

Protocol 4B: N₂O FROM MANURE MANAGEMENT

IPCC Category:	4B11 and 4B12
NFR Code:	n.a.
NOSE Code:	n.a.
NACE Code 2008	01 and 8130

Foreword

Under the Kyoto Protocol, the Netherlands is required to set up and maintain a national system to monitor its greenhouse gas emissions. One of the elements of this system is a transparent and verifiable description of the methods and processes used in this monitoring system. These methods must meet international guideline criteria, which have been defined by the United Nations (UN) and the European Union (EU).

The Netherlands meets the aforementioned requirement, for example, by defining a series of Monitoring Protocols, which describe the methods and work processes used to determine greenhouse gas emissions and the amounts of carbon sinks available. Protocols have been written for about 40 greenhouse gas sources or sinks. This document describes the protocol for one of these sources or sinks.

The protocols have been compiled in close collaboration with experts from various sectors of society in the Netherlands, particularly experts from the Emissions Registration (ER). The ER is a collaborative group that includes institutions such as CBS, WUR, RIVM and PBL. Until 31 December 2009 this was coordinated by PBL (Planbureau for the Leefomgeving, or the Netherlands Environmental Assessment Agency), but on 1 January 2010 this coordination task was taken over by RIVM (the Netherlands institute for public health and the environment). Other institutions that have contributed to the protocols include NL Agency; Ministry of Agriculture, Nature and Food Quality; and the Ministry of VROM (Housing, Spatial Planning and the Environment).

1 Scope and significance of emission sources/activities

1.1 Scope and definition

This protocol describes the method and working processes for determining N₂O emissions from animal manure, using the following manure management systems:

4B11 Liquid manure

4B12 Solid manure

The category 4B10 (anaerobic basins) is reported as NO (not occurring) under the CRF because this is not used in the Netherlands.

Emissions reported under category 4B concern only the N₂O emissions produced in animal houses, and then stored temporarily and/or processed before being transported elsewhere. The laughing gas resulting from manure production in the meadow (urine and faeces) is reported under category 4D (direct N₂O emissions from the soil).

The SBI code for these activities is 01 and 8130 (Landscape service activities).

Laughing gas emissions from animal manure management depend on the nitrogen and carbon content of the manure, the amount of time the manure is stored and the treatment method used. During storage the manure often becomes low-oxygen, which slows the nitrification process and denitrification remains low.

Nitrification is the process whereby, under high-oxygen circumstances, ammonia (NH₄⁺) is converted by bacteria into nitrate. Laughing gas can be formed as a by-product, particularly if the nitrification is limited through lack of oxygen. Nitrification does not require any organic substances (volatile solids) to be present.

Denitrification is the process whereby, under low-oxygen circumstances, bacteria can convert nitrate (NO₃⁻) into the gaseous nitrogen compound N₂, with N₂O as a by-product. Organic substances (volatile solids) are used as an energy source.

N₂O emissions from solid manure are higher than those from liquid manure, because there is very little nitrification in the latter due to the lack of oxygen.

1.2 Significance and influences

1.2.1 Contribution to total national emissions

N₂O emissions from manure management contribute less than 0.5% to the total annual greenhouse gas emissions from the Netherlands.

1.2.2 Developments that influence emissions

During the period 1990 up to today, laughing gas emitted from animal manure has increased slightly, despite a drop in total nitrogen excretion levels. This is the result of a trend towards greater production of solid manure, which has an emission factor that is 20 times higher than liquid manure. The total laughing gas emissions from manure management increased up to the year 2000, but stabilised thereafter. Emissions fell by around 13% between 2002 and 2003, due to an outbreak of avian flu in 2003, whereby poultry stocks fell by 25% in that year. Poultry stocks recovered again after 2003, and N₂O emissions increased once again.

