

Greenhouse Gas Emissions from Industrial Wastewater Treatment

Inventory Basis Review

NZ100481

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Glossary

Abbreviation	Term
B_0	Maximum mass of CH_4 able to be produced per kg biodegradable COD (kg CH_4 / kg COD)
CH_4	Methane
COD	Chemical Oxygen Demand
EF	Emission factor (kg CH_4 / kg COD)
$EF_{(WWTP)}$	WWTP N_2O Emission factor (kg N_2O -N / kg N)
EF_n	Emission factor for process n (kg CH_4 / kg COD)
EF_{sw}	Effluent surface water N_2O emission factor (kg N_2O /y)
F_{ld}	Overall fraction of influent nitrogen load discharged onto land
f_{ld}	Fraction of effluent from process n discharged to land
f_n	Fraction of methane flared
f_{sw}	Fraction of effluent discharged to surface water
m_{bCOD}	Biodegradable unit COD (kg biodegradable COD/tonne)
MCF	Methane correction factor
$N:COD_b$	Total Nitrogen to Biodegradable COD ratio
N_2O	Nitrous oxide
$N_2O_{(sw)}$	Nitrous oxide emitted from surface water (kg N_2O /y)
$N_2O_{(WWTP)}$	Nitrous oxide emitted from WWTP (kg N_2O /y)
NR	Fraction nitrogen removal achieved in WWTP
P	Annual production of industry's product (tonne/y)
p_n	Fractional of total industry waste treated using process n
r_n	Fraction of methane recovered for energy production
s	Fraction of influent biodegradable COD removed from site as biodegradable sludge
TN	Annual Total Nitrogen Load (kg/y)
TOW	Annual biodegradable COD load (kg/y)
WWTP	Wastewater Treatment Plant

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1 Introduction

1.1 Background

Each year the Ministry for the Environment (MfE) compiles New Zealand's Greenhouse Gas Inventory, the official annual report of all anthropogenic emissions and removals of greenhouse gases in New Zealand. The Inventory measures New Zealand's progress against obligations under the United Nations Framework Convention on Climate Change (UNFCCC) and the Kyoto Protocol.

The UNFCCC requires the Inventory to follow the reporting methodologies set out in the 2006 Intergovernmental Panel on Climate Change Guidelines (IPCC, 2006). Under the IPCC Guidelines, Greenhouse gas emissions and removals are reported under six sectors: Energy; Industrial Processes and Product Use (IPPU); Agriculture; Land Use, Land-Use Change and Forestry (LULUCF); and Waste.

The Waste sector covers greenhouse gas emissions resulting from the processing and disposal of solid waste, wastewater, and waste incineration. The wastewater category covers methane (CH₄) and nitrous oxide (N₂O) emissions from both domestic and industrial wastewater treatment. The emissions from industrial wastewater treatment are calculated pro-rata on annual industry production, using various industry activity and emissions parameters to link production to biodegradable wastewater load and greenhouse gas emissions.

The MfE regularly reviews the methodologies and input data used to calculate the wastewater emissions category, in order to capture any changes in industry activity and to ensure that the inventory basis reflects current best practice and knowledge. This report is the result of the latest review.

1.2 Current Wastewater Emissions Calculation Methodology

The MfE uses the methodologies set out in the 2006 IPCC Guidelines to calculate emissions from wastewater treatment. The calculation methodology used for industrial wastewater treatment is described in Sections 3 and 4 of this report.

The input parameters used to calculate industrial wastewater emissions are a combination of industry activity data and CH₄ and N₂O emission rates from the various wastewater treatment processes (emission factors). Most of the input parameters used in the calculations are New Zealand-specific, and have evolved over time as a result of various consultant reviews.

Although the primary aim of this project was to review the input parameters used in the wastewater treatment emissions category, during the course of the project a spreadsheet-based model was developed for calculating industrial wastewater emissions which conforms to the existing methodology and presents the calculations in a transparent and user-friendly format. This model can be adapted and modified over time as part of MfE's ongoing review process.

1.3 Project Scope

The aim of this study is to review the current methodology and input parameters used to calculate industrial wastewater emissions and to recommend any changes (whilst adhering to the 2006 IPCC Guidelines).

The study covers the following:

1. A review of the current methodology for calculating industrial wastewater emissions.
2. Development of an excel-based model in order to make the calculations more transparent and easily adaptable to changes in the various input parameters.
3. An assessment of the current methodology and input parameters for calculating industrial wastewater emissions.
4. Recommended changes to the methodology and/or input parameters for calculating industrial wastewater emissions.

Note: The original terms of reference covered both domestic and industrial wastewater emissions; however due to a scope change the review now covers industrial wastewater only.

2 Wastewater Emissions Category Boundaries

In order to avoid omitting or double-counting emissions, it is important that category boundaries (i.e. inclusions and exclusions) are clearly defined. These are set out briefly below.

