considerable reduction in ammonia emissions. Reduction potentials and reduction pathways have to be identified and quantified. This cannot be achieved by using mean emission factors or mean partial emission factors. In addition, the number and heterogeneity of small sources make accurate estimation of emissions from this sector particularly problematic. In recognition of these two factors, some considerable space in this guidebook is devoted to the detailed methodology for ammonia emissions from manure management. Despite the apparent complexity of the following tables, the method is easy to use in principle. It does necessarily require more input data than the simpler methodology.

The simpler method uses a simple process-based modelling approach, based on the concept of a flow of total ammoniacal nitrogen (TAN or mineral N) through the manure management system, as shown in the schematic diagram in Figure 5.1. The relative volumes of flow through the different pathways are determined by country-specific information on animal husbandry and manure management systems, while the proportion volatilised as ammonia at each stage in the system is treated as a percentage, based on measured values and expert judgement.

However, since it is clear that different manure management systems produce very different ammonia emissions, one of the major priorities in estimating emissions is to be able to distinguish between different systems. The adoption of a consistent flow model based on percentage transfers of ammoniacal N (TAN) allows different options or pathways to be incorporated in order to account for differences between real-world systems.

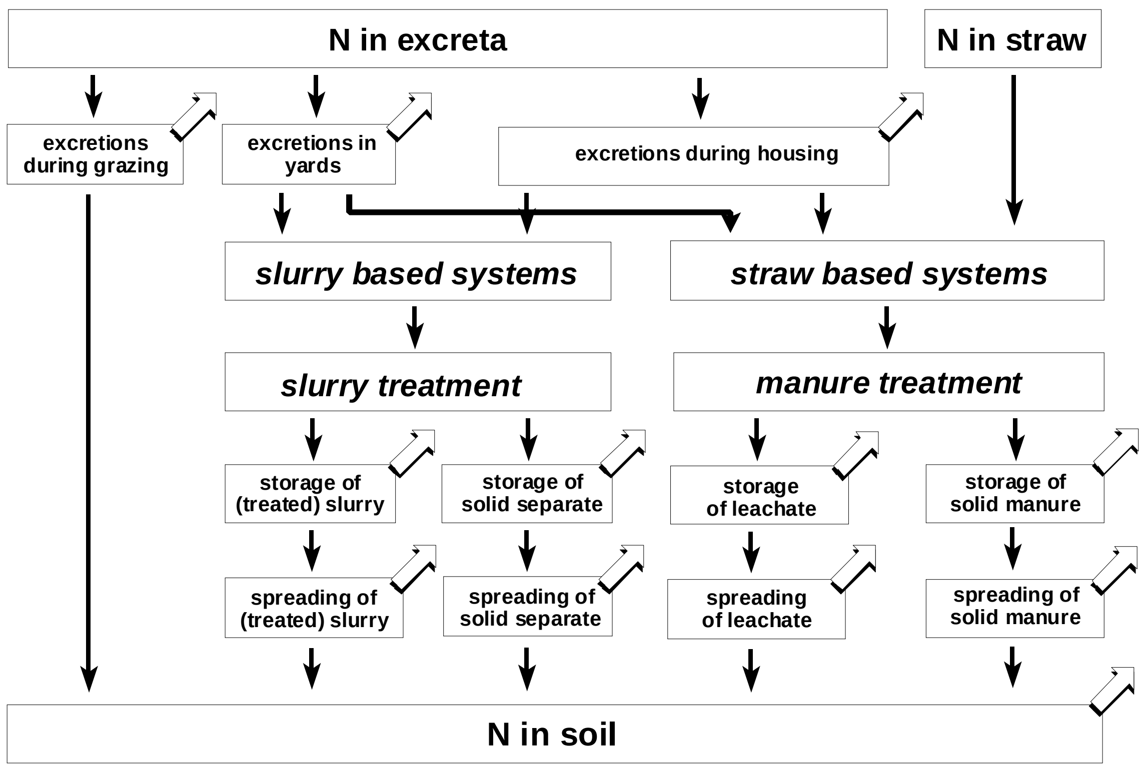
There are consequently several advantages over the simpler methodology:

- Different systems are represented at each stage to account for real differences in management systems and resulting emissions. In particular, distinctions are made between solid and liquid waste systems at each stage.
- Possible abatement measures are included as alternative systems. Measures have already been introduced in several countries in Europe, making current emission factors obsolete. In addition this enables efficient up-dating of emission estimates, and the systematic calculation of possible future emission projections and scenarios.
- Due to the hierarchical structure of the models, default values equivalent to those in the simpler method are available, so that no extra data is absolutely required. However, where information is available, it can be used systematically to improve emission estimates. This is likely to be particularly important where firm data is lacking but informed expert opinion (e.g. an estimate of the % of dairy farms producing slurry) may provide

reasonable approximations. For data-poor areas this is probably the most effective method of improving emission estimates.

- The tables (Appendix B) can also be provided as an active MS Excel spreadsheet with automatic calculation and error-checking.

