



**National Pollutant Inventory**

# **Emission Estimation Technique Manual**

**for**

**Intensive Livestock  
- Beef Cattle**

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**EMISSION ESTIMATION TECHNIQUES  
FOR  
BEEF CATTLE FEEDLOTS**

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FOR  
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## 1.0 Introduction

The purpose of all Emission Estimation Technique (EET) Manuals in this series is to assist Australian manufacturing, industrial and service facilities to report emissions of listed substances to the National Pollutant Inventory (NPI). This Manual describes the procedures and recommended approaches for estimating emissions from facilities engaged in the operation of Beef Cattle Feedlots. A beef feedlot is a confined area with watering and feeding facilities where cattle are completely hand or mechanically fed for the purpose of production (ARMCANZ, 1997). Feedlot operations consist of a number of activities including feedstock storage, feeding systems, animal housing, disposal of biological matter, waste removal/storage and waste treatment.

EET MANUAL:	Beef Cattle Feedlots
HANDBOOK:	Intensive Livestock (Beef Cattle)
ANZSIC CODE:	0125

Pacific Air & Environment Pty Ltd drafted this Manual on behalf of Environment Australia. It has been developed through a process of national consultation involving State and Territory environmental authorities and key industry stakeholders. Particular thanks is due to the Australian Lot Feeders Association (ALFA) and its members for their assistance in the development of this Manual

### 1.1 Manual Structure

This Manual is structured as follows:

- **Section 2.0** provides a brief overview of the Beef Cattle Feedlot process and emissions.
- **Section 3.1** discusses the term ‘transfer’ as it applies to the feedlot industry.
- **Section 3.2** summarises the NPI-listed substances that are triggered, or likely to be triggered, for the beef cattle feedlot industry. Category 1, 2 and 3 substances are discussed in **Sections 3.2.1, 3.2.2 and 3.2.3** respectively. **Sections 3.3, 3.4 and 3.5** detail the expected emissions to air, water and land respectively from the industry. These sections also describe the sources of these emissions and where emission estimation techniques for each of these sources are to be found.
- **Section 4.0** provides a glossary of technical terms and abbreviations used in this Manual.
- **Section 5.0** provides a list of references used in the development of this Manual.
- **Appendix A** provides an overview of the four general types of emission estimation techniques: sampling or direct measurement; mass balance; engineering calculations and emission factors, as well as example calculations to illustrate their use. Reference to relevant sections of this Appendix is recommended in understanding the application of these techniques with particular respect to the beef cattle feedlot industry.
- **Appendix B** provides a discussion of the reliability and uncertainty involved with each of the techniques presented in **Appendix A**.
- **Appendix C** provides a list of variables and symbols used throughout this Manual.

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## 1.2 Manual Application

### *Context and use of this Manual*

This NPI Manual provides a 'how to' guide for the application of various methods to estimate emissions as required by the NPI. It is recognised that the data that is generated in this process will have varying degrees of accuracy with respect to the actual emissions from beef cattle feedlot facilities. In some cases there will necessarily be a large potential error due to inherent assumptions in the various emissions estimation techniques (EETs).

*EETs should be considered as 'points of reference'*

The EETs and generic emission factors presented in this Manual should be seen as 'points of reference' for guidance purposes only. Each has associated error bands that are potentially quite large. **Appendix B** of this Manual discusses the general reliability associated with the various methods. The potential errors associated with the different EET options should be considered on a case-by-case basis as to their suitability for a particular facility. Facilities may use EETs that are not outlined in this document. They must, however, seek the consent of their relevant environmental authority to determine whether any 'in house' EETs are suitable for meeting their NPI reporting requirements.

*Hierarchical approach recommended in applying EETs*

This Manual presents a number of different EETs, each of which could be applied to the estimation of NPI substances. The range of available methods should be viewed as a hierarchy of available techniques in terms of the error associated with the estimate. Each substance needs to be considered in terms of the level of error that is acceptable or appropriate with the use of the various estimation techniques. Also the availability of pre-existing data and the effort required to decrease the error associated with the estimate will need to be considered. For example, if emissions of a substance are clearly very small, no matter which EET is applied, then there would be little gained by applying an EET which required significant additional sampling.

The steps in meeting the reporting requirements of the NPI can be summarised as follows:

*Category 1 and 1a Substances:*

Identify which reportable NPI substances are used (or exceed the bulk storage capacity for Category 1a substances) and determine whether the amounts used or handled are above the 'threshold' values and therefore trigger reporting requirements. See **Section 3.2.1** of this Manual for guidance on which Category 1 substances are likely to require reporting for the beef cattle feedlot industry. If the threshold is exceeded, emissions of these Category 1 and 1a substances must be reported for all operations/processes relating to the facility, even if the actual emissions of the substances are very low or zero.

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*Category 2a and 2b Substances:*

Determine the amount and rate of fuel (or waste) burnt each year and assess whether the threshold limits are exceeded. See **Section 3.2.2** of this Manual for a discussion which Category 2 substances are likely to be triggered for the beef cattle feedlot industry.

*Category 3 Substances:*

Determine the annual emissions to water and assess whether the threshold limits are exceeded. It is unlikely that this NPI Category will require reporting for the beef cattle feedlot industry.

*Those substances above the threshold values*

Examine the available range of EETs and determine emission estimates using the most appropriate EET.

Generally, it will be appropriate to consider various EETs as alternative options whose suitability should be evaluated in terms of:

- The associated reliability or error bands; and
- The cost/benefit of using a more reliable method.

The accuracy of particular EETs is discussed in **Appendix B**.

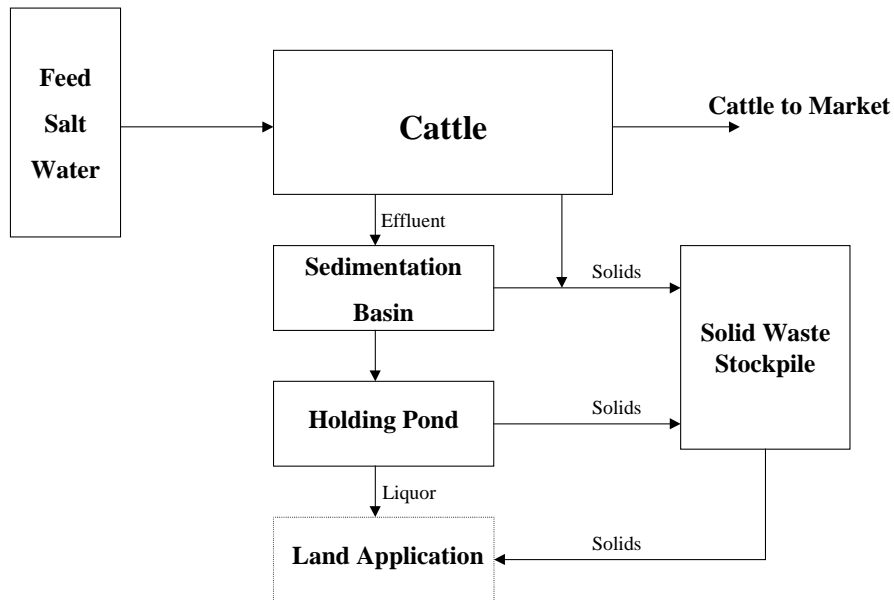
*NPI emissions in the environmental context*

It should be noted that the NPI reporting process generates emission estimates only. It does not attempt to relate emissions to potential environmental impacts, bioavailability of emissions or natural background levels.

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## 2.0 Processes and Emissions

This Manual will cover the Beef Cattle Feedlot industry as defined under ANZSIC Code 0125 - Beef Cattle Farming. These operations consists of a number of activities including feedstock storage, feeding systems, animal housing, disposal of biological matter, waste removal/storage and waste treatment. Some facilities may also generate their own power.



**Figure 1 - Beef Cattle Feedlots: Inputs and Emissions**

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## 3.0 Reportable Emission Sources

### 3.1 Transfers

Under the NPI, the following are classed as transfers and are not required to be reported:

- Discharges of substances to sewer;
- Deposit of substances to landfill; and
- Removal of substances from a facility for destruction, treatment, recycling, reprocessing, recovery, or purification.

The definition of transfer has been clarified by the NPI Implementation Working Group as: 'All emissions of listed substances, except those which are directed to, and contained by, purpose built facilities, are to be reported to the NPI. This applies irrespective of whether the substances' fate is within or outside a reporting facility boundary. With respect to receipt of NPI-listed substances, such receiving facilities are to be operating in accordance with any applicable State or Territory government requirements.'