2.1 CH₄ and N₂O Emissions Covered by Industrial Wastewater Category

Under the 2006 IPCC Guidelines, the Industrial Wastewater category covers the following emissions:

- > CH₄ and N₂O emissions from industrial wastewater treatment plants (including on site sludge treatment)
- > N₂O emissions from industrial WWTP effluent in receiving waters (rivers, lakes, sea).

2.2 CH₄ and N₂O Emissions Covered by Other Sectors and Categories

Emissions from wastewater that are covered in other inventory sectors and categories are listed in Table 2.1 below along with the relevant Inventory sector and category that includes these emissions.

Table 2-1 CH₄ and N₂O Emissions Covered by Other Sectors and Categories

Activity	Inventory Sector and Category that Includes the activity		IPCC (2006) Section	New Zealand NIR Section MFE (2015)
	Sector	Category		
Treatment of industrial wastewater in domestic wastewater treatment plants	Waste	Domestic Wastewater Treatment	Vol 5 Ch. 6	7.5
Agricultural wastewater treatment (eg stockyard, dairy shed, piggery and poultry farm effluent)	Agriculture	Manure Management	Vol. 5 Ch. 10	5.3
Industrial effluent land treatment systems	Agriculture	Emissions from Managed Soils	Vol. 4 Ch. 11	5.5
Off-site sludge treatment and disposal	Waste	Solid Waste Disposal	Vol. 5 Ch. 3	7.2
		Biological Treatment of Solid Waste	Vol. 5 Ch. 4	7.3
		Incineration of Waste	Vol. 5 Ch. 5	7.4

3 Methane Emissions Calculation Methodology

The methodology currently used for calculating CH₄ emissions from industrial wastewater follows the 2006 IPCC Guidelines and uses a Tier 2 methodology. That is, the IPCC methodology is used, but with country-specific activity data and emissions factors as opposed to default values. The methodology requires data on industry production and wastewater loads (termed activity data) and on the CH₄ emission rates from the various treatment processes used (emission factors). The methodology is described below.

3.1 Activity Data

The principal factor in determining the methane generation potential from industrial wastewater is the amount of degradable organic material in the wastewater. A common parameter used to measure the organic component of industrial wastewater is Chemical Oxygen Demand (COD). The COD measures the total organic material available for chemical oxidation (both biodegradable and non-biodegradable). As a general rule, wastewater with higher COD concentrations generally yields more methane than wastewater with lower COD levels.

The activity data output for the industrial wastewater category is the amount of organically degradable material in the wastewater produced annually (TOW). This parameter is a function of industrial production per year (annual production, P), the amount of wastewater generated per tonne of the product annually (wastewater generation, W), and the amount of biodegradable COD per volume of wastewater. In this section, the latter two parameters (W and COD) are combined to obtain the mass of biodegradable COD per tonne of industrial product (m_{bCOD}). The biodegradable COD wastewater load produced by an industry is calculated by multiplying the annual industrial production by the biodegradable unit COD wastewater load:

$$TOW = P \times m_{bCOD}$$

Where:

- TOW = Annual Biodegradable COD load (kg / y)
P = Annual production (tonne of industrial product / y)
 m_{bCOD} = Biodegradable Unit COD load (kg biodegradable COD / tonne of industrial product)

If wastewater monitoring data is available, COD loads can be calculated by multiplying the measured wastewater COD concentration by the corresponding daily wastewater volume. Most COD monitoring data measures the total COD which includes both biodegradable and non-biodegradable material. To estimate the biodegradable COD load, the total COD loads must be multiplied by the estimated biodegradable fraction.

3.2 Choice of Emission Factors

In any wastewater treatment process, influent biodegradable COD is either oxidised (converted to CO₂), anaerobically destroyed (converted to biogas), or leaves the site in effluent or in sludge. Different wastewater treatment processes and wastewaters will result in different fractions going to each route. Emission factors are used to define the fraction of influent biodegradable COD converted into methane (CH₄).

3.2.1 Emission Factor Calculations

Under the 2006 IPCC methodology, an emission factor (EF) is defined as the mass of CH₄ emitted per kg of influent biodegradable COD for a particular wastewater and treatment process. It is calculated by multiplying the maximum CH₄ generating capacity of the biodegradable COD (methane producing potential, B₀) by a methane correction factor (MCF):

$$EF = B_0 \times MCF$$

Where:

EF = Emission Factor (kg CH₄ / kg COD)

B_o = Maximum mass of CH₄ able to be produced per kg biodegradable COD (kg CH₄ / kg COD)

MCF = Methane Correction Factor

Unless country-specific data is available, it is a good practice to use the default value for B_o in the IPCC 2006 guidelines (0.25 kg CH₄ / kg COD).

The Methane Correction Factor (MCF) is process-specific and defines the fraction of biodegradable COD that is able to be converted to biogas; in effect it is fraction of influent biodegradable COD treated anaerobically. The MCF therefore depends on the split of aerobic and anaerobic environments within a process. In addition, as most processes include some form of settling step followed by separate environments for the sludge and liquid streams, it is helpful to have an estimate of the soluble and particulate COD fractions when estimating the MCF value. Default MCF values for various process types are provided in the IPCC Guidelines.