Fig. 5.1: Flows of nitrogen and emissions of ammonia from animal husbandry (broad arrows indicate locations where ammonia is emitted)



5.1.2 Data sources and default values

Animal numbers

Even on SNAP level 3, animal numbers may be aggregated within categories (e.g. other cattle - sheep and goats – horses, mules and asses - other poultry). The assumptions made in the simpler methodology about the composition of these categories of sub-categories are unlikely to represent national or sub-national conditions. It is therefore advisable to disaggregate these categories within the bounds of the census data available, in particular

-	other cattle	calves and young cattle
		male and female beef cattle
-	sheep and goats	upland and lowland sheep
		goats
-	horses, mules and asses	heavy and light horses
		asses
		mules

-	other poultry	pullets male and female turkeys ducks geese

If necessary, other animals like buffalo, deer etc. will have to be dealt with separately, if they contribute significantly to the respective total.

Nitrogen excretion rates
Nitrogen excretion rates vary between countries according to livestock breeds, dietary inputs, slaughter age, and other aspects of animal husbandry. Rates are generally greater in more intensive systems, and relationships have been observed between nitrogen excretion and milk yield, for example (Eidgenössische Forschungsanstalt, 1997; Poulsen et al., 1998; Petersen et al., 1998; Döhler et al., 2002). Table 5A in Appendix B gives examples for nitrogen excretion rates.

Dietary manipulation may be used in some situations to reduce nitrogen excretion and resulting ammonia emission. Therefore, although it is not included as an abatement measure as such, the effect of dietary manipulation can be determined by adjusting the nitrogen excretion rate. This will mainly be of use in analysing possible future abatement scenarios.

Ammoniacal nitrogen content
As the detailed method makes use of the total ammoniacal nitrogen (TAN) when calculating emissions, the initial share of TAN must be known as well as any transformation rates between organic N and TAN. Table 5B gives examples of TAN shares in excreta.

Housing and grazing
Excreta may be dropped inside houses, on pastures and paddocks or on hard standings (i.e. "sealed" surfaces, such as roads, or waiting areas for cows to be milked). For cattle, the share of excreta deposited in these areas is equivalent to the share of time animals spent in the respective area.

Nitrogen input with bedding material
With bedding material (straw, chippings etc.) additional nitrogen has to be considered within the calculations. Table 5C gives examples of the magnitude of the amounts. The TAN share of nitrogen in straw is assumed to be zero.

Volatilisation rates
The volatilisation rates given in Table 5B in Appendix B can serve as examples; they were compiled from literature published on measured values (e.g. Isermann, 1990; Klaassen, 1992; ECETOC, 1994; Döhler et al., 2002), and from discussion between a range of experts from across Europe. In particular, values have evolved through several workshops on ammonia emissions under the UN/ECE Convention on Long-Range Transboundary Air Pollution; in Laxenburg, Austria (1991), Culham, UK (1994); Den Haag, Netherlands (1995); Reggio Emilia, Italy (1997), and Bern, Switzerland (2000).

Volatilisation rates from grazing may vary between animal categories and is a function of diet soil conditions. Examples are given in Table 5D.

Volatilisation rates from housing and storage vary with meteorological conditions, particularly temperature. In extreme cases it may be reasonable to adjust the rates by a small amount to account for this effect, but in general a uniform rate for the whole of Europe is acceptable within the overall uncertainty in emission estimates, and is useful in establishing a consistent and transparent methodology. Tables 5E and 5F may be used to derive national estimates for emissions from housing and storage of slurry and farmyard manure (FYM).

Volatilisation rates from application of manure to land are quite complex, and in addition to meteorological factors (see e.g. Menzi et al., 1998) , are influenced by soil type, soil moisture conditions, crop type and condition, and others. Since spatial variations in such factors are of similar magnitude at the micro scale as at the country scale, common values for Europe as listed in the simpler methodology are again to be replaced with national partial emission factors. The examples given in Tables 5G to 5I reflect the difficulties to deal with emissions from spreading in detail, as well as the different "philosophies" applied in different countries.

Normally, a relative emission rate is determined for a reference method (i.e. broadcasting of slurry at a given temperature). Abatement measure efficiencies are then defined as the amount by which implementation of a measure reduces emissions from a particular stage or process compared to the unabated or baseline situation. The values used in the tables reflect the state of knowledge obtained in particular in the UN/ECE Ammonia Expert Group (Menzi & Achermann, 2001).

Frequency distributions

In the detailed methodology, each single partial emission factor of the simpler methodology is replaced by a weighted mean of specific partial emission factors, using emission factors and the frequency distribution characterising the composition of the herds, in particular their performance and feeding regimes distributions, as well as the distribution of housing types, storage facilities and spreading practices. However, only matching triples of animal numbers, emission factors and frequency distributions can result in sensible results. Frequency distribution are least transferable. Therefore, no examples are given in Appendix B.

5.1.3 Outline of the calculation procedure

In principle, calculations depict the nitrogen and TAN flows as indicated in Fig. 5.1 by assessing the relevant amounts at each stage (TAN potential for emissions from grazing, TAN potential for emissions from hard standings, TAN potential for emissions from housing) and distribute these pools between the amounts emitted (emissions from grazing etc) and amounts remaining in the system and forming the next pool (TAN potential for emissions from slurry based systems etc.).

Disaggregation of animal categories, housing systems etc. has to be combined with a spatial and – wherever possible – temporal disaggregation, as the effects of pollution by air-borne ammonia and ammonium are local rather than national or regional. Wherever possible, small areas are to be considered rather than nations: frequency distributions have to be collected or modelled with a comparatively high resolution in space.

In practice, this results in rather complex calculation procedures. The UN/ECE Task Force on Emission Inventories and Projections will therefore offers their help to establish national calculation worksheets (For further information please contact the Agriculture & Nature Expert Panel chair Ulrich Dämmgen, see section 20 for contact details).