In the specific context of feedlots, on-site irrigation of effluent or waste water is considered as an emission and that any NPI-listed substances, for which reporting thresholds are triggered, associated with these emissions, must be quantified and reported. Effluent sent off site for application on another facility is defined as a transfer and the emissions from this are required to be reported by the receiving facility.

### 3.2 Reporting Thresholds

The beef cattle feedlot industry potentially has NPI reporting requirements associated with:

- Ammonia produced from animals (see Section 3.2.1 for guidance on how to determine whether or not reporting on this is required for your facility);
- Emissions to air associated with the combustion of fuel (see Section 3.2.2); and
- Releases to surface waters of nitrogen or phosphorus (see Section 3.2.3).

#### 3.2.1 Category 1

The substances listed under Category 1 and 1a have extremely limited use as inputs into the beef cattle feedlot industry. There are only minor quantities of chemicals used for cleaning and veterinary purposes etc. and it is extremely unlikely these substances would exceed the 10 tonnes per year triggering limit. However, it is likely that some facilities will trigger the 10 tonnes per year limit for ammonia (as a consequence of ammonia in manure). To determine whether or not the 10 tonnes per year threshold would be exceeded at a particular facility, the calculation process outlined in Example 1 below would need to be followed.



### Example 1 - Category 1 Threshold Calculations

A beef cattle farmer has a herd of cattle equivalent to 1500 Standard Cattle Units (SCU). Is the Category 1 threshold for ammonia exceeded for the facility? (NB: 1 SCU = 600 kg)

If site specific manure data for Total Nitrogen excretion is not available, then the default value from Table 3 of this Manual can be used (75 kg Total Nitrogen/SCU/year). Based on the volatilisation data in Table 4 of this Manual, a default amount of 90%<sup>a</sup> total nitrogen is volatilised to ammonia in the overall feedlot process.

Therefore, to determine total ammonia production:

Amount of ammonia produced per SCU

$$\begin{aligned} &= \text{Total nitrogen} * \text{fraction volatilised} * \text{MW}_{\text{ammonia}} / \text{EW}_{\text{nitrogen}} \\ &= 75 \text{ kg Total N/SCU/year} * 0.9 * 17/14 \\ &= 82 \text{ kg of ammonia per SCU per year} \end{aligned}$$

Annual amount of ammonia;

$$\begin{aligned} &= \text{Herd Capacity} * \text{Annual Ammonia per SCU} \\ &= 1500 \text{ SCU} * 82 \text{ kg ammonia per SCU per year} * 1 \text{ tonne}/1000 \text{ kg} \\ &= 123 \text{ tonnes of ammonia per year.} \end{aligned}$$

The amount of ammonia produced exceeds the Category 1 reporting threshold. Therefore, reporting of emissions of ammonia to air, water and land is required under the NPI

**Note:** Based on this data, the minimum herd capacity required to trigger the Category 1 threshold is:

$$\begin{aligned} &= 10 \text{ tonnes}/123 \text{ tonnes of ammonia} * 1500 \text{ SCU} \\ &= 122 \text{ SCU (122 head @ 600 kg each)} \end{aligned}$$

<sup>a</sup> The default value of 90% was calculated using the data from Table 2 in this Manual, and assuming that the ammonia emissions consisted of losses from Fresh Manure, Feedlot Pad, Manure Stockpile, Retention Pond and some Irrigation of Effluent on-site.

### 3.2.2 Category 2

The Category 2 threshold is based on energy consumed or fuel use at a facility. The Category 2a threshold for fuel usage is triggered if:

- A facility burns 400 tonnes or more of fuel or waste per year; or
- A facility burns 1 tonne or more of fuel or waste per hour.

The Category 2b threshold is triggered if:

- A facility burns 2000 tonnes or more of fuel or waste per year; or
- A facility uses 60 000 megawatt hours (MWh) or more of energy in a year; or
- A facility's maximum potential power consumption is rated at 20 megawatts (MW) or more at any time during the year.

If there is on-site power generation (eg. diesel generator), Table 1 details the amount of fuel usage required to trigger the Category 2 reporting thresholds. It should be noted that Category 2 threshold calculations should be performed for total fuel usage. If a number of different fuels are used at one facility, the sum of each individual fuel use needs to be calculated to determine whether or not the Category 2 threshold is triggered. Please refer to the *EET Manual for Combustion Engines* for further information on emission factors for generators.

**Table 1 - Approximate Fuel Usage Required to Trigger Category 2 Thresholds**

Fuel Type	Category 2a	Category 2b
Natural Gas <sup>a</sup>	2.06 * 10 <sup>7</sup> MJ per reporting year, or at least 5.12 * 10 <sup>4</sup> MJ in any one hour in the reporting year	1.03 * 10 <sup>8</sup> MJ per reporting year
Liquefied Petroleum Gas (LPG) <sup>b</sup>	7.87 * 10 <sup>5</sup> L per reporting year, or at least 1.97 * 10 <sup>3</sup> L in any one hour in the reporting year	3.94 * 10 <sup>6</sup> L per reporting year
Biogas <sup>c</sup>	3.67 * 10 <sup>5</sup> m <sup>3</sup> per reporting year, or at least 9.17 * 10 <sup>2</sup> m <sup>3</sup> in any one hour in the reporting year	1.83 * 10 <sup>6</sup> m <sup>3</sup> per reporting year
Diesel <sup>d</sup>	4.44 * 10 <sup>5</sup> L per reporting year, or at least 1.11 * 10 <sup>3</sup> L in any one hour in the reporting year	2.22 * 10 <sup>6</sup> L per reporting year

<sup>a</sup> Assuming ideal gas with a density of 0.755 kg/m<sup>3</sup> at 15°C and 101.325 kPa. Natural gas (NSW) data from the *Natural Gas Technical Data Handbook* (AGL Gas Company (NSW) Limited, 1995)

<sup>b</sup> Assuming ideal gas with a density of 508 kg/m<sup>3</sup> at 15°C under pressure from the *Natural Gas Technical Data Handbook* (AGL Gas Company (NSW) Limited, 1995)

<sup>c</sup> Assuming 65% methane and 35% carbon dioxide ideal gas by volume with a density of 1.09 kg/m<sup>3</sup> at 15°C and 101.325 kPa.

<sup>d</sup> Assuming a density of 900 kg/m<sup>3</sup> at 15°C for fuel oil for commercial use (Perry, et al., 1997).

If a facility triggers the Category 2a threshold, all Category 2a pollutants need to be reported. If a facility triggers the Category 2b threshold, Category 2a and Category 2b pollutants need to be reported. Category 2 substances are listed in Table 2.

**Table 2 - NPI-listed Category 2 Substances**

Category 2a Substances	Category 2b Substances
Carbon Monoxide	Arsenic & compounds
Fluoride Compounds	Beryllium & compounds
Hydrochloric Acid	Cadmium & compounds
Oxides of Nitrogen	Chromium (III) compounds
Particulate Matter (PM <sub>10</sub> )	Chromium (VI) compounds
Polycyclic Aromatic Hydrocarbons	Copper & compounds
Sulfur Dioxide	Lead & compounds
Total Volatile Organic Compounds	Magnesium Oxide Fume
	Manganese & compounds
	Mercury & compounds
	Nickel & compounds
	Nickel Carbonyl
	Nickel Subsulfide
	Polychlorinated Dioxins & Furans
	<b>PLUS all Category 2a substances</b>

### 3.2.3 Category 3

From discussions with the industry, feedlots are not generally permitted to discharge effluent to surface waters. Effluent is generally directed to holding ponds and wastewater treatment processes. The liquor from the ponds is generally used for irrigation purposes.

Given that feedlots are not generally permitted to routinely release effluent or treated effluent to surface waters, it is likely that the only event that would cause such a release would be an unplanned situation such as extreme rainfall events or leaks/breaks in a settlement pond wall. In such events, it is extremely unlikely that the Category 3 reporting thresholds would be exceeded. However, there may be a need to estimate the total phosphorus and total nitrogen released to make a definitive assessment.

Table 3 provides typical default concentrations for Category 3 substances in effluent retention ponds. This data may be used as a starting point to determine whether releases of such effluent could lead to a Category 3 reporting threshold being exceeded.

Example 2 illustrates the application of this data.

**Table 3 - Default Concentrations for Category 3 NPI listed Substances in Beef Cattle Effluent Retention Ponds**

Category 3 NPI listed substances	Concentration (mg/L)
Total Nitrogen	750
Total Phosphorus	100

Source: Qld DPI, 1999

### Example 2 - Category 3 Threshold Calculations

A spill of 100 000 litres has occurred from an effluent treatment pond. The only prior treatment of the effluent was screening. Has a Category 3 threshold been exceeded?