2 Method, emission factors and activity data

2.1 Calculation method

N₂O emissions from animal manure are calculated as follows:

$$\text{N}_2\text{O emissions} = \sum_{ij} [\text{EF}_{ij}] * 44/28$$

* [amount of N in manure per animal in animal category (i) and manure management system (j)]

* [number of animals per animal category (i) and manure management system(j)]

N₂O emissions : N₂O emissions from manure management, in kg
 EF_{ij} : emission factor for the defined animal category and
 manure management system (i) in kg N₂O-N/kg N
 excreted manure
 44/28 : conversion factor from kg N₂O-N to kg N₂O
 Manure management systems (j) : system for liquid manure, plus system for solid
 manure¹.

The amount of nitrogen in manure refers to the gross amount, i.e. no deductions for ammonia emissions from stables and storage.

Comparing to the IPCC GPG method

The aforementioned method complies with that described by the IPCC in its Good Practice Guidance (IPCC, GPG, 2001; p. 4.40). Therefore the total amount of manure produced is multiplied by the emission factor, without subtracting the ammonia.

The tier 2 method is used to determine the animal numbers per category. A country-specific emission factor is used for liquid manure (Kroeze, 1994), which corresponds with the IPCC default. The IPCC default emission factor is used for solid manure.

2.2 Emission factors

A country-specific emission factor is used for liquid manure (Kroeze, 1994), which corresponds to the IPCC default value. The standard IPCC default value is used for solid manure systems.

Manure management system	Emission factors in kg N ₂ O-N / kg N manure excreted in the stable/pigsty
1. Liquid manure	0.001
2. Solid manure	0.02

Sources: Kroeze, 1994 and IPCC, 2001

2.3 Activity data

Animal population

Source: annual Landbouwtelling (agricultural census). This is a survey carried out among all agricultural companies larger than (or equal to) three Netherlands size units (NGE) and that have their headquarters in the Netherlands. Population statistics can be obtained from the CBS (Statistics Netherlands) Statline website (www.cbs.nl).

If there have been any large-scale outbreaks of animal diseases during the reporting year resulting in deviations in the average number of animals, the WUM (Working Group for Uniform calculations of Manure and mineral figures) modifies the numbers accordingly, and these modified data are used for emission calculations. The number of animals for the period 1990-2003 is also included in the Background Document to the NIR (Van der Hoek and Van Schijndel, 2006).

¹ Systems are split into those for liquid manure and those for solid manure. (Meadow manure falls outside the scope of this protocol, see Section 1.1). Liquid manure is stored in manure cellars underneath the stables, plus outside storage facilities). Solid manure is stored in stables (e.g. deep litter stables) and in outside storage facilities (dungheap).

Nitrogen excretion per animal and manure management system

The N-excretion per animal, as well as the differentiation between solid and liquid manure, are determined by the WUM (working group for uniform calculations of manure and mineral figures). The nitrogen excretion factors are updated every year. An overview of the nitrogen excretion factors used is available in the appendix to the NIR (national inventory report), and is also published on the CBS website: www.cbs.nl. Since 2006, horse manure is also included in the WUM calculations. The preceding years are assumed to be the same as the figures for 2006.

3 Working processes

Process for estimating (t-1)

If preliminary figures are required at any point, the following process is used to estimate the figure for t-1. The preliminary data for the work package leader are calculated by extrapolating them from the previous years' figures, based on prognoses for the developments in the most important activity data (taken from CBS (Statistics Netherlands) or other statistical sources).

When calculating N₂O emissions from manure management, the data concerning nitrogen excretion per manure source is corrected according to the data on changes in animal numbers in (t-1). See also the process for final definition (t-2).

INPUT	PROCESS	OUTPUT	BY WHOM
Preliminary data work package leader (t-1)	Include t-1 data in ER database	ER-db with (t-1) data	Work package leader non-CO ₂ ER working group for agriculture and land use
ER-db with (t-1) data	Check emission figures: compare with previous years (trend), modify if required and document everything	ER-db (t-1) with any modified figures	ER working group for agriculture and land use

Process for final determination of (t-2)

The final emission figures (as described in this protocol) are calculated using the following process.