3.2.2 Exported Biodegradable Sludge

For each process, the fraction of influent biodegradable COD that is exported from the site in sludge should be assessed. This is because biodegradable COD that leaves a WWTP is not converted within the treatment plant and under the IPCC methodology is deducted from the influent biodegradable COD load prior to applying the emissions factor. Any emissions from this material off-site are accounted for in the solid waste category.

3.2.3 Flared and Recovered Methane

CH₄ that is flared or combusted for energy generation is deducted from the emissions. Therefore for each process, the fraction of CH₄ flared or used for energy generation should be defined.

3.2.4 Industry Emission Factors

There are typically a range of treatment practices employed within an industry, including some sites where no treatment occurs due to direct land application or discharge to a municipal sewerage scheme. Calculating an emission factor for an industry requires knowledge of the different treatment methods employed across an industry, along with an estimate of the fraction of the total waste load treated by each method. This information can only be obtained via a survey of the industry. A weighted average emission factor is then calculated according to the following equation:

$$EF = \sum p_n EF_n (1 - s_n)$$

Where:

EF = Emission Factor (kg CH₄ / kg COD)

p_n = Fraction of total industry waste treated using process n

EF_n = Emission Factor for process n (kg CH₄ / kg COD)

s_n = Fraction of influent biodegradable COD removed from site as biodegradable sludge

3.3 Methane Emission Calculation Outputs

The following outputs are produced in the CH₄ emissions category for each industry:

$$\begin{aligned}
 \text{Total biodegradable COD load, } TOW &= P \times m_{bCOD} \\
 \text{Total exported biodegradable sludge} &= TOW \times \sum p_n s_n \\
 \text{Emission factor} &= \sum p_n EF_n (1 - s_n) \\
 \text{Total CH}_4 \text{ emissions} &= TOW \times IEF \times \sum p_n (1 - f_n - r_n) \\
 \text{Total CH}_4 \text{ flared} &= TOW \times IEF \times \sum p_n f_n \\
 \text{Total CH}_4 \text{ recovered for energy} &= TOW \times IEF \times \sum p_n r_n
 \end{aligned}$$

3.4 Methane Emission Calculations Input Parameters

Based on the above methodology, the table below summarises the input parameters required in order to calculate industrial wastewater methane emissions.

Table 3-1 Methane Emission Input Parameters

Parameter	Symbol	Units
Activity Data – for each industry:		
Annual production	P	tonne / year
Biodegradable unit COD load	m _{bCOD}	kg / tonne
Treatment processes and fraction of waste treated by each	p _n	
Emissions Data – for each process:		
Methane Correction Factor	MCF	
Fraction of biodegradable COD exported from site in sludge	s _n	
Fraction of methane flared	f _n	
Fraction of methane recovered for energy production	r _n	

4 Nitrous Oxide Emissions Calculations Methodology

The 2006 IPCC Guidelines do not include a methodology for calculating N₂O emissions from industrial wastewater treatment. Consequently a methodology has been developed in New Zealand which has been modified over time following periodic reviews. The methodology is described below.

4.1 Activity Data

Total nitrogen wastewater loads are derived from the biodegradable COD loads used for the methane emission calculations (see previous section) multiplied by the nitrogen-to-biodegradable COD ratio:

$$TN = TOW \times N:COD_b$$

Where:

TN	=	Annual Total Nitrogen load (kg / y)
TOW	=	Annual Biodegradable COD load (kg / y)
N:COD _b	=	Total Nitrogen to Biodegradable COD ratio

4.2 Emission Factors

There are two sources of N₂O emissions included in the wastewater treatment category: emissions from within the WWTP (termed “direct emissions” in the IPCC Guidelines) and emissions following discharge of treated effluent into waterways (termed “indirect emissions” in the IPCC Guidelines).

As previously mentioned in Section 2.2, N₂O emissions from effluent land treatment systems are covered by the Managed Soils category.

4.2.1 Direct Emissions

Direct N₂O emissions are calculated using emission factors, in a similar fashion to that used to calculate CH₄ emissions:

$$N_2O_{(WWTP)} = TN \times EF_{(WWTP)} \times 44/28$$

Where:

$N_2O_{(WWTP)}$	=	N ₂ O emitted from WWTP (kg N ₂ O / year)
$EF_{(WWTP)}$	=	WWTP N ₂ O emission factor (kg N ₂ O-N per kg N)
44/28	=	N ₂ O to N ₂ mass ratio

Typically, N₂O emission factors are very low (see Section 6.3). However, it is worth including N₂O emissions as some primary industry wastewaters contain a high nitrogen content and therefore N₂O emissions may still be significant even with low emission factors. In addition, N₂O has a global warming potential (GWP) of around 12 times that of CH₄ (IPCC, 2006).