If individual feedlot specific data is unavailable then, using the concentrations of total nitrogen and total phosphorus in the effluent for typical feedlot effluent pond from Table 3 above;

Concentration of Nitrogen	= 750 mg/L
Concentration of phosphorus	= 100 mg/L
Total amount released	= concentration * amount released
Total nitrogen released	= 750 mg/L * 100 000 L = $7.5 * 10^7$ mg = 75 kg released
Total phosphorus released	= 100 mg/L * 100 000L = $1.0 * 10^7$ mg = 10 kg released

These releases are significantly less than the Category 3 thresholds of 15 tonnes per annum for total nitrogen and 3 tonnes per annum for total phosphorus. Therefore, in this situation, no reporting of Category 3 substances would be required.

## 3.3 Emissions to Air

Section 3.3.1 provides guidance on the characterisation of emissions of ammonia to air from piggery operations. Section 3.3.2 provides guidance on characterising emissions to air of Category 2 substances.

### 3.3.1 Ammonia

Ammonia is released to air throughout feedlot operations, from the sheds through to the final effluent treatment and disposal processes (ie. land application of effluent). Accurately estimating the quantities of ammonia emitted can be difficult and/or expensive. Although there are no standard methods for estimating the quantity of ammonia released to the atmosphere from a feedlot, the Queensland Department of Primary Industries has provided the information in Tables 4 and 5 to estimate ammonia emissions. It should be noted that the 'Percentage of Total Nitrogen Volatilised' is expressed as a percentage of the Total Nitrogen input to the stage. In the absence of site specific data, the information provided in Tables 4 and 5 could be used as default values to calculate the ammonia losses from Beef Cattle Feedlots.

**Table 4 - Default Emission Factors for Total Nitrogen in Beef Cattle Feedlots**

Component	Emission Factor (kg Total N/SCU/yr)
Freshly Excreted Manure	75
Manure remaining on Pad	24.6 <sup>a</sup>
Run-off to Retention Pond	5.4 <sup>a</sup>

Source: Qld DPI, 1999

<sup>a</sup> Approximately 18% of the freshly excreted manure (that has not been volatilised) is transferred to the retention pond as run-off. The other 82% (that has not been volatilised) remains on the feedlot pad until it is scraped off into manure stockpiles.

**Table 5 - Percentage of Total Nitrogen Volatilised (as NH<sub>3</sub>) from Various Stages of an Intensive Beef Cattle Feedlot**

Component	Percentage of Total Nitrogen volatilised from Total Nitrogen present at each Stage
Fresh Manure	60
Manure remaining on Pad	80
Manure Stockpile	30
Retention Pond	26
Irrigation	25
Soil (post irrigation)	25

Source: Qld DPI, 1999

To calculate emissions of ammonia for the purposes of NPI reporting, the following steps should be followed:

### Step 1

Determine total ammonia production (refer to Section 3.2.1).

### Step 2

Identify the activities conducted at the facility (see Table 5 above) and the corresponding percentage of ammonia released (see also Table 5).

The key issue is that it is only on-site releases of ammonia, which are to be reported. This includes ammonia emissions from on-site irrigation. However, emissions of ammonia from off-site irrigation are not required to be estimated.

### Step 3

Multiply the total ammonia input to the activity by the percentage released (Step 2) for each activity component. The total amount of ammonia released is the sum of the releases to air from each individual activity. It is important to note that, for each stage subsequent to the first stage, the ammonia input to the stage is the difference between the ammonia input to the previous stage and the ammonia released in the previous stage.

Example 3 demonstrates the calculation of ammonia releases. The example involves the calculation of ammonia from each individual source at a specific facility, using the step by step approach outlined above.

### Example 3 - Ammonia Emissions Calculations

The beef feedlot operator in Example 1 has calculated that reporting is required for emissions of ammonia. The operator has an equivalent herd size of 1500 SCU. The farmer applies 1.5 ML/yr of water from the effluent pond on site. Some water from the effluent ponds is also provided to a neighbouring farm. Estimate the amount of ammonia released to the atmosphere from the facility.

If site-specific data is available, then this data should be used for these calculations. However, in the absence of such information, the default data given in this Manual may be used. (This example assumes that there are no on-site data available).

#### Fresh Manure Losses

From Table 4, the amount of total nitrogen produced each year from freshly excreted manure of lot fed beef cattle is equal to 75 kg Total N/SCU/year. So for a 1500 SCU feedlot:

$$\begin{aligned}\text{Annual amount of nitrogen produced} &= 1500 \text{ SCU} * 75 \text{ kg N/SCU/year} \\ &= 112\,500 \text{ kg N/year.}\end{aligned}$$

$$\begin{aligned}\text{From Table 5, 60\% of the nitrogen in the excreted manure is lost to volatilisation. So the amount of nitrogen volatilised} &= 60\% \text{ of } 112\,500 \text{ kg N/year.} \\ &= 0.6 * 112\,500 \text{ kg N/year.} \\ &= 67\,500 \text{ kg N/year}\end{aligned}$$

$$\begin{aligned}\text{Amount of ammonia released from fresh manure} &= \text{nitrogen} * \text{MW}_{\text{ammonia}} / \text{EW}_{\text{nitrogen}} \\ &= 67\,500 \text{ kg/year} * 17/14 \\ &= 81\,964 \text{ kg/year of ammonia.} \\ &= 81.96 \text{ tonnes/year of ammonia.}\end{aligned}$$

#### Ammonia losses from Pad Surface

From Table 4, the amount of total nitrogen remaining on pad after volatilisation and runoff is 24.6 kg N/SCU/year

$$\begin{aligned}\text{Annual amount of nitrogen on pad} &= 1500 \text{ SCU} * 24.6 \text{ kg N/SCU/year} \\ &= 36\,900 \text{ kg N/year}\end{aligned}$$

$$\begin{aligned}\text{From Table 5, 80\% of the nitrogen remaining on the pad is lost to volatilisation. So the amount of nitrogen volatilised} &= 80\% \text{ of } 36\,900 \text{ kg N/year} \\ &= 0.8 * 36\,900 \text{ kg N/SCU/year} \\ &= 29\,520 \text{ kg N/year}\end{aligned}$$

### Example 3 - Ammonia Emissions Calculations - cont'

Amount of ammonia released from pad surface

$$\begin{aligned} &= \text{nitrogen} * MW_{\text{ammonia}} / EW_{\text{nitrogen}} \\ &= 29\,520 \text{ kg/year} * 17/14 \\ &= 35\,846 \text{ kg/year of ammonia} \\ &= 35.85 \text{ tonnes/year of ammonia} \end{aligned}$$

#### Manure Stockpile

Amount of nitrogen entering stockpile

$$= 36\,900 \text{ kg N/year} - 29\,520 \text{ kg N/year volatilised} = 7\,380 \text{ kg N/year}$$

From Table 5, 30% of the nitrogen in the manure stockpile is lost to volatilisation. So the amount of nitrogen volatilised

$$\begin{aligned} &= 30\% \text{ of } 7\,380 \text{ kg N/year.} \\ &= 0.3 * 7\,380 \text{ kg N/year.} \\ &= 2\,214 \text{ kg N/year.} \end{aligned}$$

Amount of ammonia released from manure stockpiling

$$\begin{aligned} &= \text{nitrogen} * MW_{\text{ammonia}} / EW_{\text{nitrogen}} \\ &= 2\,214 \text{ kg N/year} * 17/14 \\ &= 2\,688 \text{ kg/year of ammonia} \\ &= 2.69 \text{ tonnes/year of ammonia.} \end{aligned}$$

#### Retention Pond

From Table 4, amount of nitrogen entering pond

$$= 5.4 \text{ kg N/SCU/year.}$$

Annual amount of nitrogen entering pond

$$\begin{aligned} &= 1\,500 \text{ SCU} * 5.4 \text{ kg N/SCU/year} \\ &= 8\,100 \text{ kg N/year.} \end{aligned}$$

From Table 5, 26% of the nitrogen in the retention pond is lost to volatilisation. So the amount of nitrogen volatilised

$$\begin{aligned} &= 26\% \text{ of } 8\,100 \text{ kg N/year.} \\ &= 0.26 * 8\,100 \text{ kg N/year.} \\ &= 2\,106 \text{ kg N/year} \end{aligned}$$

Amount of ammonia released from the retention pond

$$\begin{aligned} &= \text{nitrogen} * MW_{\text{ammonia}} / EW_{\text{nitrogen}} \\ &= 2\,106 \text{ kg N/year} * 17/14 \\ &= 2\,557 \text{ kg N/year} \\ &= 2.56 \text{ tonnes/year of ammonia.} \end{aligned}$$

Note: Alternatively, if site-specific data for the average concentration of total nitrogen in each pond were available, the following calculation could be carried out:

$$\begin{aligned} \text{Amount of ammonia released annually} &= \text{Effluent concentration} * \% \text{volatilisation} * \\ &\quad \text{Annual throughput of the pond} \end{aligned}$$

### Example 3 - Ammonia Emissions Calculations - cont'

#### Irrigation of Effluent from Pond

Under the definition by the Industry Working Group for the NPI, irrigation of the effluent to a neighbour's property is considered as a transfer. However the irrigation of effluent on-site must be included in the calculations for ammonia production.

