National Pollutant Inventory

Emission Estimation Technique Manual

for

Rubber Product Manufacture
Version 1.1

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Disclaimer

The manual was prepared in conjunction with Australian States and Territories according to the National Environment Protection (National Pollutant Inventory) Measure.

While reasonable efforts have been made to ensure the contents of this manual are factually correct, the Commonwealth does not accept responsibility for the accuracy or completeness of the contents and shall not be liable for any loss or damage that maybe occasioned directly or indirectly through the use of, or reliance on, the contents of this manual.

Erratum for Rubber Product Manufacture EET Manual (Version 1.1 – 7 January 2002) – Previous version issued December 1999.

- The revised version (1.1) has had the changes outlined below made.

Specific changes are:

Page	Outline of alteration
throughout manual	Corrected reference to NPI substance 1,1,1,2 – Tetrachloroethane. The substance was previously listed incorrectly as 1,1,2,2 - Tetrachloroethane.

EMISSION ESTIMATION TECHNIQUES
FOR
RUBBER PRODUCT MANUFACTURE

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EMISSION ESTIMATION TECHNIQUES
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RUBBER PRODUCT MANUFACTURE

LIST OF TABLES AND EXAMPLES

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 rubber product manufacturing.

The rubber product manufacturing activities covered in this Manual apply to facilities primarily engaged in the manufacture of inflatable rubber tyres, mattresses, floor coverings, hot water bottles, stationers bands, rubber gloves and any other products made using natural or synthetic rubber mixed in any proportions.

EET MANUAL: Rubber Product Manufacture

HANDBOOK: Rubber Product Manufacture

ANZSIC CODES: 2551, 2559 and all codes in the 255 ANZSIC code group.

Pacific Air & Environment Pty Ltd drafted this Manual on behalf of the Commonwealth Government. It has been developed through a process of national consultation involving State and Territory environmental authorities and key industry stakeholders.

1.1 Manual Structure

- **Section 2** discusses the NPI reporting issues associated with the rubber product manufacturing industry. **Section 2.1** discusses the issue of transfers. **Section 2.2, 2.3** and **2.4** discuss the Category 1, 2 and 3 thresholds respectively in terms of which substances are likely to trigger these thresholds. **Sections 2.5, 2.6** and **2.7** examine the potential emissions to air, water and land respectively, which are associated with rubber product manufacturing.
- **Section 3** examines each of the unit operations or processes that are relevant to the rubber product manufacturing industry and provides guidance on the application of suitable emission estimation techniques.
- **Section 4** provides a glossary of technical terms and abbreviations used in this Manual.
- **Section 5** 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 rubber product manufacturing industry.
- **Appendix B** provides a discussion of the reliability and uncertainty involved with each of the emission estimation techniques presented in **Appendix A**.
- **Appendix C** provides a list of variables and symbols used throughout this Manual.
- **Appendix D** provides details of the composition of each of the rubber compounds on which the emission factors in this Manual are based.

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 rubber product manufacturing facilities. In some cases there will necessarily be a large potential error due to inherent assumptions in the various emissions estimation techniques (EETs) and/or a lack of available information of chemical processes.

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** 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 to be 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:

- for Category 1 and 1a substances, identify which reportable NPI substances are used, produced or stored, and determine whether the amounts used or handled are above the ‘threshold’ values and therefore trigger reporting requirements;
- for Category 2a and 2b substances, determine the amount and rate of fuel (or waste) burnt each year, the annual power consumption and the maximum potential power consumption, and assess whether the threshold limits are exceeded;
- for Category 3 substances, determine the annual emissions to water and assess whether the threshold limits are exceeded; and
- for 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.

2.0 Reporting Thresholds and Emissions

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.

2.1 Transfers

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

- discharges of substances to sewer or tailings dam;
- 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."

A number of emissions from the rubber product manufacturing industry are classed as transfers. These are discussed in **Sections 2.6** and **2.7** of this Manual.

2.2 Category 1

The Category 1 threshold is triggered if a facility handles, manufactures, imports, processes, coincidentally produces, or otherwise uses 10 tonnes or more of a Category 1 substance. A facility is only required to report on the Category 1 substances that trigger thresholds. If a reporting threshold is exceeded, then emissions of these substances must be reported for all operations/processes relating to the facility, even if actual emissions are very low or zero.