4.2.2 Indirect Emissions

Indirect N₂O emissions from surface waters are calculated using an effluent emission factor multiplied by the total nitrogen load discharged with the effluent. This requires an estimate of the nitrogen reduction in the WWTP:

$$N_2O_{(sw)} = TN (1 - NR) \times f_{sw} \times EF_{(sw)} \times 44/28$$

Where:

N_2O_{sw}	=	N_2O emitted from surface water (kg N_2O / year)
NR	=	Fraction nitrogen removal achieved in WWTP
f_{sw}	=	Fraction of effluent discharged to surface water
EF_{sw}	=	Effluent surface water N_2O emission factor (kg N per kg N)

The total emission factor for a particular process can be calculated by combining the two equations:

$$EF = (EF_{WWTP} + (1 - NR) f_{sw} EF_{sw})$$

Where:

EF	=	Total N_2O emission factor (kg N_2O -N emitted per kg N)
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As with the CH_4 emissions, where there are several processes within an industry, an industry implied emission factor can be calculated using the fraction of the total waste treated by each process:

$$IEF = \sum p_n EF_n$$

The fraction of nitrogen discharged to land from an industry can also be calculated as follows:

$$F_{ld} = \sum p_n (1 - NR_n) f_{ldn}$$

Where:

F_{ld}	=	Overall fraction of influent nitrogen load discharged onto land
f_{ld}	=	Fraction of effluent from process n discharged to land

The total mass of nitrogen discharged to land via industrial wastewater treatment could then be transferred across to the Managed Soils category.

4.3 Nitrous Oxide Emission Calculation Outputs

The following outputs are produced in the N_2O emissions category for each industry:

Total TN load, TN	=	$P \times m_{bCOD} \times N/COD$
Implied emission factor	=	$\sum p_n EF_n$
Total N_2O emissions	=	$TN \times IEF \times 44/28$

Whilst not currently calculated or recorded, it would be useful to also include the total nitrogen load discharged to land so that this figure can be transferred across to the Managed Soils category:

Total N discharged to land	=	$TN \times F_{ld}$
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4.4 Nitrous Oxide Emission Calculation Input Parameters

Based on the methodology described above, the table below summarises the data required in order to calculate the wastewater treatment N₂O emissions.

Table 4-1 Nitrous Oxide Emission Data Requirements

Parameter	Symbol	Units
Activity Data – for each industry:		
Total nitrogen to biodegradable COD ratio	N:COD _b	
Fraction of effluent treated by process that is discharged to surface water	f _{sw}	
Fraction of effluent treated by process that is discharged to land	f _{ld}	
Emissions Data – for each process:		
Nitrogen removal efficiency	NR	
WWTP emission factor	EF _{WWTP}	kg NO ₂ -N/kg N
Effluent surface water emission factor	EF _{sw}	kg NO ₂ -N/kg N

5 Current Emissions Calculation Basis

5.1 Previous Reports

The existing industrial wastewater emissions calculation methodology and input parameters are based on previous reports covering activity and emissions data. The following reports on industrial wastewater treatment emissions were made available to Cardno as part of the current review:

SCS-Wetherill Environmental (2002): National Greenhouse Gas Inventory from the Waste Sector 1990 – 2020 (SWE)

This report was prepared in association with Bruce Wallace Partners Ltd (BWP) and covered the entire Waste inventory. The study included a report from Albert van Oostrom, a meat industry waste expert, which provided the unit COD load and emission data for meat processing wastewater that remains the basis for the meat processing CH₄ calculations.

Beca (2007): National Greenhouse Gas Inventory from Wastewater Treatment and Discharge

This report updated the domestic and industrial wastewater inventory. The report considered only meat processing and pulp and paper to be significant industrial CH₄ sources, and meat processing to be the only significant N₂O source. Biodegradable sludge removal was assumed to be zero for all industries as it was considered that any sludge removed from sites was stabilised sufficiently so that further methane generation was negligible.

Beca (2013): Industrial Wastewater Greenhouse Gas Estimates from the Pulp and Paper, Wool Scouring and Wine Industries for New Zealand's GHG Inventory

This report reviewed activity and CH₄ emission data for the pulp and paper, wool scouring and wine industries. N₂O emissions were not investigated.

MfE Greenhouse Inventory Draft Report and Spreadsheet

MfE provided Cardno with the following documents that provided information on the current basis for the industrial wastewater inventory:

- *New Zealand's Greenhouse Gas Inventory 1990 – 2013 (Unpublished draft)*
- Excel file titled *2014 submission - Industrial wastewater emissions (867497)*

It is assumed that the excel spreadsheet is the current basis for the industrial wastewater inventory.

5.2 Current Industrial Wastewater Emissions Inventory

Meat processing, pulp and paper manufacturing, and winemaking are currently the only industries included in the wastewater inventory. The table below summarises the 2012 wastewater inventory which is the most recent year in the MfE spreadsheet.