In the absence of site-specific data Table 3 provides a default value of 750 mg/L for the concentration of total nitrogen data in effluent ponds for Australian feedlots.

From Table 5, 25% of the nitrogen in the irrigation water is volatilised to ammonia. Therefore, total nitrogen volatilised

$$\begin{aligned} &= \% \text{volatilised} * \text{conc of N} * \text{amount irrigated} \\ &= 0.25 * 750 \text{ mg/L} * 1\,500\,000 \text{ L/yr} * 1 \text{ kg}/1\,000\,000 \text{ mg} \\ &= 281 \text{ kg N/year.} \end{aligned}$$

So, ammonia volatilised from the irrigation of pond effluent

$$\begin{aligned} &= \text{nitrogen} * \text{MW}_{\text{ammonia}} / \text{EW}_{\text{nitrogen}} \\ &= 281 \text{ kg N/year} * 17/14 \\ &= 341 \text{ kg/year of ammonia.} \\ &= 0.341 \text{ tonnes/year of ammonia.} \end{aligned}$$

#### Soil losses after Irrigation

From Table 5, 25% of the nitrogen remaining in the effluent that reaches the soil is then volatilised.

$$\begin{aligned} \text{Amount of nitrogen in soil} &= 0.75 * \text{concentration of N} * \text{amount irrigated} \\ &= 0.75 * 750 \text{ mg/L} * 1\,500\,000 \text{ L/yr} * 1 \text{ kg}/1\,000\,000 \text{ mg} \\ &= 844 \text{ kg N/year.} \end{aligned}$$

$$\begin{aligned} \text{So, total nitrogen volatilised} &= \% \text{volatilised} * \text{amount in soil} \\ &= 0.25 * 844 \text{ kg N/year.} \\ &= 211 \text{ kg N/year.} \end{aligned}$$

Therefore, ammonia volatilised from soil after irrigation

$$\begin{aligned} &= \text{nitrogen} * \text{MW}_{\text{Ammonia}} / \text{EW}_{\text{Nitrogen}} \\ &= 211 \text{ kg /year} * 17/14 \\ &= 256 \text{ kg/year of ammonia} \\ &= 0.256 \text{ tonnes/year of ammonia.} \end{aligned}$$

#### Total amount of Ammonia released to Air

Total NH<sub>3</sub> released

$$\begin{aligned} &= \text{Fresh Manure} + \text{Pad} + \text{Stockpile} + \text{Retention Pond} + \\ &\quad \text{Irrigation} + \text{Post Irrigation Soil losses} \\ &= 81.96 \text{ tonnes/yr} + 35.85 \text{ tonnes/yr} + 2.69 \text{ tonnes/yr} + \\ &\quad 2.56 \text{ tonnes/yr} + 0.341 \text{ tonnes/yr} + 0.256 \text{ tonnes/yr} \\ &= 123.66 \text{ tonnes/yr} \end{aligned}$$

Note: The emissions from irrigation (to neighbour) and from the sludge (sold off-site) are classed as transfers and hence are not reportable to the NPI. Emissions from the spreading of manure sludge from ponds (on-site) are considered to contain mainly inorganic nitrogen and organic nitrogen that is bound and, hence, there will be minimal emissions of ammonia. There is currently no published data available to estimate these emissions.



### 3.3.2 Category 2 Substances

For guidance on the estimation of emissions from fuel combustion, refer to the *Emission Estimation Technique Manual for Combustion in Boilers*. For combustion engines (eg. diesel), refer to the *Emission Estimation Technique Manual for Combustion Engines*.

It is important to recognise that if the Category 2 threshold is triggered, all releases of PM<sub>10</sub> need to be reported. Estimation of PM<sub>10</sub> emissions from feedlots floors can be complex. The most accurate method is through sampling. This however can become quite expensive. Guidance on the approaches to sampling is found in the *Emission Estimation Technique Manual for Fugitive Emissions*. Alternatively, a conservative estimate of PM<sub>10</sub> emissions can be made using an emission factor of 17.3 tonnes of PM<sub>10</sub>/1000 head per annum (USEPA, 1997).

Example 4 illustrates the use of emission factors to calculate emissions from combustion and other sources.

#### **Example 4 - PM<sub>10</sub> Emissions from Feed Yards that Trigger the Category 2 Threshold**

To maintain a feedlot with an annual throughput of 25 000 head, a beef cattle farmer uses a combination of fuels to power a boiler, various vehicles, feed mixers and pen cleaning equipment. What are the reportable emissions of PM<sub>10</sub> for this feedlot?

Natural Gas (Boiler)	= 5 150 000 MJ	= 132 732 m <sup>3</sup>	= 100 tonnes
Diesel (Vehicles, Mixers, etc)	= 350 000 L	= 315 tonnes	
Total amount of fuel burnt per annum = 415 tonnes			

The annual amount of fuel burnt exceeds the Category 2a reporting threshold. Therefore, reporting of emissions of all Category 2a substances (listed in table 2) to air, water and land is required under the NPI. The *Emission Estimation Technique Manual for Combustion in Boilers* can be used to estimate the emissions from the boiler and the *Emission Estimation Technique Manual for Combustion Engines* can be used to estimate emissions from diesel use.

This example only addresses PM<sub>10</sub> emissions. Other Category 2 substances can be calculated in a similar manner.

#### Emissions from Diesel Combustion

Diesel used = 350 000 L/yr = 350 m<sup>3</sup>/yr

Using the *Emission Estimation Technique Manual for Combustion Engines* (Table 4 p20)

PM <sub>10</sub> (from diesel engines)	= Fuel used per year * Emission Factor
	= 350 m <sup>3</sup> /yr * 5.01 kg (PM <sub>10</sub> )/m <sup>3</sup>
	= 1753.5 kg (PM <sub>10</sub> )/yr
	= 1.75 tonnes (PM <sub>10</sub> )/yr

#### Example 4 - PM<sub>10</sub> Emissions from Feed Yards that Trigger the Category 2 Threshold cont'

##### Emissions from Natural Gas Combustion

Natural Gas used = 132 732 m<sup>3</sup>/yr

Using the *Emission Estimation Technique Manual for Combustion in Boilers* (Table 26, p35)

$$\begin{aligned}\text{PM}_{10} \text{ (from natural gas in boiler)} &= \text{Fuel used per year} * \text{Emission Factor} \\ &= 132\,732 \text{ m}^3/\text{yr} * 121.6 \text{ kg (PM}_{10}\text{)}/10^6 \text{ m}^3 \\ &= 16.14 \text{ kg (PM}_{10}\text{)}/\text{yr} \\ &= 0.016 \text{ tonnes (PM}_{10}\text{)}/\text{yr}\end{aligned}$$

##### Emissions from Cattle Feed Yards

In the absence of site-specific dust emission data, the default emissions factor for feedlot fugitive dust (ie 17.3 tonnes of PM<sub>10</sub>/1000 head per annum) can be used.

$$\begin{aligned}\text{Throughput of cattle} &= 15\,000 \text{ head}/\text{yr} \\ \text{PM}_{10} \text{ (from cattle feed yard)} &= \text{Throughput per year} * \text{Emission Factor} \\ &= 15\,000 \text{ head}/\text{yr} * 17.3 \text{ tonnes (PM}_{10}\text{)}/1000 \text{ head} \\ &= 259.5 \text{ tonnes (PM}_{10}\text{)}/\text{yr}\end{aligned}$$

##### Total PM<sub>10</sub> emissions per annum

$$\begin{aligned}\text{Total PM}_{10} \text{ emissions} &= \text{PM}_{10} \text{ (diesel)} + \text{PM}_{10} \text{ (natural gas)} + \text{PM}_{10} \text{ (cattle feed yard)} \\ &= 1.75 + 0.016 + 259.5 \text{ tonnes (PM}_{10}\text{)}/\text{yr} \\ &= \mathbf{261.27 \text{ tonnes (PM}_{10}\text{)}/\text{yr}}.\end{aligned}$$

Note: Even though the dust from the cattle yard is the major source of the emissions, NPI reporting for PM<sub>10</sub> (and all category 2 substances) is only triggered by energy usage, as per page 5 of the *NPI Guide*.