Table 1 shows the NPI-listed substances that may trigger the Category 1 threshold for rubber product processing activities. This table has been compiled from an analysis of emission factor data compiled by the USEPA (USEPA, 1999). For guidance on the application of emission factors, please refer to **Appendix A.4** of this Manual.

Table 1 - Category 1 Substances that may Trigger Thresholds

Substances	
Acetaldehyde	n-Hexane
Acetonitrile	Methyl Methacrylate
Acrylonitrile	4,4-Methylene bis 2,4 aniline (MOCA)
Benzene	Methyl Ethyl Ketone
Biphenyl	Methyl Isobutyl Ketone
1,3-Butadiene	Phenol
Carbon Disulfide	Styrene
Chloroethane	1,1,1,2-Tetrachloroethane
Chloroform	Tetrachloroethylene
Chlorophenols	1,1,2-Trichloroethane
Cumene	Toluene
1,2-Dichloroethane	Total Volatile Organic Compounds
Dibutyl Phthalate	Vinyl Chloride Monomer
1,2-Dibromoethane	Xylenes
Ethylbenzene	

2.3 Category 2

The Category 2 threshold is based on energy consumption or fuel use. 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.

Based on these thresholds, the amount of fuel usage required to trigger these thresholds may be calculated (as shown in Table 2). 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.

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

Fuel Type	Category 2a	Category 2b
Natural Gas[a]	$2.06 * 10^7$ MJ per reporting year, or at least $5.14 * 10^4$ MJ in any one hour in the reporting year	$1.03 * 10^8$ MJ per reporting year
Liquefied Petroleum Gas (LPG)[b]	$7.87 * 10^5$ L per reporting year, or at least $1.97 * 10^3$ L in any one hour in the reporting year	$3.94 * 10^6$ L per reporting year
Diesel[c]	$4.44 * 10^5$ L per reporting year, or at least $1.11 * 10^3$ L in any one hour in the reporting year	$2.22 * 10^6$ L per reporting year
Propane[d]	$2.02 * 10^7$ MJ per reporting year, or at least $5.04 * 10^4$ MJ in any one hour in the reporting year	$1.01 * 10^8$ MJ per reporting year
Butane[e]	$1.98 * 10^7$ MJ per reporting year, or at least $4.96 * 10^4$ MJ in any one hour in the reporting year	$9.92 * 10^7$ MJ per reporting year

[a] Assuming natural gas with a gross heating value of 51.4 MJ/kg. Natural gas (NSW) data from the *Natural Gas Technical Data Handbook* (AGL Gas Company (NSW) Limited, 1995).
[b] Assuming ideal gas with a density of 508 kg/m^3 at 15°C under pressure from the *Natural Gas Technical Data Handbook* (AGL Gas Company (NSW) Limited, 1995).
[c] Assuming a density of 900 kg/m^3 at 15°C for fuel oil for commercial use (Perry & Green, 1997)
[d] Assuming a gross heating value of 50.4 MJ/kg at 25°C and 101.325 kPa (Lide, 1994).
[e] Assuming a gross heating value of 49.6 MJ/kg at 25°C and 101.325 kPa (Lide, 1994).

From discussions with industry, it is likely that the Category 2a threshold will be triggered at some manufacturing facilities. The Category 2b threshold may be triggered, depending on energy use. If a facility triggers the Category 2a threshold, all Category 2a pollutants need to be reported. If a facility triggers the Category 2b threshold, all Category 2a and Category 2b pollutants need to be reported. Category 2 substances are listed in Table 3.

Table 3 - Category 2 Substances that Trigger Reporting

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_{10})	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
	PLUS all Category 2a substances

2.4 Category 3

Under Clause 13 of the *NPI NEPM,* the reporting threshold for a Category 3 substance is exceeded in a reporting period if the activities of the facility involve the emission to water (excluding groundwater) of:

- 15 tonnes or more per year of Total Nitrogen; or
- 3 tonnes per year or more of Total Phosphorus.

For rubber product manufacturing facilities, it is extremely unlikely that there will be licensed discharges to surface waters. Stormwater run-off may trigger NPI reporting requirements, although it is unlikely that this run-off would contain levels of nitrogen or phosphorus that would lead to the triggering of the Category 3 threshold. If however, your facility has a significant, or potentially significant, release of aqueous nitrogen or phosphorus, you will need to go through the process of determining whether or not Category 3 reporting requirements are triggered for your facility.

2.5 Emissions to Air

Table 4 is a summary of NPI-listed substances that may be emitted into the air from various process operations of rubber product manufacturing.

