

Protocol

6B: CH₄ and N₂O from waste water

IPCC Category:	6B
NFR Code:	n.a.
NOSE Code:	n.a.
NACE Code 2008	3700

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.

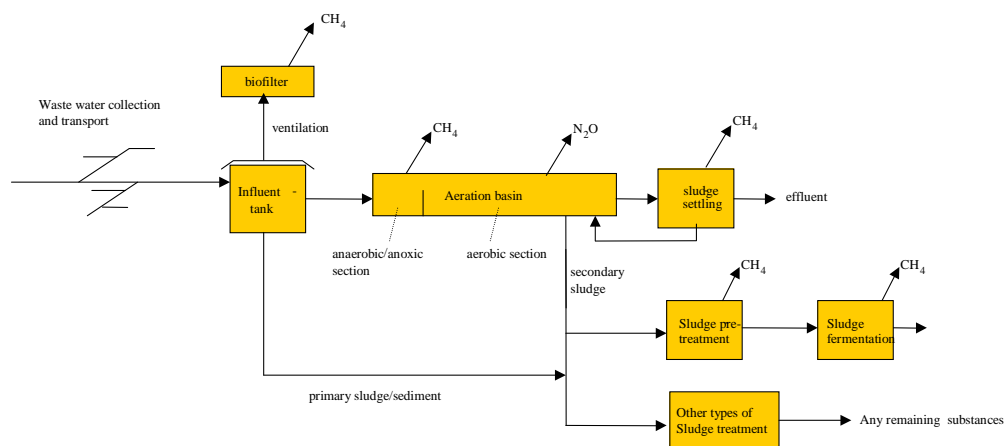
The protocols have been compiled in close collaboration with experts from various sectors of society in the Netherlands, particularly experts from the Emissions Registration (ER). The ER is a collaborative group that includes institutions such as CBS, WUR, RIVM and PBL. Until 31 December 2009 this was 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 monitoring of CH₄ and N₂O emissions that are released during the treatment processes and discharging of waste water at waste water treatment plants (WWTP) and in septic tanks (IPCC category 6B within the Netherlands. The related activities concern the SBI (industrial) code 3700 for communal/municipal WWTPs (i.e. waste water collection and treatment). Emissions of septic tanks are assigned to the target group 'Consumers'. For industrial WWTPs these activities concern the target groups 'Other industry', 'Chemical industry' and 'Waste removal companies'.

Waste water treatment processes cause emissions of both methane and laughing gas. The figure below shows the sections of a typical waste water treatment plant where microbes cause CH₄ and N₂O emissions.



Under *aerobic* circumstances the biodegradable organic material (degradable organic carbon, or DOC) in the waste water is bacteriologically converted into CO₂. Methane is formed under *anaerobic* conditions. In the initial stage, DOC in waste water or sludge is hydrolysed and then converted via methanogenic bacteria into biogas: a mixture of CO₂ and methane.

Laughing gas can be released as a by-product during nitrification and denitrification of nitrogenous pollutants. During the nitrification process ammonia is converted into nitrate. If there is not enough oxygen present, then NO₂ (an intermediate product of nitrification) can be used as an oxidant, thus creating N₂O. This is also formed during the subsequent denitrification process. N₂O is also formed during and after discharging effluent and other waste water flows into surface water.

A distinction is made between emissions from communal and industrial waste water treatment plants and septic tanks. Industrial waste water treatment plants are primarily anaerobic plants where only CH₄ is emitted. The emissions from communal waste water treatment plants are split into emissions from the water line and from the sludge line (CH₄ en N₂O). For households not connected to the national sewer network, waste water is collected in anaerobic septic tanks that convert DOC into CH₄. See the TNO report (TNO, 2004) for further specifications.

1.2 Significance and influences

1.2.1 Contribution to total national emissions

CH₄ emissions from this source contribute less than 0.5% to the annual greenhouse gas emissions from the Netherlands.

N₂O emissions from this source contribute less than 0.5% to the annual greenhouse gas emissions from the Netherlands.

1.2.2 Developments that influence emissions

No specific measures are taken at the source to try and reduce CH₄ or N₂O emissions. Emissions are therefore primarily determined by the number of plants and their workloads. Any developments/adjustments will be documented in the CRF (common reporting factor).