### 3.4 Emissions to Water

As feedlots are, generally, prohibited to discharge effluent to surface waters it would only be in the event of an accidental or unplanned release or of a significant run off from irrigation of sludge or effluent that reporting of total nitrogen and total phosphorus may be required.

However, as discussed in Section 3.2.3, even if such releases do occur, it is extremely unlikely that any such reporting would be required. However, if there is the potential for emissions of nitrogen and phosphorus to surface waters to exceed the Category 3 Reporting Thresholds, the calculation methodology outlined in Section 3.2.3 of this Manual should be used to assess whether or not reporting is required.

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### 3.5 Emissions to Land

The on-site irrigation of slurry or effluent is classed as an emission under the NPI and reporting is required on this. For the purposes of NPI reporting, the only constituents of this which are required to be reported are:

- Ammonia. For the purposes of NPI reporting, it can be assumed that all ammonia is eventually volatilised (ie released to air) and, therefore, it can be assumed that there are no releases to land or to water. This will eliminate any potential for double counting of emissions. See Section 3.3 of this Manual for guidance on the calculation of these emissions to air.
- Run off of nitrogen and phosphorus to surface water (see Section 3.4 above for a discussion of this).

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## 4.0 Glossary of Technical Terms and Abbreviations

ANZSIC	Australian and New Zealand Standard Industrial Classification
CEMS	Continuous Emission Monitoring System
EEA	European Environment Agency
EET	Emission Estimation Technique
EF	Emission Factor
EFR	Emission Factor Rating
NEPM	National Environment Protection Measure
NPI	National Pollutant Inventory
VOC	Volatile Organic Compounds
PM <sub>10</sub>	Particulate matter with an equivalent aerodynamic diameter of 10 micrometres or less (ie. ≤10µm)
SCU	Standard Cattle Unit. This is an animal with a live weight at exit from the feedlot of 600 kg.
Transfer	Transfers consist of a deposit of a substance into landfill, or discharge of a substance to a sewer or tailings dam, or removal of a substance from a facility for destruction, treatment, recycling, reprocessing, recovery or purification ( <i>NEPM</i> , Clause 3(3)). Emissions classed as transfers are not required to be reported under the NPI.
TSP	Total Suspended Particulate
USEPA	United States Environmental Protection Agency

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## 5.0 References

AGL Gas Company (NSW) Limited, 1995, *Natural Gas Technical Data Book*, Industrial Applications Department - AGL Gas Company (NSW) Limited, Five Dock, Australia.

ANZSIC: Australian and New Zealand Standard Industrial Classification, Australian Bureau of Statistics & NZ Dept of Statistics 1993  
ABS Catalogue No 1292.0

Agriculture and Resource Management Council of Australia and New Zealand (ARMCANZ), 1997, *National Guidelines for Beef Cattle Feedlots in Australia*, 2<sup>nd</sup> Ed., CSIRO, Collingwood, Victoria, Australia.

Perry, R. and Green, D., 1997, *Perry's Chemical Engineers' Handbook*, 7<sup>th</sup> Ed., McGraw-Hill, New York, USA.

Qld DPI, 1999. Communication between Matt Scholl (PAE) and Ken Casey from the Queensland Department of Primary Industries - Intensive Livestock Environmental Management Services

The following EET Manuals are available at the NPI Homepage (<http://www.environment.gov.au/net/mpi.html>), and from your local environmental protection agency:

- *Emission Estimation Technique Manual for Combustion in Boilers*
- *Emission Estimation Technique Manual for Combustion Engines; and*
- *Emission Estimation Technique Manual for Fugitive Emissions.*

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## Appendix A - Emission Estimation Techniques

Estimates of emissions of NPI-listed substances to air, water and land should be reported for each substance that triggers a threshold. The reporting list and detailed information on thresholds are contained in the *NPI Guide* at the front of this Handbook.

In general, there are four types of emission estimation techniques (EETs) that may be used to estimate emissions from your facility.

The four types described in the *NPI Guide* are:

- Sampling or direct measurement;
- Mass balance;
- Fuel analysis or other engineering calculations; and
- Emission factors.

Select the EETs (or mix of EETs) that is most appropriate for your purposes. For example, you might choose to use a mass balance to best estimate fugitive losses from pumps and vents, direct measurement for stack and pipe emissions, and emission factors when estimating losses from storage tanks and stockpiles.

If you estimate your emission by using any of these EETs, your data will be displayed on the NPI database as being of 'acceptable reliability'. Similarly, if your relevant environmental authority has approved the use of EETs that are not outlined in this handbook, your data will also be displayed as being of 'acceptable reliability'.

This Manual seeks to provide the most effective emission estimation techniques for the NPI substances relevant to this industry. However, the absence of an EET for a substance in this handbook does not necessarily imply that an emission should not be reported to the NPI. The obligation to report on all relevant emissions remains if reporting thresholds have been exceeded.

**You are able to use emission estimation techniques that are not outlined in this document. You must, however, seek the consent of your relevant environmental authority. For example, if your company has developed site-specific emission factors, you may use these if approved by your relevant environmental authority.**

You should note that the EETs presented or referenced in this Manual relate principally to average process emissions. Emissions resulting from non-routine events are rarely discussed in the literature, and there is a general lack of EETs for such events. However, it is important to recognise that emissions resulting from significant operating excursions and/or accidental situations (eg. spills) will also need to be estimated. Emissions to land, air and water from spills must be estimated and added to process emissions when calculating total emissions for reporting purposes. The emission resulting from a spill is the net emission, ie. the quantity of the NPI reportable substance spilled, less the quantity recovered or consumed during clean up operations.

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The **usage**<sup>a</sup> of each of the substances listed as Category 1 and 1a under the NPI must be estimated to determine whether the 10 tonnes (or 25 tonnes for VOCs) reporting threshold is exceeded. If the threshold is exceeded, **emissions** of these Category 1 and 1a substances must be reported for all operations/processes relating to the facility, even if the actual emissions of the substances are very low or zero.

<sup>a</sup>Usage is defined as meaning the handling, manufacture, import, processing, coincidental production or other uses of the substances.

A list of the variables and symbols used in this Manual may be found in **Appendix C**.

## A.1 Direct Measurement

You may wish to undertake direct measurement in order to report to the NPI, particularly if you already do so in order to meet other regulatory requirements. However, the NPI does not require you to undertake additional sampling and measurement. For the sampling data to be adequate and able to be used for NPI reporting purposes, it would need to be collected over a period of time, and to be representative of operations for the whole year.

### A.1.1 Sampling Data

Stack sampling test reports often provide emissions data in terms of kg per hour or grams per cubic metre (dry). Annual emissions for NPI reporting can be calculated from this data. Stack tests for NPI reporting should be performed under representative (ie. normal) operating conditions. You should be aware that some tests undertaken for a State or Territory license condition may require the test be taken under maximum emissions rating, where emissions are likely to be higher than when operating under normal operating conditions.

An example of test results is summarised in Table 6. The table shows the results of three different sampling runs conducted during one test event. The source parameters measured as part of the test run include gas velocity and moisture content, which are used to determine exhaust gas flow rates in m<sup>3</sup>/s. The filter weight gain is determined gravimetrically and divided by the volume of gas sampled, as shown in Equation 1 to determine the PM concentration in grams per m<sup>3</sup>. Note that this example does not present the condensable PM emissions.

Pollutant concentration is then multiplied by the volumetric flow rate to determine the emission rate in kilograms per hour, as shown in Equation 2 and Example 5.

#### Equation 1

$$C_{PM} = C_f / V_{m,STP}$$

where:

$$\begin{aligned} C_{PM} &= \text{concentration of PM or gram loading, g/m}^3 \\ C_f &= \text{filter catch, g} \\ V_{m,STP} &= \text{metered volume of sample at STP, m}^3 \end{aligned}$$

**Equation 2**

$$E_{PM} = C_{PM} * Q_d * 3.6 * [273 / (273 + T)]$$

where:

$$\begin{aligned}
 E_{PM} &= \text{hourly emissions of PM, kg/hr} \\
 C_{PM} &= \text{concentration of PM or gram loading, g/m}^3 \\
 Q_d &= \text{actual stack gas volumetric flow rate, m}^3/\text{s, dry} \\
 3.6 &= \text{3600 seconds per hour multiplied by 0.001 kilograms per gram} \\
 T &= \text{temperature of the gas sample, } ^\circ\text{C}
 \end{aligned}$$

**Table 6 - Stack Sample Test Results**

Parameter	Symbol	Test 1	Test 2	Test 3
Total sampling time (sec)		7 200	7 200	7 200
Moisture collected (g)	$g_{\text{MOIST}}$	395.6	372.6	341.4
Filter catch (g)	$C_f$	0.0851	0.0449	0.0625
Average sampling rate (m <sup>3</sup> /s)		$1.67 * 10^{-4}$	$1.67 * 10^{-4}$	$1.67 * 10^{-4}$
Standard metered volume (m <sup>3</sup> )	$V_{m,STP}$	1.185	1.160	1.163
Volumetric flow rate (m <sup>3</sup> /s), dry	$Q_d$	8.48	8.43	8.45
Concentration of particulate (g/m <sup>3</sup> )	$C_{PM}$	0.0718	0.0387	0.0537

**Example 5 - Using Stack Sampling Data**

PM emissions calculated using Equation 1 and Equation 2 (above) and the stack sampling data for Test 1 (presented in Table 6, and an exhaust gas temperature of 150°C (423 K)).