Table 4 - Common Air Emissions from Rubber Product Manufacturing Processes

Activity	Air Emissions	Sources of Information
Process Operations • Mixing • Milling • Extrusion • Calendering • Curing • Grinding • Wastewater treatment • Unloading and loading of raw materials and products	• Acetaldehyde • Acetonitrile • Acrylonitrile • Benzene • Biphenyl • 1,3-Butadiene • Cadmium & compounds • Carbon Disulfide • Chloroethane • Chloroform • Chromium (III) compounds • Chromium (VI) compounds • Cobalt & compounds • Cumene • 1,2-Dichloroethane • Dibutyl Phthalate • 1,2-Dibromoethane • Ethylbenzene • n-Hexane • Lead & compounds • Methyl Methacrylate • 4,4-Methylene bis 2,4 aniline (MOCA) • Methyl Ethyl Ketone • Methyl Isobutyl Ketone • Nickel & compounds • Particulates (PM_{10}) • Phenol • Styrene • 1,1,1,2-Tetrachloroethane • Tetrachloroethylene • 1,1,2-Trichloroethane • Chlorophenols • Toluene • Vinyl Chloride • Xylenes	**Section 3** of this Manual provides EETs for mixing, milling, extrusion, calendering, curing and grinding operations. **Appendix A** of this Manual provides guidance on the application of emission factors and other estimation techniques that may be used to characterise emissions from these activities. Guidance on the estimation of emissions to air from storage and loading/unloading operations is provided in the *Emission Estimation Technique Manual for Fuel and Organic Liquid Storage.* Guidance on the estimation of emissions from wastewater treatment is provided in the *Emission Estimation Technique Manual for Sewage and Wastewater Treatment*.
Combustion Processes • On-site energy/heat/steam production using oil/gas/coal • Gas flaring	• Carbon Monoxide • Fluoride Compounds • Hydrochloric Acid • Oxides of Nitrogen • Particulate Matter (PM_{10}) • Polycyclic Aromatic Hydrocarbons • Sulfur Dioxide • Total Volatile Organic Compounds • Arsenic & compounds • Beryllium & compounds • Cadmium & compounds • Chromium (III) compounds • Chromium (VI) compounds • Copper & compounds • Lead & compounds • Magnesium Oxide Fume • Manganese & compounds • Mercury & compounds • Nickel & compounds • Nickel Carbonyl • Nickel Subsulfide	Guidance on the estimation of emissions from energy production processes is provided in the *Emission Estimation Technique Manual for Combustion in Boilers* and the *Emission Estimation Technique Manual for Combustion Engines.* Guidance on the estimation of emissions from gas flaring processes is provided in the *Emission Estimation Technique Manual for Petroleum Refining* (Section 4.1.1.2).

2.6 Emissions to Water

For rubber product manufacturing facilities, it is expected that all the process liquid effluent and waste streams will be:

- sent to sewer;
- sent off-site for treatment, recycling or recovery; or
- recycled through the process.

If wastewater treatment occurs on-site (and the effluent is released to a surface water body), it needs to be examined for potential emissions. Please refer to the *Emission Estimation Technique Manual for Sewage and Wastewater Treatment* for guidance on how to estimate these emissions.

There may be NPI reporting issues associated with stormwater run-off. If stormwater contains NPI-listed substances, most facilities are likely to be required by their relevant State or Territory environment agency to closely monitor and measure these emissions. These sampling data can be used to calculate emissions for the purposes of NPI reporting.

2.7 Emissions to Land

Emissions of substances to land on-site include solid wastes, slurries, sediments, spills and leaks, storage and distribution of liquids. Such emissions may contain NPI-listed substances. It is expected that, for the rubber product manufacturing industry, all of these substances will be sent to sewer, sent off-site for treatment or recycling or sent to landfill. These are classed as transfers and, as a consequence, are not required to be reported. There may be reporting requirements for releases to land associated with:

- spills or accidental releases of NPI-listed substances to land (if spills occur, see the *Emission Estimation Technique Manual for Organic Chemical Processing Industries* (Section 9.2) for guidance on how to estimate these releases);

- releases of NPI-listed substances to groundwater (see the *Emission Estimation Technique Manual for Organic Chemical Processing Industries* (Section 9.1) for guidance on how to estimate these releases); and

- on-site disposal, where the on-site disposal does not meet the definition provided in **Section 2.1** of this Manual.