2 Method, emission factors and activity data

2.1 Calculation method

The calculation formulas are as follows:

1. Method for calculating methane emissions, communal WWTPs

$$\text{CH}_4, \text{ WWTP} = \text{CH}_4, \text{ water line} + \text{CH}_4, \text{ sludge fermenter} = 0.0085 * \text{COD}_{\text{influent}}$$

Where:

CH_{4, WWTP} : Total methane emissions WWTPs (in kg year⁻¹)

CH_{4, water line} : Methane emissions at water line WWTPs (in kg year⁻¹)
 = EF_{water line} * COD_{influent} = 0.007 * COD_{influent}

EF_{water line} = 0.007

COD_{influent} : chemical oxygen demand of influent WWTP (in kg year⁻¹)
 = DOC_{WWTP} (amount of organic components in the waste water)

CH_{4, sludge fermenter} : Methane emission of sludge fermenters WWTPs (in kg year⁻¹)
 = EF_{sludge} * DOC_{sludge} * (1-MR_{ind}) = 0.0015 * COD_{influent}

EF_{sludge} = 0.0567

DOC_{sludge} : amount of degradable organic components = 0.37 * COD_{influent} (in kg year⁻¹)

COD_{influent} : chemical oxygen demand of influent WWTP (in kg year⁻¹)

MR_{ind} : CH₄ generation and combustion efficiency of sludge fermenter = 0.94 (-)

2. Method for calculating laughing gas emissions from WWTPs

The N₂O emissions that occur during the treatment process are calculated as follows:

$$\text{N}_2\text{O}_{\text{WWTP}} = 44/28 * \text{EF}_{\text{N}_2\text{O}} * \text{N}_{\text{Kj, influent}} * \eta_{\text{N}}$$

Where:

N₂O_{WWTP} : laughing gas emissions (in kg year⁻¹)¹

EF_{N₂O} : 0.01 (kg N₂O-N / kg N_{Kj}), IPCC-default

η_N : removal efficiency of nitrogen in the WWTP as fraction of influent (source: CBS [Statline](#))

N_{Kj, influent} : amount of nitrogen in the influent, according to Kjeldahl (in kg year⁻¹) (bron: CBS [Statline](#)). (Instead of N_{Kj, influent} also N_{total} can be used.)

44/28 : conversion factor from N to N₂O (-)

¹ N₂O_{WWTP} = 1.6 * N₂O-N_{WWTP}

The indirect N₂O emissions from surface water that occur when discharging effluent from WWTPs and direct discharges from households and industries, are calculated as follows:

$$N_2O_{\text{WWTP,effluent}} = N_{\text{effluent}} * \text{conversion factor} * 44/28$$

Where:

N ₂ O _{WWTP,effluent} :	indirect laughing gas emissions from discharging N to surface water t (in kg yr ⁻¹)
N _{effluent} :	the sum of the nitrogen present in effluent from waste water treatment plants, industry and consumers
Conversion factor:	0.01 (IPCC default), i.e. 1% of the nitrogen in effluent is converted into N ₂ O
44/28:	conversion factor, from N to N ₂ O (-)

3. Method for calculating methane emissions from septic tanks

$$CH_{4,\text{septic tanks}} = EF_{\text{st}} * DOC_{\text{st}} = 7.5 * n_{\text{st}}$$

Where:

CH_{4,septic tanks} : Methane emissions from septic tanks (in kg year⁻¹)
 EF_{st} : emission factor of septic tank = 0.125 (g/g)

$$DOC_{\text{st}} = n_{\text{st}} * DOC_{\text{cap}} = 60 * n_{\text{st}}$$

DOC_{st} : amount of organic material in septic tanks (in kg year⁻¹)
 DOC_{cap} : amount of organic material per capita = 60 (in kg year⁻¹)
 n_{st} : number of persons not connected to the sewer system ≈ number of septic tanks

4. Method for calculating methane emissions from industrial anaerobic waste water treatment plants

$$CH_{4,\text{ind}} = DOC_{\text{ind}} * EF_{\text{ind}} * (1 - MR_{\text{ind}}) = 0.056 * \text{capacity}$$

Where:

CH_{4,ind} : Methane emissions from industrial anaerobic WWTP's (in kg year⁻¹)
 MR_{ind} : extraction and combustion efficiency of the plant = 99%
 DOC_{ind} : amount of organic material in industrial waste water (in kg yr⁻¹)
 = workload level * capacity * BOD/i.e. * COD/BOD

Workload level = 80%
 Capacity : total capacity of industrial anaerobic WWTP's in the Netherlands
 BOD : biological oxygen demand = 20 (in kg year⁻¹)
 COD : chemical oxygen demand (in kg year⁻¹)
 COD/BOD : 1.5 - 2
 i.e. : inhabitant equivalent

EF_{ind} : emission factor for industrial anaerobic plants = 0.176

Further information on activity data and emission factors used can be found in Sections 2.3 and 2.2 of this protocol.