This is shown below:

$$\begin{aligned}
 C_{PM} &= C_f / V_{m,STP} \\
 &= 0.0851 / 1.185 \\
 &= 0.072 \text{ g/m}^3 \\
 \\
 E_{PM} &= C_{PM} * Q_d * 3.6 * [273 / (273 + T)] \\
 &= 0.072 * 8.48 * 3.6 * (273 / 423 \text{ K}) \\
 &= 1.42 \text{ kg/hr}
 \end{aligned}$$

The information from some stack tests may be reported in grams of particulate per cubic metre of exhaust gas (wet). Use Equation 3 below to calculate the dry particulate emissions in kg/hr.

**Equation 3**

$$E_{PM} = Q_a * C_{PM} * 3.6 * (1 - \text{moist}_R / 100) * [273 / (273 + T)]$$

where:

$$\begin{aligned}
 E_{PM} &= \text{hourly emissions of PM in kilograms per hour, kg/hr} \\
 Q_a &= \text{actual (ie. wet) cubic metres of exhaust gas per second, m}^3/\text{s} \\
 C_{PM} &= \text{concentration of PM or gram loading, g/m}^3 \\
 3.6 &= \text{3600 seconds per hour multiplied by 0.001 kilograms per gram} \\
 \text{moist}_R &= \text{moisture content, \%} \\
 273 &= \text{273 K (0}^\circ\text{C)} \\
 T &= \text{stack gas temperature, } ^\circ\text{C}
 \end{aligned}$$



Total suspended particulates (TSP) are also referred to as total particulate matter (total PM). To determine PM<sub>10</sub> from total PM emissions, a size analysis may need to be undertaken. The weight PM<sub>10</sub> fraction can then be multiplied by the total PM emission rate to produce PM<sub>10</sub> emissions. Alternatively, it can be assumed that 100% of PM emissions are PM<sub>10</sub>; ie assume that all particulate matter emitted to air has an equivalent aerodynamic diameter of 10 micrometres or less ie. ≤10µm. In most situations, this is likely to be a conservative assumption, but it may be a suitable technique to obtain a reasonable characterisation of emissions for the purposes of NPI reporting.

To calculate moisture content use Equation 4

#### Equation 4

Moisture percentage = 100 \* weight of water vapour per specific volume of stack gas/ total weight of the stack gas in that volume.

$$moist_R = \frac{100 * \left( \frac{g_{moist}}{1000 * V_{m,STP}} \right)}{\left( \frac{g_{moist}}{1000 * V_{m,STP}} \right) + \rho_{STP}}$$

where:

- moist<sub>R</sub> = moisture content, %
- g<sub>moist</sub> = moisture collected, g
- V<sub>m,STP</sub> = metered volume of sample at STP, m<sup>3</sup>
- ρ<sub>STP</sub> = dry density of stack gas sample, kg/m<sup>3</sup> at STP  
 {if the density is not known a default value of 1.62 kg/m<sup>3</sup> may be used. This assumes a dry gas composition of 50% air, 50% CO<sub>2</sub>}

#### Example 6 - Calculating Moisture Percentage

A 1.2m<sup>3</sup> sample (at STP) of gas contains 410g of water. To calculate the moisture percentage use Equation 4.

$$moist_R = \frac{100 * \left( \frac{g_{moist}}{1000 * V_{m,STP}} \right)}{\left( \frac{g_{moist}}{1000 * V_{m,STP}} \right) + \rho_{STP}}$$

$$\begin{aligned} g_{MOIST} / 1000 * V_{m,STP} &= 410 / (1000 * 1.2) \\ &= 0.342 \\ moist_R &= 100 * 0.342 / (0.342 + 1.62) \\ &= 17.4\% \end{aligned}$$

### A.1.2 Continuous Emission Monitoring System (CEMS) Data

A continuous emission monitoring system (CEMS) provides a continuous record of emissions over time, usually by reporting pollutant concentration. Once the pollutant concentration is known, emission rates are obtained by multiplying the pollutant concentration by the volumetric gas or liquid flow rate of that pollutant.

Although CEMS can report real-time hourly emissions automatically, it may be necessary to estimate annual emissions from hourly concentration data Manually. This Section describes how to calculate emissions for the NPI from CEMS concentration data. The selected CEMS data should be representative of operating conditions. When possible, data collected over longer periods should be used.

It is important to note that, prior to using CEMS to estimate emissions, you should develop a protocol for collecting and averaging the data in order that the estimate satisfies the local environmental authority's requirement for NPI emission estimations.

To monitor SO<sub>2</sub>, NO<sub>x</sub>, VOC, and CO emissions using a CEMS, you use a pollutant concentration monitor that measures the concentration in parts per million by volume dry air (ppm<sub>vd</sub> = volume of pollutant gas/10<sup>6</sup> volumes of dry air). Flow rates should be measured using a volumetric flow rate monitor. Flow rates estimated based on heat input using fuel factors may be inaccurate because these systems typically run with high excess air to remove the moisture out of the kiln. Emission rates (kg/hr) are then calculated by multiplying the stack gas concentrations by the stack gas flow rates.

Table 7 presents example CEMS data output for three periods for a hypothetical furnace. The output includes pollutant concentrations in parts per million dry basis (ppm<sub>vd</sub>), diluent (O<sub>2</sub> or CO<sub>2</sub>) concentrations in percent by volume dry basis (%v, d) and gas flow rates; and may include emission rates in kilograms per hour (kg/hr). This data represents a snapshot of a hypothetical boiler operation. While it is possible to determine total emissions of an individual pollutant over a given time period from this data, assuming the CEMS operates properly all year long, an accurate emission estimate can be made by adding the hourly emission estimates if the CEMS data is representative of typical operating conditions.

**Table 7 - Example CEMS Output for a Hypothetical Furnace Firing Waste Fuel Oil**

Time	O <sub>2</sub> content	Concentration				Gas Flow Rate (Q)  m <sup>3</sup> /s	Production Rate of Product (A)  tonnes/hour
		SO <sub>2</sub> (ppm <sub>vd</sub> )	NO <sub>x</sub> (ppm <sub>vd</sub> )	CO (ppm <sub>vd</sub> )	VOC (ppm <sub>vd</sub> )		
1	10.3	150.9	142.9	42.9	554.2	8.52	290
2	10.1	144.0	145.7	41.8	582.9	8.48	293
3	11.8	123.0	112.7	128.4	515.1	8.85	270

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Hourly emissions can be based on concentration measurements as shown in Equation 5.

#### Equation 5

$$E_i = (C * MW * Q * 3600) / [22.4 * ((T + 273)/273) * 10^6]$$

where:

$E_i$	=	emissions of pollutant i, kg/hr
$C$	=	pollutant concentration, ppm <sub>v,d</sub>
$MW$	=	molecular weight of the pollutant, kg/kg-mole
$Q$	=	actual stack gas volumetric flow rate, m <sup>3</sup> /s
$3600$	=	conversion factor, s/hr
$22.4$	=	volume occupied by one mole of gas at standard temperature and pressure (0°C and 101.3 kPa), m <sup>3</sup> /kg-mole
$T$	=	temperature of gas sample, °C

Actual annual emissions can be calculated by multiplying the emission rate in kg/hr by the number of actual operating hours per year (OpHrs) as shown in Equation 6 for each typical time period and summing the results.

#### Equation 6

$$E_{kpy,i} = \sum (E_i * OpHrs)$$

where:

$E_{kpy,i}$	=	annual emissions of pollutant i, kg/yr
$E_i$	=	emissions of pollutant i, kg/hr (from Equation 5)
$OpHrs$	=	operating hours, hr/yr

Emissions in kilograms of pollutant per tonne of product produced can be calculated by dividing the emission rate in kg/hr by the activity rate (production rate (tonnes/hr) during the same period. This is shown in Equation 7 below.