Table 5-1 2012 Wastewater Treatment Emissions Inventory

Industry	CH ₄ Emissions		N ₂ O Emissions	
	kt p.a	% of total	kt p.a	% of total
Meat Processing (cattle, sheep, lambs, pigs, goat, deer)	3.000	65%	0.1413	70.9%
Poultry Processing	0.568	12%	0.0519	26.1%
Rendering Only Plants	0.610	13%	0.0061	3.1%
Pulp and Paper Processing	0.390	8%	0.0000	0.0%
Winemaking	0.069	1%	0.0000	0.0%
Total	4.636	100%	0.1994	100%

5.3 Industries Not Currently Included in Industrial Wastewater Category

The significant organic industries in New Zealand that are currently not included in the industrial wastewater category are discussed briefly below.

Dairy Processing

No anaerobic ponds are currently used in dairy processing wastewater treatment. There is one known site using anaerobic digestion (Tirau) however the biogas generated at this site is either used for energy recovery or flared (Beca, 2007). The non-inclusion of dairy processing in the CH₄ inventory is therefore appropriate.

N₂O emissions from dairy processing wastewater are not currently included in the inventory. Activity data is required in order to assess whether these emissions are significant or not.

Wool Scouring

There are currently four wool scouring plants operating in New Zealand. All four plants currently discharge into a municipal sewer system. Three of the plants, at Timaru, Hastings and Napier, only perform primary treatment prior to discharge. The fourth plant at Belfast near Christchurch uses a combination of dissolved air flotation, biological treatment and evaporation prior to discharge. The non-inclusion of wool scouring in the wastewater inventory is currently still appropriate.

Fellmongers and Tanneries

Rendering, blood drying, fellmongers and tanneries are the major by-product operations from the meat processing industry. Currently, rendering and blood drying wastewater COD loads are included within the meat processing emissions calculation (although a small fraction of the overall meat processing load is currently deducted and calculated separately as “rendering”). This is appropriate as the majority of rendering and blood meal plants are located at meat processing plants (in addition, there are several independent rendering and blood meal plants). Fellmongers and tanneries are now mostly located at standalone facilities.

Fellmongers treat raw skins in a series of chemical treatments (unhairing, liming, deliming, bating, pickling) to produce hides. Tanning involves further chemical treatment of the processed hides to produce leather. SWE (2002) reported an average unit biodegradable COD load of 180 kg/tonne of product for fellmongers and tanneries, which was the highest reported unit COD load of any industry in New Zealand. However, the emission factor is assumed to be zero for both fellmongers and tanneries. Fellmongery wastewater is unsuitable for anaerobic treatment due to high concentrations of sulphur in the wastewater. Therefore, aerobic treatment is provided for those sites that do not discharge to sewers. Tanneries in New Zealand are all located in towns and discharge to sewer.

Breweries

Breweries have never been included in the wastewater inventory as all major breweries discharge to a municipal sewer or use aerobic treatment processes (SWE, 2002).

Fruit and Vegetable Processing

Fruit and vegetable processing has never been included in the wastewater inventory as most fruit and vegetable processing plants discharge to municipal sewers. Where on site treatment is provided, the treatment is nearly always aerobic (SWE, 2002).

Fish Processing

Fish processing has never been included in the wastewater inventory as fish processing plants discharge to municipal sewers.

6 Assessment of Current Emissions Calculation Basis

6.1 Review of Current Emissions Calculation Basis

The current emissions calculation spreadsheet was reviewed for information gaps and errors. Issues identified are listed in Table 6-1 below.

Table 6-1 Industrial Wastewater Emissions Calculations: Issues and Data Requirements

Issue	Comment & Recommended Actions
Meat Processing	
Activity Data	<p>Fraction of waste treated by various processes is from 2002 and should be updated with a new industry survey.</p> <p>It is recommended to not separate out rendering loads, in order to simplify the inventory calculations. This is reasonable as there are only a few standalone rendering plants in New Zealand the rest are combined with meat processing plants and so the unit COD load includes for rendering operations.</p> <p>Missing data:</p> <ul style="list-style-type: none"> - Fractions of effluent applied to land and surface waters for each process <p>Poultry processing should be separated out from meat processing to allow for different activity data for this industry.</p> <p>An industry survey of poultry processing is required to confirm the fraction of waste treated in anaerobic ponds and the unit COD load, which is currently high compared to the meat processing value.</p>
Emissions Data	<p>Missing data:</p> <ul style="list-style-type: none"> - Nitrogen removal efficiencies and N₂O emission factors
Pulp and Paper	
Activity Data	<p>Current inventory uses Beca (2007) unit COD load of 32.3 kg/t. Update to Beca (2013) implied value of 36 kg/t.</p> <p>Missing data:</p> <ul style="list-style-type: none"> - N:COD ratio of wastewater - Fractions of effluent discharged to land and waterways
Emissions Data	<p>Current inventory uses the 2002 emission factor of 0.005. Using Beca (2013) data an implied emission factor of 0.017 is calculated; this increases methane emissions significantly.</p> <p>Beca (2013) calculates biodegradable sludge exports however to be consistent with other wastewater categories it is recommended that exported sludge be set to zero as sludge is assumed to be well stabilised prior to leaving the site.</p> <p>Missing data:</p> <ul style="list-style-type: none"> - Nitrogen removal efficiencies and N₂O emission factors
Winemaking	
Activity Data	<p>Adjust unit COD load to be on total crushed grape production basis rather than proportion of production that is treated on site.</p>

6.2 Industry Activity Data Surveys

As the meat industry makes up the majority of the emissions, it was considered useful to attempt to gather up to date activity data from this industry as the current activity data relating to wastewater treatment practices is now over 10 years old. In addition, it was considered useful to the gather activity data on the dairy industry in order to assess the significance of N₂O emissions from this industry.