5.2 Nitrous Oxide

No more detailed methodology is proposed for estimating emissions of N_2O. However, countries may use their own estimates for any step in the IPCC method if this will increase precision. In particular countries are encouraged to estimate NH_3 losses and N excretion by livestock using the methods described in this chapter, rather than the IPCC default values.

With the simpler methodology default ammonia emission factors are used. The detailed methodology makes use of country specific information on all the parameters involved like dietary information, local farming situations and use of low emission land spreading techniques. Volatilisation percentages can also be based on measurements of ammonia emissions from stables, storages and land application of wastes, as described in the ammonia methodology.

Once emissions have been calculated at whatever is determined by the national experts to be the most appropriate level of detail, results should also be aggregated up to the minimum standard level of information. This will allow for comparability of results among all participating countries. The data and assumptions used for finer levels of detail should also be reported to ensure transparency and replicability of methods.

6 RELEVANT ACTIVITY STATISTICS

6.1 Ammonia and animal numbers

For the simpler methodology, data is required on animal numbers for each of the categories listed in Table 4.2. The annual agricultural census can supply these data. Otherwise the statistical information from Eurostat can be used or the FAO Production Yearbook.

For the detailed methodology, the same data is required on animal numbers. Beside information is needed for all the parameters mentioned in Paragraph 5.1 (see also Appendices A and B).

6.2 Nitrous Oxide

The IPCC Guidelines (IPCC/OECD/IEA, 1997) provide default emission factors and other parameter values (N-excretion per animal, fraction of manure produced per animal waste management system, amount manure-N that leaches from soils, etc.) needed to estimate N_2O emissions from manure management. The only input data needed include animal numbers for six animal categories. These can be obtained from FAO databases.

7 POINT SOURCE CRITERIA

7.1 Ammonia

Emissions of ammonia should be considered on an area basis.

8 EMISSION FACTORS, QUALITY CODES AND REFERENCES

8.1 Ammonia

Emission factors for the simpler methodology are listed in Appendix 1. For the detailed methodology, emission factors and their frequency distributions have to be derived nationally. Guidance is given in Appendix B.

8.2 Nitrous oxide

The simpler methodology provides tools for an estimate in chapter 5.

9 SPECIES PROFILES

10 UNCERTAINTY ESTIMATES

10.1 Ammonia and animal numbers

Uncertainties in ammonia emission factors are in the magnitude of 30 %.

Uncertainties in animal numbers per class of animals are in the magnitude of 10 %.

Animal numbers, (partial) emission factors and frequency distributions are likely to be biassed, data sets are often incomplete. For this edition of the Guidebook, no quality statements can be given other than those mentioned above. However, experts compiling animal numbers, national expert guesses for emission factors and frequency distributions are strongly requested to document their findings, decisions and calculus to facilitate reviewing of their respective inventories.

10.2 Nitrous Oxide

Although the bacterial processes leading to N_2O emissions (nitrification and denitrification) are reasonably well understood, it is as yet difficult to quantify nitrification and denitrification rates in terrestrial and aquatic systems. In addition, the observed fluxes of N_2O show large temporal and spatial variation. As a result, the estimates of national emissions of N_2O from manure management are relatively uncertain, as reflected in the ranges of the default emission factors. Mosier et al. (1998) applied the IPCC method to the world and estimated agricultural emissions with an uncertainty range of about a factor of 20: 1 - 19 Tg N_2O-N per year. This only reflects the uncertainty in emission factors. In addition, there is considerable uncertainty in other factors, including N excretion by animals and amount of N leaching from soils.

11 WEAKEST ASPECTS/PRIORITY AREAS FOR IMPROVEMENT IN CURRENT METHODOLOGY

11.1 Ammonia

The simpler methodology applies a single average emission factor per animal. This takes no account of differing farming situations between countries or even in different areas of a particular country. On the other hand differing situations with regard to soil characteristics and temperature are also not taken into account.

At present, the detailed methodology is based on ammonia emission factors for individual countries or representative areas of Europe only.

11.2 Nitrous Oxide

The IPCC Guidelines was developed as a methodology applicable to any world country. As mentioned earlier, the IPCC method does not include the effects of soil type, fertiliser type, crop or climate on N_2O formation. Some European countries may, however, have access to country-specific data, making more reliable estimates possible. In some countries studies may have shown that country-specific conditions allow for adaptation of the emission factors. Or countries may apply process-based models to investigate their agricultural emissions of N_2O.

12 SPATIAL DISSAGGREGATION CRITERIA FOR AREA SOURCES

12.1 Ammonia

Considering the potential for ammonia to have local effects on ecology, ammonia emissions estimates should be disaggregated on the basis of animal husbandry data as much as possible. In The Netherlands or Germany for example the ammonia emissions are calculated per municipality and thereupon allotted to a grid of 5 by 5 km^2 or 50 by 50 km^2, respectively.

12.2 Nitrous Oxide

Spatial disaggregation of emissions from animal manure management systems may be possible if the spatial distribution of animal population is known. Soil maps may allow for disaggregation of soil emissions, if the spatial variation of N inputs is known. It may be difficult to disaggregate indirect emissions that take place at remote sites. With present emission partial factors, an accuracy is pretended which is unrealistic.

13 TEMPORAL DISAGGREGATION CRITERIA

13.1 Ammonia

The simpler methodology suffices with the ammonia emissions estimate without temporal disaggregation.