It should be noted that the emission factor calculated below assumes that the selected time period (ie. hourly) is representative of annual operating conditions and longer time periods should be used for NPI reporting where they are available. Use of the calculation is shown in Example 5.

#### Equation 7

$$E_{kpt,i} = E_i / A$$

where:

$E_{kpt,i}$	=	emissions of pollutant i per tonne of product produced, kg/t
$E_i$	=	hourly emissions of pollutant i, kg/hr
$A$	=	production, t/hr

Example 7 illustrates the application of Equation 5, Equation 6 and Equation 7.

### Example 7 - Using CEMS Data

This example shows how SO<sub>2</sub> emissions can be calculated using Equation 5 based on the CEMS data for Time Period 1 shown in Table 7, and an exhaust gas temperature of 150°C (423 K).

$$\begin{aligned}
 E_{\text{SO}_2,1} &= (C * MW * Q * 3600) / [(22.4 * (T + 273/273)) * 10^6] \\
 &= (150.9 * 64 * 8.52 * 3600) / [22.4 * (423/273) * 10^6] \\
 &= 296\,217\,907 / 34\,707\,692 \\
 &= 8.53 \text{ kg/hr}
 \end{aligned}$$

For Time Period 2, also at 150°C

$$E_{\text{SO}_2,2} = 8.11 \text{ kg/hr}$$

For Time Period 3, also at 150°C

$$E_{\text{SO}_2,3} = 7.23 \text{ kg/hr}$$

Say representative operating conditions for the year are:

$$\begin{aligned}
 \text{Period 1} &= 1500 \text{ hr} \\
 \text{Period 2} &= 2000 \text{ hr} \\
 \text{Period 3} &= 1800 \text{ hr}
 \end{aligned}$$

Total emissions for the year are calculated by adding the results of the three Time Periods using Equation 6:

$$\begin{aligned}
 E_{\text{kpy,SO}_2} &= E_{\text{SO}_2,1} * \text{OpHrs} + E_{\text{SO}_2,2} * \text{OpHrs} + E_{\text{SO}_2,3} * \text{OpHrs} \\
 &= (8.53 * 1500) + (8.11 * 2000) + (7.23 * 1800) \text{ kg} \\
 &= 42\,021 \text{ kg/yr}
 \end{aligned}$$

Emissions, in terms of kg/tonne of product produced when operating in the same mode as time period 1, can be calculated using Equation 7

$$\begin{aligned}
 E_{\text{kpt,SO}_2} &= E_{\text{SO}_2} / A \\
 &= 8.53 / 290 \\
 &= 2.94 * 10^{-2} \text{ kg SO}_2 \text{ emitted per tonne of product produced}
 \end{aligned}$$

When the furnace is operating as in time periods 2 or 3, similar calculations can be undertaken for emissions per tonne.

## A.2 Using Mass Balance

A mass balance identifies the quantity of substance going in and out of an entire facility, process, or piece of equipment. Emissions can be calculated as the difference between input and output of each listed substance. Accumulation or depletion of the substance within the equipment should be accounted for in your calculation.

Mass balance calculations for estimating emissions to air of NPI-listed substances can be represented conceptually by Equation 8.

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### Equation 8

$$E_{kpy,i} = \text{Amount in}_i - \text{Amount out}_i$$

where:

$$\begin{aligned} E_{kpy,i} &= \text{emissions of pollutant } i, \text{ kg/yr} \\ \text{Amount in}_i &= \text{amount of pollutant } i \text{ entering the process, kg/yr} \\ \text{Amount out}_i &= \text{amount of pollutant } i \text{ leaving the process as a waste} \\ &\quad \text{stream, article or product, kg/yr} \end{aligned}$$

The term “Amount out<sub>i</sub>” may actually involve several different fates for an individual pollutant. This could include the amount recovered or recycled, the amount leaving the process in the manufactured product, the amount leaving the process in wastewater, the amount emitted to the atmosphere, or the amount of material transferred off-site as hazardous waste or to landfill. A thorough knowledge of the different fates for the pollutant of interest is necessary for an accurate emission estimate to be made using the mass balance approach.

The amount of a particular substance entering or leaving a facility is often mixed within a solution as a formulation component or as a trace element within the raw material. To determine the total weight of the substance entering or leaving the process, the concentration of the substance within the material is required. Using this concentration data, Equation 9 can be applied as a practical extension of Equation 8.

### Equation 9

$$E_{kpy,i} = [(Q_{in} * C_{in}) - (Q_{pr} * C_{pr}) - (Q_{rec} * C_{rec}) - (Q_{waste} * C_{waste})] / 10^6$$

where:

$$\begin{aligned} E_{kpy,i} &= \text{emissions of pollutant } i, \text{ kg/yr} \\ Q_{in}, Q_{pr}, Q_{rec}, Q_{waste} &= \text{quantity of raw material, product, recycled material or waste} \\ &\quad \text{respectively, that is processed (generally expressed in kg for} \\ &\quad \text{solids, L for liquids)} \\ C_{in}, C_{pr}, C_{rec}, C_{waste} &= \text{concentration of substance } i \text{ in the raw material, product,} \\ &\quad \text{recycled material or waste respectively, that is processed} \\ &\quad \text{annually (usually mg/kg for solids, mg/L for liquids)} \\ 10^6 &= \text{conversion from milligrams to kilograms.} \end{aligned}$$

Wastewater treatment may precipitate the reportable chemical in a sludge. Facilities are often required to obtain data on the concentration of metals or other substances in sludges as part of their licensing requirement and this data can be used to calculate the emissions as kilograms of sludge multiplied by the concentrations of the substance in the sludge. Although listed substances in sludges transferred off-site do not require reporting, determining this loss can assist with determining other process losses or may require reporting if the sludge is disposed of on-site.

For many chemicals used and emitted during chemical processes, some degradation in treatment may occur so that the entire chemical is not transferred to the sludge. Facilities can estimate the amount of reportable compounds in the sludge by using measured data, or by subtracting the amount biodegraded from the total amount removed in treatment.

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The amount of removal can be determined from operating data, and the extent of biodegradation might be obtained from published studies. If the biodegradability of the chemical cannot be measured or is not known, reporting facilities should assume that all removal is due to absorption to sludge.

### A.3 Engineering Calculations

An engineering calculation is an estimation method based on physical/chemical properties (eg. vapour pressure) of the substance and mathematical relationships (eg. ideal gas law).

#### A.3.1 Fuel Analysis

Fuel analysis is an example of an engineering calculation and can be used to predict SO<sub>2</sub>, metals, and other emissions based on application of conservation laws, if fuel rate is measured. The presence of certain elements in fuels may be used to predict their presence in emission streams. This includes elements such as sulfur that may be converted into other compounds during the combustion process.

The basic equation used in fuel analysis emission calculations is the following:

#### Equation 10

$$E_{kpy,i} = Q_f * C_i / 100 * (MW_p / EW_f) * OpHrs$$

where:

$E_{kpy,i}$	=	annual emissions of pollutant i, kg/yr
$Q_f$	=	fuel use, kg/hr
OpHrs	=	operating hours, hr/yr
$MW_p$	=	molecular weight of pollutant emitted, kg/kg-mole
$EW_f$	=	elemental weight of pollutant in fuel, kg/kg-mole
$C_i$	=	concentration of pollutant i in fuel, weight percent, %

For instance, SO<sub>2</sub> emissions from fuel oil combustion can be calculated based on the concentration of sulfur in the fuel oil. This approach assumes complete conversion of sulfur to SO<sub>2</sub>. Therefore, for every kilogram of sulfur (EW = 32) burned, two kilograms of SO<sub>2</sub> (MW = 64) are emitted. The application of this EET is shown in Example 8.

### Example 8 - Using Fuel Analysis Data

This example shows how SO<sub>2</sub> emissions can be calculated from fuel combustion based on fuel analysis results, and the known fuel flow of the engine. E<sub>kpy,SO<sub>2</sub></sub> may be calculated using Equation 10 and given the following:

Fuel flow (Q <sub>f</sub> )	=	20 900 kg/hr
Weight percent sulfur in fuel	=	1.17 %
Operating hours	=	1500 hr/yr

$$\begin{aligned} E_{\text{kpy,SO}_2} &= Q_f * C_i / 100 * (MW_p / EW_f) * \text{OpHrs} \\ &= (20\,900) * (1.17/100) * (64 / 32) * 1500 \\ &= 733\,590 \text{ kg/yr} \end{aligned}$$

#### A.4 Emission Factors

In the absence of other information, default emission factors can be used to provide an estimate of emissions. Emission factors are generally derived through the testing of a general source population (eg. boilers using a particular fuel type). This information is used to relate the quantity of material emitted to some general measure of the scale of activity (eg. for boilers, emission factors are generally based on the quantity of fuel consumed or the heat output of the boiler).