Wastewater activity data from the pulp and paper and winemaking industries were the subject of a recent report by Beca (2013) so these industries were not surveyed.

The following information was requested on an individual site basis:

- Average daily production
- Wastewater treatment processes used
- Effluent discharge destination (land, river, ocean, sewer)
- Any available wastewater volume, COD or nitrogen data

The five major New Zealand meat processing companies were contacted, as well as the Poultry Industry Association and Fonterra. The responses received at the time of publishing this report are as follows:

- | | |
|--------------------------------|-----------------|
| • AFFCO | Did not respond |
| • Alliance | Responded |
| • ANZCO | Did not respond |
| • Silver Farm Meats | Responded |
| • Ovation NZ Ltd | Responded |
| • Poultry Industry Association | Responded |
| • Fonterra | Responded |

6.3 Nitrous Oxide Emission Parameters

Significant uncertainty in the N₂O emission data has been noted in previous reports (SWE 2002, Beca 2007). A recent paper reviewing N₂O emission factors from wastewater treatment plants (Law et al 2012) also found a wide variation in measured N₂O emission rates. A single N₂O emission factor value for all activated sludge and aerated lagoon processes was selected based on data found in the literature. For all other processes, the N₂O emission factor is assumed to be zero.

For all treated effluent discharges to surface waters, the default 2006 IPCC emission factor should be applied to the effluent N load discharged. In order to calculate the effluent N loads based on the influent N loads, typical nitrogen removal rates for the main treatment processes were selected and are presented overleaf.

6.4 Biodegradable COD in Exported Sludge

Currently the biodegradable COD in exported sludge is assumed to be zero for all industries. The basis for this assumption is that all sludges that are exported from wastewater treatment sites are fully stabilised and hence have negligible methane generation potential in landfills or other off site treatment facilities.

This is considered a reasonable assumption for the meat, dairy and wine industries. However for the pulp and paper industry Beca (2013) calculated biodegradable sludge generation rates for the main treatment processes used in this industry. Sludge generation for pulp and paper has been included in the revised model.

Table 6-2 Nitrous Oxide Selected Emission Parameters

Process / Parameter	Value	Comment
Anaerobic Pond		
N ₂ O emission factor	0.00	
N removal efficiency	20%	Russell and Cooper (1992)
Aerated lagoon / activated sludge		
N ₂ O emission factor	0.005	Typical of actual measured values reported in Law et al (2012) Note: This value corresponds to the value cited in IPCC (2006) for manure management (forced aeration systems)
N removal efficiency (with BNR)	80%	Typical value
N removal efficiency (no BNR)	20%	Typical value
Unaerated facultative pond		
N ₂ O emission factor	0.00	N ₂ O is primarily emitted from aerated zones due to stripping (Law <i>et al</i> 2012) therefore emissions will be low in unaerated ponds.
N removal efficiency	20%	Craggs (2005)
Surface water emissions following effluent discharge		
N ₂ O emission factor	0.005	IPCC (2006) default value

7 Revised Emissions Calculation Basis

7.1 Individual Industries

The tables below show the parameters used to calculate the 2012 emissions calculations and revised values resulting from this review.

Table 7-1 Meat Processing Wastewater Inventory Basis

Parameter	Units	2012 Value	Revised Value	Comment
Activity Data:				
Production	t p.a. carcass	1,332,858	1,159,595	Exclude poultry from basis (make poultry its own category)
m_{bCOD}	kgCOD _b /t	50	50	No new data so keep van Oostrom (2002) value
TN:COD _b		0.080	0.090	Updated from June 2015 industry survey
Wastewater treatment:	% of production			
Anaerobic ponds		38.8	6.0%	Updated from June 2015 industry survey
Anaerobic pond + Aerated process			20%	Updated from June 2015 industry survey
Aerated process			10%	Updated from June 2015 industry survey
Primary treatment only			64%	Updated from June 2015 industry survey
All others including no treatment		61.2	n/a	
Receiving Environment:	% treated			
Anaerobic ponds	to surface water	n/a	10%	Updated from June 2015 industry survey
	to land	n/a	40%	Updated from June 2015 industry survey
Anaerobic pond + Aerated process	to surface water	n/a	30%	Updated from June 2015 industry survey
	to land	n/a	10%	Updated from June 2015 industry survey
Aerated Process	to surface water	n/a	50%	Updated from June 2015 industry survey
	to land	n/a	50%	Updated from June 2015 industry survey
Primary Treatment Only	to surface water	n/a	12%	Updated from June 2015 industry survey
	to land	n/a	17%	Updated from June 2015 industry survey
Emission Data:				
Anaerobic pond systems				
MCF		0.55	0.55	No new data so keep van Oostrom (2002) value
Sludge removal fraction		0.00	0.00	
Nitrogen removal	%	0.00	20	
N ₂ O Emission Factor		0.020	0.00	Revised emission factor
Aerated Process				
MCF		0.00	0.00	
Sludge removal fraction		0.00	0.00	
Nitrogen removal	%	0.00	20	
N ₂ O Emission Factor		0.020	0.005	Revised emission factor
N ₂ O surface water Emission Factor		0.00	0.005	IPCC (2006) default value