In the detailed methodology, first tools for a temporal disaggregation are provided (see this Guidebook, Vol. 1, chapter "The temporal variation of emission data and the GENEMIS project, BTMP-1 ff.).

13.2 Nitrous Oxide

Process-based models will be needed to quantify N_2O emissions dynamically. Soil emissions are known to take place shortly after fertilisation. However, considerable emissions may take place during fallow periods. Emissions from stables probably take place during all seasons. The timing of indirect emissions may be the most difficult to estimate, since there may be a considerable time lag between N excretion by animals and the eventual N_2O formation in aquatic systems due to N leaching and runoff.

14 ADDITIONAL COMMENTS

15 SUPPLEMENTARY DOCUMENTS

15.1 Ammonia

No supplementary documents are needed to calculate national ammonia emissions, as outlined for the simpler methodology. The scientific basis of the emission factors calculations is briefly reported in Appendix A (Van Der Hoek, 1998).

For the detailed methodology the documents of ECETOC (1994), the UN/ECE Working Group on Technology (Haanstra, 1995), the MARACCAS model (Cowell and ApSimon, 1998) or the GAS-EM model (Dämmgen et al., 2002) can be useful.

16 VERIFICATION PROCEDURES

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19 RELEASE VERSION, DATE AND SOURCE

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Updated by: Ulrich Dämmgen, Federal Agricultural Research Centre, Braunschweig, Germany (Chairman of Agriculture and Nature Panel);

J. Webb, ADAS Research, Wolverhampton, UK;

Leny Lekkerkerk, Ministry of Agriculture, Nature Management and Fisheries, Ede, The Netherlands (Chairman of Agriculture and Nature Panel).

Contributions of: Giuseppe Bonazzi, Liliana Cortellini, Laura Valli, Centro Ricerche Produzioni Animali, Reggio Emilia, Italy;

Sue Couling, Silsoe Research Institute, Silsoe, United Kingdom;

David Cowell, Imperial College of Science, Technology and Medicine, London, Great Britain;

Klaas Van Der Hoek, RIVM, Bilthoven, The Netherlands;

Carolien Kroeze, WIMEK, Wageningen, The Netherlands;

Brian Pain, IGER North Wyke, Okehampton, Devon, UK (Chairman of Agricultural Panel)

Original authors: Klaas Van Der Hoek, RIVM, Bilthoven, The Netherlands;

Sue Couling, Silsoe Research Institute, Silsoe, United Kingdom;

20 POINT OF ENQUIRY

Any comments on this chapter or enquiries should be directed to:

Ulrich Dämmgen

Institut für Agrarokologie
Bundesforschungsanstalt für Landwirtschaft
Bundesallee 50
38116 Braunschweig
Germany

Tel: +49 531 596 2601
Fax: +49 531 596 2599
Email: ulrich.daemmgen @fal.de

APPENDIX A

EXPLANATION OF THE AMMONIA EMISSION FACTORS USED IN THE SIMPLER METHODOLOGY TO CALCULATE THE EMISSION OF AMMONIA

This appendix gives more detailed information about the default ammonia emission factors and the categories of animals. These parameters are necessary to calculate the national emission of ammonia by agricultural sources. The calculation starts with the average nitrogen excretion of the animal. Ammonia losses during housing, storage of manure outside the building, grazing and application of manure are calculated as a volatilisation percentage of the 'incoming' amount of nitrogen. This means that when for example a slurry storage tank is covered, the volatilisation percentage declines and the amount of nitrogen available for landspreading increases and consequently the emission of ammonia during spreading also increases.

The volatilisation percentages for stables are derived from the Dutch ammonia emission factors for animal housing. These emission factors are based on measurements during the winter season for dairy cattle and during a full year for pigs and poultry. The volatilisation percentages for slurry storage tanks and landspreading originate from research in the United Kingdom and The Netherlands. For landspreading it is assumed that all slurries and solid wastes are spread on the field without using techniques to reduce emissions of ammonia.

The simpler methodology for calculating ammonia emissions uses default emission factors as presented in Table 3 (Chapter 4.1). The underlying data for these ammonia emission factors are presented in this Appendix in Table 3A. With the detailed methodology for every parameter a country specific value can be used. When an emission reduction technique is applied with an emission reduction for example of 80 %, the corresponding volatilisation percentage has to be multiplied with 0.2.

Number of animals
The default ammonia emission factors have to be used in relation to the average number of animals in a certain year. This number of animals is obtained from the annual agricultural census. This means that the number of animal places or the number of delivered animals is not relevant in respect to the presented default emission factors. For example a farm with 100,000 animal places for broilers counts 75,000 broilers as an average number of animals. This is due to a production cycle of 8 weeks, consisting of 6 weeks animal production followed by 2 weeks cleaning of the housing.

Dairy cows
The nitrogen excretion of a dairy cow depends on many factors. First of all there is a difference in milk production (and feeding level) per dairy cow within and between the European countries. Further the amount of nitrogen fertiliser applied to pasture varies and hence the nitrogen content of the grass. This means that the nitrogen intake and excretion per dairy cow also differs within and between countries. The nitrogen excretion of 100 kg per year is based on an European averaged milk yield of about 4500 kg milk per dairy cow per year and on a moderate use of fertiliser. It appears that for most countries this figure is quite reasonable. Dairy cows in calf are considered as dairy cows.