The aforementioned methods correspond to those listed in the Revised 1996 IPCC Guidelines (IPCC, 1997, pp. 6.17-6.28) and the Good Practice Guidance (GPG, 2001, pp. 5.14-5.24). This is also explained further in a report (TNO, 2004) by TNO (Dutch organisation for applied scientific research). Country-specific parameters and emission factors are used to determine CH₄ emissions. The IPCC default emission factor is used when determining N₂O emissions from communal waste water treatment plants.

2.2 Emission factors

1. Emission factors for calculating methane emissions from communal WWTPs

The following *country-specific emission factors* are used to calculate methane emissions from communal WWTPs (TNO, 2004):

$$EF_{\text{water line}} = B_{o,\text{WWTP}} * \eta_{\text{DOC}} * MCF_{\text{WWTP}} = 0.007 \text{ (g/g)}$$

B_{o,WWTP} : methane formation during anaerobic conversion DOC = 0.25 (g/g)
 η_{DOC} : conversion rate of DOC into gaseous compounds in WWTPs = 0.8 (g/g)
 MCF_{WWTP} : fraction of DOC that is anaerobically converted in sewers and WWTPs = 0.035 (g/g)

$$EF_{\text{sludge}} = B_{o,\text{sludge}} * \eta_{\text{sludge}} * MCF_{\text{sludge}} = 0.0567 \text{ (g/g)}$$

B_{o,sludge} : methane formation during anaerobic conversion of sludge = 0.25 (g/g)
 η_{sludge} : conversion rate of sludge in anaerobic fermenter = 0.42 (-)
 MCF_{sludge} : fraction of DOC in sludge that is anaerobically degraded = 0.54 (-)

2. Emission factor for calculating laughing gas emissions from communal WWTPs

The *IPCC default value* (IPCC, 1997, p. 6.28; TNO, 2004) is used to calculate laughing gas emissions from WWTPs:

$$EF_{\text{N}_2\text{O}} : 0.01 \text{ (kg N}_2\text{O-N / kg removed N)}$$

IPCC defaults are used for the calculation of indirect N₂O emissions from surface water, as a result of communal and industrial discharges [TNO, 2004] + [IPCC, 1997: p. 6.28]:

Conversion factor: 0.01 (kg N₂O-N / kg N), i.e. 1% of the nitrogen in effluent is converted to N₂O

3. Emission factor for calculating methane emissions from septic tanks

The following *country-specific emission factor* is used to calculate methane emissions from septic tanks (TNO, 2004):

$$EF_{st} = B_{o,st} * \eta_{st} * MCF_{st} = 0.125 \text{ (g/g)}$$

$B_{o,st}$: methane formation during anaerobic conversion DOC = 0.25 (g/g)
 η_{st} : converting DOC into gaseous compounds = 100%
 MCF_{st} : fraction of DOC that is converted anaerobically 0.5 (-)

4. Emission factor for calculating methane emissions from industrial anaerobic waste water treatment plants

The following *country-specific emission factor* is used to calculate methane emissions from industrial anaerobic waste water treatment plants (TNO, 2004):

$$EF_{ind} = B_{o,ind} * \eta_{ind} * MCF_{ind} = 0.176 \text{ (g/g)}$$

$B_{o,ind}$: methane formation per kg converted DOC in industrial anaerobic plants = 0.22 (g/g)
 η_{st} : removal efficiency of DOC in the fermenter = approx. 80%
 MCF_{st} : extent to which degradation occurs under anaerobic conditions = 1 (-)

2.3 Activity data

In order to calculate emissions as reported under Section 2.1, the following information is required each year:

- $COD_{influent}$: chemical oxygen demand of the waste water to be treated (source: CBS [Statline](#))
- $N_{kj, influent}$: amount of nitrogen in the influent, according to Kjeldahl (source: CBS [Statline](#))
- $N_{effluent}$: total nitrogen present in effluent from waste water treatment plants, industry and consumers (bron: [Emissieregistratie](#))
- Capacity : of the industrial anaerobic WWTPs (in inhabitant equivalents) (source: CBS; from 2009 onwards also available at Statline)
- n_{st} : number of people not connected to the sewer network (Source: [RWS Waterdienst, 2008](#) (% not connected) and CBS, [Statline](#) (number of inhabitant))

These data can be taken from the waste water statistics on the CBS website (www.cbs.nl), via Statline, under Milieu (Environment, nature and space) or via the search keyword 'afvalwater' (waste water).

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 from 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).