Table 7-2 Poultry Processing Wastewater Inventory Basis

Parameter	Units	2012 Value	Revised Value	Comment
Activity Data:				
Production	t p.a. carcass	n/a	173,263	Poultry previously included in meat processing
m_{bCOD}	kgCOD _b /t	50	50	No new data so keep van Oostrom (2002) value
TN:COD _b		0.080	0.090	Updated from June 2015 industry survey
Wastewater treatment:	% of production			
Anaerobic ponds		38.8	25%	Updated from June 2015 industry survey
Anaerobic pond + Aerated process			0%	Updated from June 2015 industry survey
Aerated process			35%	Updated from June 2015 industry survey
Primary treatment only			40%	Updated from June 2015 industry survey
All others including no treatment		61.2	n/a	
Receiving Environment:	% treated			
Anaerobic ponds	to surface water	n/a	10%	Updated from June 2015 industry survey
	to land	n/a	40%	Updated from June 2015 industry survey
Anaerobic pond + Aerated process	to surface water	n/a	30%	Updated from June 2015 industry survey
	to land	n/a	10%	Updated from June 2015 industry survey
Aerated Process	to surface water	n/a	50%	Updated from June 2015 industry survey
	to land	n/a	50%	Updated from June 2015 industry survey
Primary Treatment Only	to surface water	n/a	12%	Updated from June 2015 industry survey
	to land	n/a	17%	Updated from June 2015 industry survey
Emission Data:				
Anaerobic pond systems				
MCF		0.55	0.55	No new data so keep van Oostrom (2002) value
Sludge removal fraction		0.00	0.00	
Nitrogen removal	%	0.00	20	
N ₂ O Emission Factor		0.020	0.00	Revised emission factor
Aerated Process				
MCF		0.00	0.00	
Sludge removal fraction		0.00	0.00	
Nitrogen removal	%	0.00	20	
N ₂ O Emission Factor		0.020	0.005	Revised emission factor
N ₂ O surface water Emission Factor		0.00	0.005	IPCC (2006) default value

Table 7-3 Dairy Processing Wastewater Inventory Basis

Parameter	Units	2012 Value	Revised Value	Comment
Activity Data:				
Production	Litres raw milk p.a.			No figures corresponding to loads available yet
m _b COD				No figures corresponding to loads available yet
TN:COD _b		n/a	0.044	John Russell (Fonterra) pers. comm. 12/6/15
Wastewater treatment:				
	% of production			
Activated sludge		n/a	31%	John Russell (Fonterra) pers. comm. 12/6/15
Land treatment		n/a	32%	John Russell (Fonterra) pers. comm. 12/6/15
Others		n/a	36%	John Russell (Fonterra) pers. comm. 12/6/15
Receiving Environment:				
	% treated			
Activated sludge	to surface water	n/a	100%	Assume all activated sludge goes to surface water
	to land	n/a	0%	
Land treatment	to surface water	n/a	0%	
	to land	n/a	100%	
All others	to surface water	n/a	0%	Assume others are connected to sewer
	to land	n/a	0%	
Emission Data:				
Activated sludge				
Methane Correction Factor		n/a	0.00	
Sludge removal fraction		n/a	0.00	
Nitrogen removal	%	n/a	20	
N ₂ O Emission Factor		n/a	0.005	
Land treatment				
Methane Correction Factor		n/a	0.00	
Sludge removal fraction		n/a	0.00	
Nitrogen removal	%	n/a	0.00	
N ₂ O Emission Factor		n/a	0.00	
All others				
Methane Correction Factor		n/a	0.00	
Sludge removal fraction		n/a	0.00	
Nitrogen removal	%	n/a	0.00	
N ₂ O Emission Factor		n/a	0.00	
N ₂ O surface water Emission Factor		n/a	0.005	IPCC (2006) default value