Also the length of the grazing period varies and hence the ratio nitrogen excreted in the pasture and nitrogen excreted in the housing. The grazing period is set at about 180 days and the corresponding nitrogen excretion is 50 kg of nitrogen. The dairy cows however remain a couple of hours a day in the housing for milking, so it is assumed that 20 % of the excreted nitrogen is collected in the housing. Effectively 40 kg of nitrogen are excreted in the pasture and 60 kg in the housing.

Slurry based systems store the wastes under a slatted floor inside the building and/or in slurry storage tanks outside the building. When all the slurry is stored outside the building, there is still a considerable emission of ammonia from the stable due to permanent presence of wastes in the building. The ammonia losses in the storage outside the building are based on an open storage tank that is in use for 6 months per year and as mentioned not provided with a cover.

When solid farmyard manure is produced the emission from housing is likely to be smaller but the emission from the farmyard manure pile is greater. In the simpler methodology, it is assumed that emissions of ammonia are equal to slurry based systems. However, in the detailed methodology distinctions are made between solid and liquid waste systems.

The emissions from landspreading are based on slurries. With solid wastes the percentage of mineral nitrogen is lower than in slurries, but in contrast to slurries, there is no rapid infiltration into the soil. It is therefore assumed that emissions from landspreading of solid wastes are equal to slurry based systems. The detailed methodology assumes differences in ammonia emission between the two systems.

Other cattle
Thirty-six percent of European cattle are dairy cows and the remainder are categorised as 'other cattle'. The composition of the other cattle is assumed as:

- 39 % young cattle for replacement with a nitrogen excretion of 46 kg (stable 24 kg and pasture 22 kg);
- 10 % suckling cows with a nitrogen excretion of 80 kg (stable 35 kg and pasture 45 kg);
- 15 % beef cattle housed all year with a nitrogen excretion of 40 kg.

This results in an average annual nitrogen excretion of 50 kg pro animal, of which 30 kg in the stable and 20 kg on pasture. The figures in Table 4A (Appendix A) deal with slurry based systems. As indicated for dairy cows the emissions of ammonia from solid manure based systems are supposed to be equal to slurry based systems.

Sheep
The number of sheep varies during the year due to lambing in spring. Therefore the figures in Table 3A are based on a ewe, including 1-1.5 adherent lambs. The combined excretion of the ewe and lambs is 20 kg of nitrogen per year. If the number of ewes is not known from the agricultural census, the following approach can be used. Is the agricultural census performed around December then about 75 % of the counted sheep are ewes. For agricultural census data around May about 50 % of the counted sheep are ewes.

Horses, mules and asses
The figures in Table 3A are meant as an average for adult as well as for young animals.

Pigs and poultry
As far as these animals are kept indoors, the conditions are more or less comparable over Europe. Therefore it is assumed that for pigs and poultry the Dutch situation can be used for the other European countries, although it is recognised that the size of pig and poultry units differs considerably between countries. There are also differences between countries in the ages, and hence size and annual N excretion, at which animals are slaughtered.

For all animal categories in Table 3A the emission factors are calculated for use with the number of animals counted in the agricultural census. The number of animal places is for pigs and poultry often 10-20 % higher due to vacancy of the house between two consecutive animal production periods. It is important to note that the data from the agricultural census have to be used.

For pigs liquid manure systems are assumed. The ammonia losses in the storage outside the building are based on an open storage tank in use for 6 months per year.

Solid manure based systems maybe give less emission in the stable, but depending on the structure of the pile, storage emissions can be greater (a loose pile gives increased emissions). Total emissions of ammonia are assumed to be the same for slurry based and solid manure based systems in the simpler methodology. According to the detailed methodology the systems differ in ammonia emission.

Table 3A presents calculations for fattening pigs and for a sow with her piglets until 20 kg and 0.3 young sows. The nitrogen excretion of the sow and piglets is 32 kg per year and the 0.3 young sows add 4 kg of nitrogen per year. This means that the emission factors have to be multiplied with the number of fattening pigs and sows as they are counted in the agricultural census. If the agricultural census only gives an 'overall' figure for pigs, then approximately 50 % of the animals are fattening pigs and 10 % are sows. The remainder of the animals are piglets etc. and their emissions of ammonia are already included in the ammonia emissions of the sows.

About 50 % of the laying hens producing eggs are kept on liquid manure systems. The remaining laying hens, their parent animals and the broilers have solid manure based systems. In the simpler methodology the ammonia emissions from liquid manure and solid manure based systems are assumed to be the same.

The figures for other poultry are based on the values for turkeys.

Simpler methodology for whole animal classes
When statistical data are lacking for some animal categories as used in Tables 3 and 4 the following approach can be applied.

For cattle it can be assumed that approximately 36 % of the herd are dairy cows and 64 % are other cattle like young cattle, beef cattle and suckling cows.

From the total number of pigs about 50 % are fattening pigs (heavier than circa 20 kg) and about 10 % are sows. The remainder of the pigs are young sows and piglets and their ammonia emissions are already included in the emissions of the sows.

For poultry is it more complex to make a subdivision. Using a very rough estimation 45 % of the poultry are laying hens, 50 % broilers and 5 % other poultry. However there can be a big variation in this subdivision from country to country.

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Table 4A. Default ammonia emission factors for manure management.