3.0 Unit Sources/Operations

3.1 Introduction

The unit processes/emission sources considered in this Section are:

- Mixing (**Section 3.2**);
- Milling (**Section 3.3**);
- Extrusion (**Section 3.4**);
- Calendering (**Section 3.5**);
- Platen Press Curing (**Section 3.6.2.1**);
- Autoclave Curing (**Section 3.6.2.2**);
- Hot Air Curing (**Section 3.6.2.3**); and
- Grinding (**Section 3.7**).

It is likely that, for some substances, an overall facility mass balance may be an appropriate emission estimation technique for rubber product manufacturing facilities. A discussion and overview of mass balance as an emission estimation technique is provided in **Appendix A.2.1** of this Manual.

However, it is recognised that for some facilities, the information necessary to successfully carry out a facility mass balance may not be available. In these situations, the default emission factors presented in this Section may be utilised. Guidance on the use of emission factors for characterising emissions may be found in **Appendix A.4** of this Manual.

It may also be that some of these sources can be considered, collectively, as fugitive sources (for example, if all of the releases occur inside a building and are released through a stack and/or through building vents and apertures). In this situation, the *Emission Estimation Technique Manual for Fugitive Emissions* provides guidance on the characterisation of these sources.

3.2 Mixing

3.2.1 General Description

Mixing involves the addition of several additives to the raw rubber. These additives depend on the desired composition of the product and usually include rubber, filler, extender oils, accelerators and antioxidants. VOC emissions occur when chemicals such as cements, solvent tackifiers and release agents are added to the raw material. Hydrocarbons may be released when solvents or adhesives are applied to the surface of the rubber.

3.2.2 Emission Factors

Emission factors for mixing operations are provided in Table 5.

Table 5 - Emission Factors for Mixing

Substance	Emission Factor[g] (kg substance/kg of rubber processed)
Acetaldehyde[a]	$1.22 * 10^{-6}$
Acetonitrile	$4.63 * 10^{-7}$
Acrylonitrile	$3.38 * 10^{-6}$
Benzene	$1.47 * 10^{-7}$
Biphenyl	$1.69 * 10^{-8}$
1,3-Butadiene	$1.76 * 10^{-7}$
Cadmium & compounds	$2.49 * 10^{-9}$
Carbon Disulfide	$1.36 * 10^{-5}$
Chloroethane	$7.75 * 10^{-7}$
Chloroform	$1.76 *10^{-7}$
Chlorophenols[b]	-[h]
Chromium (Cr) compounds[c]	$1.97 * 10^{-8}$
Cumene	$2.86 * 10^{-7}$
1,2-Dibromoethane	-[h]
Dibutyl Phthalate	$6.38 * 10^{-8}$
1,2-Dichloroethane	-[h]
Ethylbenzene	$3.71 * 10^{-7}$
n-Hexane	$6.90 * 10^{-6}$
Lead & compounds	$5.84 * 10^{-9}$
Methylene bis 2,4 aniline	-[h]
Methyl Isobutyl Ketone	$4.63 * 10^{-6}$
Nickel & compounds	$3.63 * 10^{-8}$
PM_{10}[d]	$3.21 * 10^{-4}$
Styrene	$5.89 * 10^{-7}$
1,1,1,2-Tetrachloroethane	-[h]
Tetrachloroethylene	$4.90 * 10^{-7}$
1,1,2-Trichloroethane	-[h]
Toluene	$2.14 * 10^{-6}$
Total VOCs[e]	$1.06 * 10^{-4}$
Vinyl Chloride Monomer	$1.32 * 10^{-8}$
Xylenes[f]	$1.65 * 10^{-6}$

Source: USEPA, 1999. The emission factors presented in this section are taken from a draft document published by the USEPA (USEPA, 1999). This document presents emission factors for a number of NPI-listed substances from the processing of 23 separate compounds. The composition of each of these compounds is listed in **Appendix D** of this Manual. If a facility would like to refer to emission factor data for any of the individual compounds, it should consult USEPA (1999).

[a] The sum of acetaldehyde and (acetaldehyde + isobutane data). This is a conservative estimate of acetaldehyde emissions.

[b] The sum of 2,4,5-trichlorophenol and 2,4,6-trichlorophenol data.

[c] The USEPA does not distinguish between chromium (III) and chromium (VI) compounds.

[d] The emission factor published by the USEPA (USEPA, 1999) is for Total Particulate Matter. In the absence of site-specific particle size distribution data, it can be conservatively assumed that Total Particulate Matter is equal to PM_{10}.