Table 7-4 Pulp and Paper Wastewater Inventory Basis

Parameter	Units	2012 Value	Revised Value	Comment
Activity Data:				
Production	t p.a pulp + paper	2,414,290	2,414,290	
m _b COD	kgCOD _b /t	32.3	36.0	Based on Beca (2013) information
TN:COD _b		0.0038	0.0038	No new data so keep SWE (2002) value
Wastewater treatment - % of production				
Anaerobic pond		n/a	7.0%	Beca (2013) Table 34 and Appendix A
Partial mix aerated ponds		n/a	44%	Beca (2013) Table 34 and Appendix A
MBBR/activated sludge		n/a	40%	Beca (2013) Table 34 and Appendix A
No treatment – to sewer		n/a	9.0%	Beca (2013) Table 34 and Appendix A
Receiving Environment: % treated				
Anaerobic pond system	to surface water	n/a	100	
	to land	n/a	0	
Partial mix aerated ponds	to surface water	n/a	100	
	to land	n/a	0	
MBBR/activated sludge	to surface water	n/a	100	
	to land	n/a	0	
Emission Data:				
Anaerobic pond				
Methane Correction Factor		n/a	0.80	Beca (2013) Table 28
Sludge removal fraction		n/a	0.40	Beca (2013) Table 34
Nitrogen removal	%	n/a	0.00	
N ₂ O Emission Factor		n/a	0.00	
Partial mix aerated lagoon				
Methane Correction Factor		n/a	0.05	Beca (2013) Table 28
Sludge removal fraction		n/a	0.40	Beca (2013) Table 34
Nitrogen removal	%	n/a	20	
N ₂ O Emission Factor		n/a	0.005	
MBBR / activated sludge				
Methane Correction Factor		n/a	0.00	Beca (2013) Table 28
Sludge removal fraction		n/a	0.40	Beca (2013) Table 34
Nitrogen removal	%	n/a	20	
N ₂ O Emission Factor		n/a	0.005	
N ₂ O surface water Emission Factor		0.00	0.005	IPCC (2006) default value

Table 7-5 Winery Wastewater Inventory Basis

Parameter	Units	2012 Value	Revised Value	Comment
Activity Data:				
Production	t p.a crushed grapes	n/a	331,000	Use total crushed grape output
m _b COD	kgCOD _b /t		12.42	Beca (2013)
TN:COD _b		n/a	n/a	No data available
Wastewater treatment - % of production				
Septic tank		n/a	0.35%	Beca (2013)
Storage tanks		n/a	1.64%	Beca (2013)
Storage ponds		n/a	0.21%	Beca (2013)
Unknown on site treatment		n/a	65%	Beca (2013)
No treatment – to sewer		n/a	33%	Beca (2013)
Receiving Environment: % treated				
Septic tank	to surface water	n/a	0	
	to land	n/a	100	
Storage tank	to surface water	n/a	0	
	to land	n/a	100	
Storage ponds	to surface water	n/a	0	
	to land	n/a	100	
Unknown treatment	to surface water	n/a	0	
	to land	n/a	100	
Emission Data:				
Septic tank				
Methane Correction Factor		n/a	0.50	Beca (2013)
Sludge removal fraction		n/a	0.00	
Nitrogen removal	%	n/a	0.00	
N ₂ O Emission Factor		n/a	0.00	
Storage tank				
Methane Correction Factor		n/a	0.00	Beca (2013)
Sludge removal fraction		n/a	0.00	
Nitrogen removal	%	n/a	0.00	
N ₂ O Emission Factor		n/a	0.00	
Storage ponds				
Methane Correction Factor		n/a	0.10	Beca (2013)
Sludge removal fraction		n/a	0.00	
Nitrogen removal	%	n/a	0.00	
N ₂ O Emission Factor		n/a	0.00	
Unknown Treatment				
Methane Correction Factor		n/a	0.10	Beca (2013) assumed to be aerobic ponds
Sludge removal fraction		n/a	0.00	
Nitrogen removal	%	n/a	0.00	
N ₂ O Emission Factor		n/a	0.00	
N ₂ O surface water Emission Factor		0.00	0.005	IPCC default value

7.2 Summary

Using the same production values, the revised 2012 emissions are shown below.

Table 7-6 2012 Wastewater Treatment Emissions Inventory

Industry	CH ₄ Emissions		N ₂ O Emissions	
	kt p.a	% of total	kt p.a	% of total
Meat Processing (cattle, sheep, lambs, pigs, goat, deer)	2.073	60%	0.0111	42.1%
Poultry Processing	0.298	8.6%	0.0024	9.0%
Dairy Processing	0.000	0.0%	0.0128	48.9%
Pulp and Paper Processing	1.017	29%	0.0000	0.0%
Winemaking	0.068	2.0%	0.0000	0.0%
Total	3.456	100%	0.0262	100%

8 Summary and Conclusions

The calculation methodology and input parameters used by MfE for calculating the industrial wastewater treatment CH₄ and N₂O emissions has been reviewed.

The main outcomes and conclusions of the review are as follows:

- > An excel-based model has been developed so that the various input parameters used for all calculations can be easily identified and changed in future.
- > The meat processing category now includes all rendering loads in order to simplify calculations.
- > Poultry processing has been separated out as this category has its own industry body and activity data.
- > The meat and poultry processing industries were surveyed in order to update activity data in these industries.
- > Dairy processing has been included in order to capture nitrous oxide emissions from activated sludge treatment plants and discharges to surface waters.

Further work in the following areas would add value by reducing data gaps in the inventory:

- > Nitrogen to biodegradable COD ratio in pulp and paper industry wastewater

9 References

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