	Ratio[1]	kg N	kg NH_3	Ratio[1]	kg N	kg NH_3
	100901 Dairy cows			100902 Other cattle		
N excretion in housing		60.00			30.00	
Emission in housing	12 %	7.20	8.7	12 %	3.60	4.4
N in outside storage		52.80			26.40	
Emission in outside storage	6 %	3.17	3.8	6 %	1.58	1.9
N available for landspreading		49.63			24.82	
..... of which mineral N[2]	50 %	24.82		50 %	12.41	
Emission of landspreading	40 %	9.93	12.1	40 %	4.96	6.0
Total ammonia emission			28.5			14.3
	100903 Fattening pigs			100904 Sows[3]		
N excretion in housing		14.00			36.00	
Emission in housing	17 %	2.38	2.89	17 %	6.12	7.43
N in outside storage		11.62			29.88	
Emission in outside storage	6 %	0.70	0.85	6 %	1.79	2.18
N available for landspreading		10.92			28.09	
..... of which mineral N[2]	50 %	5.46		50 %	14.04	
Emission of landspreading	40 %	2.18	2.65	40 %	5.62	6.82
Total ammonia emission			6.39			16.43
	100905 Sheep[3]			100906 Horses		
N excretion in housing		2.00			20.00	
Emission in housing	10 %	0.20	0.24	12 %	2.40	2.9
N in outside storage		1.80			17.60	
N available for landspreading		1.80			17.60	
.... of which mineral N[2]	20 %	0.36		20 %	3.52	
Emission of landspreading	50 %	0.18	0.22	50 %	1.76	2.2
Total ammonia emission			1.34			8.0
	100907 Laying hens			100908 Broilers		
N excretion in housing		0.80			0.60	
Emission in housing	20 %	0.16	0.19	20 %	0.12	0.15
N in outside storage		0.64			0.48	
Emission in outside storage	4 %	0.03	0.03	3 %	0.01	0.02
N available for landspreading		0.61			0.47	
.... of which mineral N[2]	40 %	0.25		40 %	0.19	
Emission of landspreading	50 %	0.12	0.15	50 %	0.09	0.11
Total ammonia emission			0.37			0.28
	100909 Other poultry			100910 Fur animals[3]		
N excretion in housing		2.00			4.10	
Emission in housing	20 %	0.40	0.48	12 %	0.49	0.60
N in outside storage		1.60			3.61	
Emission in outside storage	3 %	0.05	0.06			
N available for landspreading		1.55			3.61	
.... of which mineral N[2]	40 %	0.62		50 %	1.80	
Emission of landspreading	50 %	0.31	0.38	50 %	0.90	1.09
Total ammonia emission			0.92			1.69

[1] Ratio N volatilised as NH_3-N volatilised / N in animal waste

[2] N in animal waste consists of mineral N (available for volatilisation) and organic N. In liquid manure N contains about 50 % mineral N; solid manure contains a lower percentage of mineral N

[3] The values are calculated for female adult animals; the emissions of the young animals are included in the given values

APPENDIX B

TABLES FOR THE CALCULATION OF THE EMISSION OF AMMONIA ACCORDING TO THE DETAILED METHODOLOGY.

Table 5A Nitrogen excretion rates

	Range [1]	Spain [2]	Nether-lands	UK [3]	Denmark [4]	Switzer-land [5]	Germany [6]
Mammals	kg place^{-1} a^{-1} N				kg animal^{-1} a^{-1} N	kg place^{-1} a^{-1} N	kg place^{-1} a^{-1} N
Dairy cows, less than 5000 kg a^{-1} milk	60 – 110						
Dairy cows, 5000 to 6000 kg a^{-1} milk, low amount of concentrate	100 – 140						
Dairy cows, 5000 to 6000 kg a^{-1} milk, > 500 kg a^{-1} concentrate	80 – 100						
Dairy cows, 9000 to 10000 kg a^{-1} milk	110-140						
Dairy cows		60.23	134.0				
Dairy cows and heifers				106		105	
Dairy cows, heavy breed					128		115
Dairy cows, Jersey					107		
Mutterkühe							96
Suckling cows			111.3				
Dairy heifers in calf				58			
Beef cattle, extensive, mainly grazing	40 – 50						
Beef cattle, intensive, maize silage	30 – 40						
Beef cows and heifers		43.8		61			
Beef heifers in calf				58			
Bulls > 2 a			105.8	84			
Bulls 1 – 2 a		43.8	105.8	56			
Beef > 2 a				72			
Beef cattle		50.19				60	
Beef cattle male, 1 – 2 a			58.0				42
Beef cattle female, 1 – 2 a			89.8				44
Calves < 1 a				29			16
Breeding sows incl. piglets	30 – 40	14.79	29.8	30.0			
Dry sows				15.6			
Sows until weaning					25.7		
Sows + 21 pigs of 25 kg					36.7		
Sows plus litter (plus boar)						35	36
Boars			22.4	15.6			
Fatteners > 110 kg				15.6			
Fatteners, 25 – 100 kg, no phase feeding	15 – 18						

Table 5A Nitrogen excretion rates (continued)