Emission factors require 'activity data', that is combined with the factor to generate the emission estimates. The generic formula is:

$$\text{Emission Factor} \left( \frac{\text{mass}}{\text{unit of activity}} \right) * \text{Activity Data} \left( \frac{\text{unit of activity}}{\text{time}} \right) = \text{Emission Rate} \left( \frac{\text{mass}}{\text{time}} \right)$$

For example, if the emission factor has units of '*kg pollutant/m<sup>3</sup> of fuel burned*', then the activity data required would be in terms of '*m<sup>3</sup> fuel burned/hr*', thereby generating an emission estimate of '*kg pollutant/hr*'.

An emission factor is a tool used to estimate emissions to the environment. In this Manual, it relates the quantity of substances emitted from a source, to some common activity associated with those emissions. Emission factors are obtained from US, European, and Australian sources and are usually expressed as the weight of a substance emitted, divided by the unit weight, volume, distance, or duration of the activity emitting the substance (eg. kilograms of sulfur dioxide emitted per tonne of fuel burned).

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Emission factors are used to estimate a facility's emissions by the general equation:

**Equation 11**

$$E_{kpy,i} = [A * OpHrs] * EF_i * [1 - (CE_i/100)]$$

where :

- $E_{kpy,i}$  = emission rate of pollutant i, kg/yr
- $A$  = activity rate, t/hr
- $OpHrs$  = operating hours, hr/yr
- $EF_i$  = uncontrolled emission factor of pollutant i, kg/t
- $CE_i$  = overall control efficiency of pollutant i, %.

Emission factors developed from measurements for a specific process may sometimes be used to estimate emissions at other sites. Should a company have several processes of similar operation and size, and emissions are measured from one process source, an emission factor can be developed and applied to similar sources. It is necessary to have the site specific emission factor reviewed and approved by State or Territory environment agencies prior to its use for NPI estimations.



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## **Appendix B - Emission Estimation Techniques: Acceptable Reliability and Uncertainty**

This section is intended to give a general overview of some of the inaccuracies associated with each of the techniques. Although the National Pollutant Inventory does not favour one emission estimation technique over another, this section does attempt to evaluate the available emission estimation techniques with regards to accuracy.

Several techniques are available for calculating emissions from beef cattle feedlot facilities. The technique chosen is dependent on available data, and available resources, and the degree of accuracy sought by the facility in undertaking the estimate.

### **B.1 Direct Measurement**

Use of stack and/or workplace health and safety sampling data is likely to be a relatively accurate method of estimating air emissions from beef cattle feedlot facilities. However, collection and analysis of samples from facilities can be very expensive and especially complicated where a variety of NPI-listed substances are emitted, and where most of these emissions are fugitive in nature. Sampling data from a specific process may not be representative of the entire manufacturing operation, and may provide only one example of the facility's emissions.

To be representative, sampling data used for NPI reporting purposes needs to be collected over a period of time, and to cover all aspects of production.

In the case of CEMS, instrument calibration drift can be problematic and uncaptured data can create long-term incomplete data sets. However, it may be misleading to assert that a snapshot (stack sampling) can better predict long-term emission characteristics. It is the responsibility of the facility operator to properly calibrate and maintain monitoring equipment and the corresponding emissions data.

### **B.2 Mass Balance**

Calculating emissions from beef cattle feedlot facilities using mass balance appears to be a straightforward approach to emission estimation. However, it is likely that few Australian facilities consistently track material usage and waste generation with the overall accuracy needed for application of this method. Inaccuracies associated with individual material tracking, or other activities inherent in each material handling stage, can result in large deviations for total facility emissions. Because emissions from specific materials are typically below 2 percent of gross consumption, an error of only  $\pm 5$  percent in any one step of the operation can significantly skew emission estimations.

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### B.3 Engineering Calculations

Theoretical and complex equations, or models, can be used for estimating emissions from beef cattle feedlot processes. Use of emission equations to estimate emissions from beef cattle farming facilities is a more complex and time-consuming process than the use of emission factors. Emission equations require more detailed inputs than the use of emission factors but they do provide an emission estimate that is based on facility-specific conditions

### B.4 Emission Factors

Every emission factor has an associated emission factor rating (EFR) code. This rating system is common to EETs for all industries and sectors and therefore, to all Industry Handbooks. They are based on rating systems developed by the United States Environmental Protection Agency (USEPA), and by the European Environment Agency (EEA). Consequently, the ratings may not be directly relevant to Australian industry. Sources for all emission factors cited can be found in the reference section of this document. The emission factor ratings will not form part of the public NPI database.

When using emission factors, you should be aware of the associated EFR code and what that rating implies. An A or B rating indicates a greater degree of certainty than a D or E rating. The less certainty, the more likely that a given emission factor for a specific source or Category is not representative of the source type. These ratings notwithstanding, the main criterion affecting the uncertainty of an emission factor remains the degree of similarity between the equipment/process selected in applying the factor, and the target equipment/process from which the factor was derived.

The EFR system is as follows:

A	-	Excellent
B	-	Above Average
C	-	Average
D	-	Below Average
E	-	Poor
U	-	Unrated

## Appendix C - List of Variables and Symbols

Variable	Symbol	Units
Conversion from kilograms to tonnes	$10^3$	kg/tonne
Conversion from milligrams to kilograms	$10^6$	mg/kg
Density of air	$\rho_a$	kg/m <sup>3</sup>
Density of material	$\rho_m$	kg/L
Dry density of stack gas sample	$\rho_{STP}$	kg/m <sup>3</sup> at STP
Activity rate	A	units/hr, eg. t/hr
Surface area	area	m <sup>2</sup>
Overall control efficiency	CE <sub>i</sub>	% reduction in emissions of pollutant i
Filter Catch	C <sub>f</sub>	grams
Concentration of pollutant i	C <sub>i</sub>	kg/L
Concentration of pollutant i in material	C <sub>i</sub>	kg/L
Concentration of substance i in the raw material, product, recycled material or waste respectively, that is processed annually	C <sub>in</sub> , C <sub>pr</sub> , C <sub>rec</sub> , C <sub>waste</sub>	(usually mg/kg for solids, mg/L for liquids)
Concentration of PM <sub>10</sub>	C <sub>PM10</sub>	grams/m <sup>3</sup>
Uncontrolled emission factor for pollutant i	EF <sub>i</sub>	kg of pollutant/tonne
Total emissions of pollutant i per hour	E <sub>i</sub>	kg/hr
Emissions per tonne	E <sub>kpt,i</sub>	kilograms of pollutant i per tonne of fuel consumed
Annual emissions of pollutant i	E <sub>kpv,i</sub>	kg/yr
Elemental weight of pollutant in fuel	EW <sub>f</sub>	kg/kg-mole
Molecular Weight of pollutant i	MW <sub>i</sub>	kg/kg-mole
Operating hours	OpHrs	hr/yr
Pollutant concentration	ppm <sub>vd</sub>	volume of pollutant gas/10 <sup>6</sup> volume of dry air
Saturation vapour pressure of pollutant i	P <sub>sat,i</sub>	kilopascals (kPa)
Total pressure	P <sub>t</sub>	kPa
Vapour pressure of pollutant i	P <sub>vap,i</sub>	kPa
Volumetric flow rate,	Q	m <sup>3</sup> /s
Volumetric flow rate of stack gas	Q <sub>a</sub>	actual cubic metres per second (m <sup>3</sup> /s)
Volumetric flow rate of stack gas	Q <sub>d</sub>	dry cubic metres per second (m <sup>3</sup> /s)
Fuel used	Q <sub>f</sub>	t/hr
Material entering the process	Q <sub>in</sub> or Amount in <sub>i</sub>	kg/hr
Material leaving the process	Q <sub>out</sub> or Amount out <sub>i</sub>	kg/hr
Ideal gas constant	R	kPa.m <sup>3</sup> /(kgmol).K
Standard Temperature & Pressure	STP	0°C (273 K) and 1 atmosphere 101.3 kPa
Temperature	T	°Celsius (°C) or Kelvin (K)
Total suspended particulates or Total particulate matter (total PM)	TSP or PM	mg/m <sup>3</sup>
Metered volume at STP	V <sub>m,STP</sub>	m <sup>3</sup>
Total VOC emissions	E <sub>VOC</sub>	kg/L
Moisture collected	g <sub>moist</sub>	grams
Moisture content	moist <sub>R</sub>	%
Percentage weight of pollutant i	Wt% <sub>i</sub>	%