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
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	Task force

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
CBS statistics and aforementioned formulas	Calculations	Emissions and activity data in ER (Emissions Registration) format	Work package leader, MEWAT task force (water emissions)
CH ₄ and N ₂ O emissions from wastewater	Check figures	Figures validated by task force	MEWAT task force
Validated figures	Include (t-2) data in ER database	ER-db with (t-2) data	Work package leader
ER-db with (t-2) data	Check, and trend analysis of air emissions: explain deviations or modify figures	Final defined emission figures (t-2)	Task forces and PBL experts

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.

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

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}
6B	Emissions from wastewater handling	CH ₄	20	25	32
6B	Emissions from wastewater handling	N ₂ O	20	50	54

The uncertainty in annual CH₄ and N₂O emissions from waste water handling were estimated at about 30% and 50%, respectively. The uncertainty in activity data was based on expert judgements and estimated at 20%. The uncertainty in emission factors for CH₄ and N₂O were estimated at 25 and 50%, respectively [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

Emissions from septic tanks and industrial waste water treatment plants were not known until 2003; the CH₄ emissions were simply calculated from the sludge line. A study was carried out in 2004 (TNO, 2004) to find the most suitable method of determining these emissions (conform the IPCC guidelines) for all emissions originating from waste water treatment.

Until the NIR 2008, in the calculation of N₂O emissions from Public WWTP's a fixed value was used for η_{Nkj} (removal efficiency of nitrogen in the WWTP, as fraction of influent). Given the development of nitrogen removal in public WWTP's, the removal efficiency has rapidly increased. Therefore, from NIR 2009 onwards a year-dependent removal efficiency η_{N} is used in the emission calculations (Baas, 2008).

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

- Baas, C.M., N₂O emissions from domestic and commercial waste water treatment, Proposal for modification of the calculation method, CBS, internal memo, 2008
- CBS Statistieken en Statline database
 - removal efficiency of Nitrogen in the WWTP, as fraction of influent (CBS [Statline](#)):
Thema → Natuur en Milieu → Water → Zuivering van stedelijk afvalwater → Zuivering afvalwater; zuiveringsproces; select 'rendement zuiveringsproces'.

- amount of nitrogen in the influent, according to Kjeldahl (in kg jr-1) (CBS Statline):
English version, select Theme→Nature and Environment→Urban waste water treatment; region; select 'Influent waste water'
- chemical oxygen demand of influent WWTP (CBS [Statline](#)):
English version, select Theme→Nature and Environment→Urban waste water treatment; region; select 'Influent waste water'
- total capacity of industrial anaerobic WWTP's (CBS, information available at Ronnie Huwae, rhwe@cbs.nl). From 2009 onwards available at Statline.
- number of inhabitants in the Netherlands (CBS, [Statline](#)):
Thema→Bevolking→Bevolking; kerncijfers→Bevolking naar geslacht; select 'Totale bevolking'

Emissieregistratie, 2008: www.emissieregistratie.nl

- sum of the nitrogen present in effluent from waste water treatment plants, industry and consumers

Selecteer Kies compartiment, stof, bron
stof = N-totaal,
compartiment = Belasting oppervlaktewater,
emissiebronnen = doelgroepen 'Consumenten', 'Overige industrie', 'Chemische industrie', 'Raffinaderijen' en 'Riolering en waterzuivering'.

- IPCC, 1997: Revised 1996 IPCC Guidelines for National Greenhouse Gas Emission Inventories, Three volumes: Reference Manual, Reporting Guidelines and Workbook. IPCC/OECD/IEA. IPCC WG1 Technical Support Unit, Hadley Centre, Meteorological Office, Bracknell, UK
- IPCC, 2001: Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories, IPCC-TSU NGGIP, Japan
- Olivier J.G.J., L.J. Brandes and R.A.B. te Molder, 2009 (in print) Uncertainty in the Netherlands' greenhouse gas emissions inventory: Estimate of annual and trend uncertainty for Dutch sources of greenhouse gas emissions using the IPCC Tier 1 approach, PBL-Report 500080013, Bilthoven
- RWS-Waterdienst, 2008: Factsheet Effluentten Rwwz's, regenwaterriolen, niet aangesloten riolen, overstorten en IBA's, versie juni 2008: Table 2, p. 5, % not connected. <http://www.emissieregistratie.nl/erpubliek/documenten/Water/Factsheets/Effluenten%20RWWZI.pdf>
- Oonk J., 2004: *Methaan- en lachgasemissies uit afvalwater (Methane and laughing gas emissions from waste water)*, TNO report R2004/486, November 2004, TNO, Delft, the Netherlands.

6.2 Additional information

Not applicable