	Range [1]	Spain [2]	Nether-lands	UK [3]	Denmark [4]	Switzer-land [5]	Germany [6]
Fatteners, 25 – 100 kg, with phase feeding	12 – 15						
Fatteners, 25 – 100 kg, with phase feeding and pure amino acids	10 – 14						
Fatteners 20 – 110 kg				15.6			
Growing pigs 20 – 50 kg		5.76	13.4				
Slaughter pigs 25 – 95 kg					3.25		
Fattening pigs		8.5				15	11.5
Weaners < 20 kg				2.3			
Sheep						16	13
Adult sheep		10.22					
Ewes			26.0	11.0			
Lambs		2.92		1.7			
Goats						18	
Adult goats		8.76	22.4				
Growing kids		2.19					
Horses		25.55				60	50
Horses, weight 400 kg					38		
Horses, weight 600 kg					50		
Horses, weight 800 kg					63		
Mink and ferret			3.5		0.895		
Fox and finnracoon			9.0		0.895		
Rabbits			8.1				
Poultry							
Laying hens	0.60 – 0.80	0.6		0.85		0.71	0.74
Laying hens < 18 weeks			0.33				
Laying hens > 18 weeks			0.69				
Hens in battery cage sys-tems					0.742		
Deep litter hens					0.854		
Free-range hens					0.813		
Organic hens					0.917		
Broilers	0.35 – 0.50	0.3	0.57	0.60		0.40	0.29
Pullets				0.40		0.34	
Breeding hens				1.1			
Turkeys (male)				1.88			
Turkeys (female)				1.00			
Turkeys			1.97			1.4	1.5
Turkeys for breeding < 7 months			2.52				
Turkeys for breeding > 7 months			3.04				
Geese							0.73
Ducks			1.09	1.2			0.60

[1] Menzi & Achermann, 2001; [2] Spanish Ministry of Agriculture, 2001; [3] Webb, 2000; [4] Poulsen & Kristensen, 1998; [5] Eidgenössische Forschungsanstalt, 1997; [6] Döhler et al., 2002.

Table 5B: TAN content in excreta

	UK [1)]	Switzer-land [d)]	Germany [e)]
Mammals	$kg\ kg^{-1}$ N	$kg\ kg^{-1}$ N	$kg\ kg^{-1}$ N
Cattle	0.60		0.50
Cattle, slurry		0.60	
Cattle, slurry poor in solids		0.70	
Pigs	0.70	0.75	0.66
Sheep	0.60		
Goats			
Horses		0.40	0.40
Poultry			
Laying hens	0.70		0.70
Broilers			0.70
Turkeys	0.70		
Geese	0.70		
Ducks	0.70		

[1] Webb, 2001; [2] Eidgenössische Forschungsanstalt, 1997; [3] Döhler et al., 2002.

Table 5C: Exemplary nitrogen inputs with straw

	UK [1)]	Germany [2)]
	kg animal^{-1} a^{-1} N	kg place^{-1} a^{-1} N
Cattle		
Dairy cows and heifers	6.0	
Dairy cows, tied systems and cubicles		7.8
Dairy cows, deep litter		13.8
Beef 1 – 2 years	3.6	
Beef cattle, tied systems		4.6
Beef cattle, deep litter		8.8
Pigs		
Sows plus litter	2.4	8.3
Fatteners 20 – 110 kg	0.8	
Fatteners, deep litter		1.4
Fatteners, free ventilated boxes		0.7
Sheep		
Lowland sheep	0.24	
Horses		12.6

[1] Webb, 2001; [2] Döhler et al., 2002.

Table 5D: Partial emission factors grazing (expressed as share of TAN or total N available)

	Spain [1)]	UK [2)]	Switzer-land [3)]	Germany [4)]
Mammals		kg kg^{-1} N	kg kg^{-1} N	kg kg^{-1} N
	Total N	TAN	Total N	Total N
Cattle	0.08		0.05	0.08
Dairy cows and heifers		0.130		
Dairy heifers in calf		0.157		
Beef cows and heifers		0.057		
Pigs				
Sheep	0.046		0.05	0.08
Lowland ewes		0.113		
Upland ewes		0.034		
Lambs		0.236		
Goats	0.046		0.05	
Horses	0.08		0.05	0.08

[1] Spanish Ministry of Agriculture, 2001; [2] Webb, 2001; [3] Eidgenössische Forschungsanstalt, 1997; [4] Döhler et al., 2002.

Table 5E: Exemplary partial emission factors housing (expressed as share of TAN or total N available)

		Denmark 1)	Switzer-land 2)	Germany 3)
Mammals		kg kg^{-1} N	kg kg^{-1} N	kg kg^{-1} N
			Total N	Total N
Cattle	Slurry		0.07	
	FYM		(1)	
Dairy cows and heifers	Slurry	0.313		
	FYM	0.236		
Beef 1 – 2 years	Slurry	0.285		
	FYM	0.234		
Dairy and beef cattle, tied systems	Slurry			0.04
	FYM			0.039
Dairy and beef cattle, and beef cubicles	Slurry			0.118
	FYM			0.118
Dairy and beef cattle deep litter	FYM			0.127
Pigs	Slurry		0.15	
	FYM		(2)	
Sows plus litter	Slurry	0.235		0.167
	FYM	0.275		0.167
Fatteners 20 – 110 kg	Slurry	0.278		
	FYM	0.306		
Fatteners, insulated houses	Slurry			0.23
Fatteners, deep litter, insulated houses	FYM			0.33
Fatteners, free ventilated boxes	FYM			0.17
Sheep	FYM		(1)	
Lowland sheep	FYM	0.258		
Goats			(1)	
Horses			(1)	
Poultry				
Laying hens		0.335		
Dung pit			0.6	0.337
Dung belt			0.2	
	Without drying			0.162
	With drying			0.042
Broilers		0.256	0.4	0.138
Geese				0.548
Ducks				0.5
Turkeys male		0.361		0.4
Turkeys female		0.339		0.4

(1) 7 % of total N + 30 % of the remaining TAN
(2) 15 % of total N + 30 % of the remaining TAN

[1] Poulsen & Kristensen, 1998; [2] Eidgenössische Forschungsanstalt, 1997; [3] Döhler et al., 2002.