INPUT	PROCESS	OUTPUT	BY WHOM
<p>Nitrogen excretion, per animal: Liquid manure via WUM /CBS (Statistics Netherlands) (A)</p> <p>Animal numbers (CBS/Statline) (B)</p>	<p>Calculate nitrogen excretion liquid manure stable and storage</p> <p>A * B</p>	<p>Nitrogen excretion liquid manure, stable and storage in EXCEL spreadsheet (C)</p>	<p>Work package leader non-CO₂ ER working group for agriculture and land use</p>

INPUT	PROCESS	OUTPUT	BY WHOM
Nitrogen excretion per animal: solid manure (D) (via WUM/CBS) Animal numbers (CBS/Statline) (B)	Calculate nitrogen excretion in solid manure: Stable and storage $D * B$	Nitrogen excretion for solid manure: stable and storage in EXCEL spreadsheet (E)	Work package leader non-CO ₂ ER working group for agriculture and land use
<i>N₂O emission factors per:</i> Manure management system (Van der Hoek and Van Schijndel, 2006): - Solid Manure(F) - Liquid manure (G)	Calculate N ₂ O emissions Solid manure (E) x (F) Liquid manure (C) x (G)	N ₂ O emissions per: Manure management system in EXCEL spreadsheet (H)	Work package leader non-CO ₂ ER working group for agriculture and land use
N ₂ O emission (H)	Initial validation of emission figures via trend analysis and expert judgement	validated emission figures in EXCEL spreadsheet (= Final data Work package leader (t-2)) (I)	Work package leader non-CO ₂ ER working group for agriculture and land use
Final data Work package leader (t-2) (I)	Include (t-2) data in ER database	ER-db with (t-2) data (J)	Work package leader non-CO ₂ ER working group for agriculture and land use
ER-db with (t-2) data (J)	Check, and trend analysis of air emissions: explain deviations or modify figures	Final defined emission figures (t-2) (K)	TNO (Org. for applied scientific research)

4 Uncertainty and quality

4.1 Estimating uncertainties

A Tier-1 uncertainty analysis is implemented every year before the NIR is submitted by the ER, based on the greenhouse gas inventory and in compliance with IPCC guidelines. The assumptions used and the results thereof are described in a background report to the NIR. In addition to this, where included in the QA/QC programme for the relevant period, extra analyses are implemented regularly in specific situations, which include any updating of the Tier-2 uncertainty analyses.

The Tier-2 uncertainty assessment was last updated in 2006. This assessment showed that a Tier-1 uncertainty assessment is sufficiently reliable and that Tier-2 uncertainty assessments need only be implemented at periodic intervals of around 5 years, unless a major change in an important source is sufficient to require earlier reassessment.

- Source-specific uncertainty

The uncertainty estimate_{total} concerns the root of the sum of uncertainty in the data sources used (AD_{onz}) in the square and the uncertainty of the emission factor (EF_{onz}) in the square. The extent of the total uncertainty is here primarily determined by the greatest AD or EF uncertainty.

$$\text{Uncertainty estimate}_{\text{total}} = \sqrt{EF_{\text{onz.}}^2 + AD_{\text{onz.}}^2}$$

The uncertainty estimates concerning the data sources (AD) and emission factors (EF) used, and the total uncertainty estimate, are listed in the following table.

IPCC	Category	Gas	AD _{onz.}	EF _{onz.}	Uncertainty estimates _{tot}
4B	Emissions from manure management	N ₂ O	10	100	100

The uncertainty in the N₂O emission from the management of manure from cattle and swine was estimated to be approximately 100%, annually. The uncertainty in the amount of animal manure (10%) was based on a 5% uncertainty in animal numbers and a 5 to 10% uncertainty in excretion per animal (RIVM, 1999). The resulting uncertainty of 7 to 11% was rounded off to 10%. The uncertainty in the N₂O emission factors for manure management, based on expert judgments, was estimated to be 100% [Olivier et al, 2009].

4.2 Quality assurance and quality control (QA/QC)

The ER work package leaders check that:

1. the basic data are well documented and adopted (check for typing errors, use of the correct unit sizes and correct conversion);
2. the calculations have been implemented correctly;
3. assumptions are consistent, also whether specific parameters (e.g. activity data) are used consistently;
4. complete and consistent data sets have been supplied.

Any actions that result from these checks are noted on an ‘action list’. Before defining the data, supervisors check whether the relevant actions on this list, plus the QC checks, have all been completed. Defining the data is carried out by the WEM (working group on emissions monitoring), and confirmed in writing via an e-mail from the institute representatives to the ER project leader at PBL.

The work package leaders fill out a new documentation sheet when adding new data. For reasons of efficiency a minimum level has been set for obligatory documentation, i.e. 5% changes at target group level, and 0.5% at levels concerning the national total. These documentation sheets form part of the trend analysis, as well as the eventual definition of the data set.

The ER work package leaders communicate by e-mail regarding these QC checks, results and actions. They send a printed copy to the ER secretary, who keeps a logbook and compiles these e-mails into an ‘action list’. This shows explicitly that the required checks and corrections have been carried out.

4.3 Verification

In order to check the quality of the emission figures for the sources in this protocol, general QA/QC procedures have been followed that are in line with the IPCC guidelines. These are described further in the QAQC programme used by the National System, and the annual working plans published by the ER.

- Sector-specific QC

No additional specific verification procedures are implemented for the sources defined in this protocol.

4.4 Possibilities for improvement compared to the current calculation method

4.4.1 History

At the beginning of the 1990s there was no differentiation between liquid and solid manure. N₂O emissions were calculated by taking the total nitrogen production from manure management (in the stable and storage facilities) and multiplying this by the N₂O emission factor for anaerobic manure storage (Kroeze, 1994). N₂O emissions are very low during anaerobic storage of (liquid and solid) manure. This was later summarised in a methodological description (Spakman, *et al.*, 1997). The emission factor used is identical to the default IPCC emission factor for liquid manure storage. The assumption at that time was that liquid manure, and most of the solid manure, was anoxic during storage. Since the percentage of nitrogen excretion in solid manure (in stable and storage facilities) was also very low (around 13% in 1990) the amount of solid manure that might not be stored in anaerobic circumstances was considered negligible.

In accordance with the IPCC Guidelines (1997), the current method differentiates between storage of liquid and solid manure, where the IPCC default emission factor is used for solid manure. A consistent timeseries also exists now. Figures for fur-covered animals have been added for the years 1990 and 1991, and for cattle (1990-1994) the meat calves have been split into meat calves for rosé veal production and meat calves for white veal production. The timeseries is also now complete, as horses and ponies have been included.

Another modification concerns the source of the activity data used, with respect to the nitrogen excretions in the animal housing and meadow. From 2005 onwards, the WUM (Working group for uniform calculations of manure and mineral figures) figures form the basis for nitrogen excretions per manure management system (see also Section 2.3). The activity data used previously were taken from data used to calculate ammonia emissions. These activity data are also based on the WUM nitrogen excretion figures and lead to the same extent of the total nitrogen excretion, but are distributed differently over animal housing (liquid and solid) manure and meadow manure. In comparison with the WUM figures, calculations for ammonia show total nitrogen excretions in the stable to be generally higher, and nitrogen excretions in the meadow to be somewhat lower. This results from the starting points used to calculate ammonia emissions. Since the WUM data on nitrogen excretions in stable and meadow form the basis for ammonia calculations, these data are also used as a basis for the N₂O calculations (rather than use the slightly modified data, such as that used to calculate ammonia emissions).

The N-excretion figures for all animal categories have been recalculated in 2009. The previous method did not take account of feed losses, and the feed intake by dairy cattle was underestimated. The N-excretions are calculated on the basis of feed intake.

Figures for horses and ponies (from 1990 onwards) have also been recalculated in 2009. Before this date the N-excretion factors used did not differentiate between horses and ponies [Van der Hoek *et al.*, 2006]. However, from the NIR 2009 onwards, the N-excretion factors for horses and ponies are calculated via the same method used to calculate all other animal categories. The N-excretion factors are available from 2006 onwards. The figures for 2006 are also used for all preceding years.

4.4.2 Future

Not applicable

5 Remaining aspects

5.1 Point source criteria

Not applicable

5.2 Substance profiles

Not applicable

5.3 Regionalisation

Not applicable

5.4 Time-based variations in source strength

Not applicable

6 References and additional information

6.1 References

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6.2 Additional information

Not applicable