Table 5F: Exemplary NH_3-N losses from storage

		UK [1)]	Switzer-land [2)]	Germany [3)]	Germany [3)]
		kg kg^{-1} N	kg kg^{-1} N	kg kg^{-1} N	kg kg^{-1} N
		TAN	TAN	TAN	Total N
Cattle					
Slurry			0.15		
Slurry	Tank	0.069			
	Open tank				0.080
	Solid cover				0.008
	Natural crust				0.024
	Floating cover, chaff				0.016
	Floating cover, granules and film				0.012
	Lagoon	0.438			0.150
	Storage inside building underneath slatted floor				0.024
FYM			0.30	0.60	
Pigs					
Slurry			0.12		
Slurry	Tank	0.040			
	Open tank				0.150
	Solid cover				0.015
	Natural crust				0.105
	Floating cover, chaff				0.030
	Floating cover, granules and film				0.023
	Lagoon	0.28			0.25
	Storage inside building underneath slatted floor				0.10
FYM		0.021	0.30	0.60	
Horses			0.30	0.60	
FYM					
Laying hens		0.22	0.20	0.04	
Broilers		0.37	0.10	0.03	

[1] Webb, 2001; [2] Eidgenössische Forschungsanstalt, 1997; [3] Döhler et al., 2002.

Table 5G: Exemplary partial NH_3 emission factors for spreading of slurry and farmyard manure, United Kingdom inventory (expressed as share of TAN, Pain et al., 1997)

	Incorporation	Cattle and pigs			Sheep	Layers	All other poultry
Slurry		DM < 4 %	4 % < DM < 8 %	DM > 8 %			
Broadcast [1]							
August to April	Without	0.15	0.37	0.59			
	Within 1 day	0.105	0.259	0.413			
	Within 1 week	0,135	0.333	0.53			
Summer	Without	0.60	0.60	0.60			
	Within 1 day	0.42	0.42	0.42			
	Within 1 week	0.54	0.54	0.54			
FYM							
Broadcast							
All year	Without	0.76			0.76	0.45	0.45
	Within 1 day	0.342				0.158	0.045
	Within 1 week	0.57				0.315	0.113

[1] % reduction of EF for bandspreading and trailing shoe: 0 %, for injection 80 %

Table 5H: Exemplary partial NH_3 emission factors for spreading of slurry and farmyard manure, mean soil temperature 15 °C, German inventory (expressed as share of TAN, Döhler et al. 2002)

	Animal category	Cattle		Pigs		Poultry
	Applied to	Arable land	Grassland	Arable land	Grassland	Arable land
Slurry						
	Incorporation within					
Broadcast	1 h	0.10		0.04		
	4h	0.26		0.09		
	6h	0.35		0.11		
	12	0.44		0.16		
	24	0.46		0.21		
	48	0.50		0.25		
	No incorp.	0.50	0.60	0.25	0.30	
Trailing hose	1 h	0.04		0.02		
	4h	0.15		0.06		
	6h	0.20		0.08		
	12	0.30		0.11		
	24	0.39		0.14		
	48	0.46		0.17		
	Bare soil, no incorpo-ration	0.45		0.18		
	Vegetation < 0.3 m	0.63	0.60	0.25	0.21	
	Vegetation > 0.3 m	0.35	0.60	0.13	0.30	
Trailing shoe			0.60		0.15	
Open slot			0.54		0.12	
Solid manure						
Broadcast	1 h	0.09		0.09		0.00
	4h	0.45		0.45		0.18
	24h	0.90		0.90		0.45
	48	0.90		0.90		0.90
	No incorporation	0.90		0.90		0.90

Table 5I: Exemplary partial NH_3 emission factors related to TAN for the spreading of slurry at various mean soil temperatures, German inventory (expressed as share of TAN, Döhler et al. 2002)

Type	**Incorporation after**	**Broad cast**				**Trailing hose**			
	h	5 °C	10 °C	15 °C	25 °C	5 °C	10 °C	15 °C	25 °C
		Bare soil			Stubbles	Bare soil			Stubbles
Cattle slurry									
	1	0.03	0.06	0.10	0.20	0.01	0.03	0.04	0.10
	4	0.10	0.18	0.26	0.65	0.06	0.10	0.15	0.35
	6	0.14	0.25	0.35	0.78	0.09	0.14	0.20	0.47
	12	0.22	0.32	0.43	0.85	0.15	0.22	0.30	0.70
	24	0.26	0.36	0.46	0.90	0.22	0.31	0.39	0.80
	48	0.30	0.40	0.50	0.90	0.26	0.36	0.46	0.90
Pig slurry									
	1	0.01	0.025	0.04	0.15	0.01	0,01	0.02	0.08
	4	0.04	0,06	0.09	0.37	0.02	0.04	0.06	0.19
	6	0.05	0.08	0.11	0.47	0.03	0.05	0.08	0.25
	12	0.08	0.12	0.16	0.60	0.045	0.08	0.11	0.37
	24	0.09	0.16	0.21	0.67	0.06	0.11	0.14	0.48
	48	0.10	0.20	0.25	0.70	0.07	0.14	0.18	0.55

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