[e] Taken from Total Method 25A Organic Data. Method 25A organics are those that may be measured with a flame ionisation detector (FID) according to USEPA *Method 25A* (EMTIC, 1997).

[f] The sum of m-xylene, o-xylene and p-xylene data.

[g] The mean of the emission factor data for 23 compounds which are listed in **Appendix D** of this Manual.

[h] Below the lower limit of the measurement technique. In the absence of other data, assume zero emissions.

3.3 Milling

3.3.1 General Description

Milling involves the transfer of the rubber to breakdown and feed mills for mixing and further decomposition of the raw rubber.

3.3.2 Emission Factors

Emission factors for milling operations are provided in Table 6.

Table 6 - Emission Factors for Milling

Substance	Emission Factor[e] (kg substance/kg rubber processed)
Acetaldehyde[a]	$6.30 * 10^{-7}$
Acetonitrile	$2.40 * 10^{-7}$
Acrylonitrile	$1.43 * 10^{-6}$
Benzene	$7.47 * 10^{-8}$
Biphenyl	$2.01 * 10^{-8}$
1,3-Butadiene	$9.3 * 10^{-8}$
Carbon Disulfide	$5.13 * 10^{-6}$
Chloroethane	$4.02 * 10^{-7}$
Chloroform	$9.13 * 10^{-8}$
Cumene	$1.47 * 10^{-7}$
1,2-Dibromoethane	-[f]
Dibutyl Phthalate	$4.62 * 10^{-8}$
1,2-Dichloroethane	$4.06 * 10^{-8}$
Ethylbenzene	$1.99 * 10^{-7}$
n-Hexane	$3.52 * 10^{-6}$
Methyl Isobutyl Ketone	$2.05 * 10^{-6}$
Methylene bis 2,4 aniline	-[f]
Styrene	$3.17 * 10^{-7}$
1,1,1,2-Tetrachloroethane	-[f]
Tetrachloroethylene	$1.46 * 10^{-7}$
Toluene	$1.03 * 10^{-6}$
Total VOCs[b]	$1.53 * 10^{-4}$
1,1,2-Trichloroethane	-[f]
Trichlorophenols[c]	-[f]
Vinyl Chloride Monomer	$6.83 * 10^{-9}$
Xylenes[d]	$8.52 * 10^{-7}$

Source: USEPA, 1999. The emission factors presented in this section are taken from a draft document published by the USEPA (USEPA, 1999). This document presents emission factors for a number of NPI-listed substances from the processing of 23 separate compounds. The composition of each of these compounds is listed in **Appendix D** of this Manual. If a facility would like to refer to emission factor data for any of the individual compounds, it should consult USEPA (1999).

[a] The sum of acetaldehyde and (acetaldehyde + isobutane data). This is a conservative estimate of acetaldehyde emissions.

[b] Taken from Total Method 25A Organic Data. Method 25A organics are those that may be measured with a flame ionisation detector (FID) according to USEPA *Method 25A* (EMTIC, 1997).

[c] The sum of 2,4,5-trichlorophenol and 2,4,6-trichlorophenol data.

[d] The sum of m-xylene, o-xylene and p-xylene data.

[e] The mean of the emission factor data for 23 compounds which are listed in **Appendix D** of this Manual.

[f] Below the lower limit of the measurement technique. In the absence of other data, assume zero emissions.

3.4 Extrusion

3.4.1 General Description

Softened rubber is forced through a die, forming a long continuous strip in the shape of tread or tube stock. This strip is cut in appropriate lengths and the cut ends are generally coated with a rubber cement.

3.4.2 Emission Factors

Emission factors for extrusion operations are provided in Table 7.

Table 7 - Emission Factors for Extrusion Operations

Substance	Mean Emission Factor[e] (kg substance/kg rubber processed)
Acetaldehyde	$6.52 * 10^{-7}$
Acetonitrile	$1.92 * 10^{-7}$
Acrylonitrile	$1.82 * 10^{-6}$
Benzene	$9.68 * 10^{-8}$
Biphenyl	$1.00 * 10^{-8}$
1,3-Butadiene	$1.18 * 10^{-7}$
Carbon Disulfide	$7.16 * 10^{-6}$
Chloroethane	$3.25 * 10^{-7}$
Chloroform	$8.32 * 10^{-8}$
Chlorophenols[a]	-[f]
Chromium (Cr) compounds[b]	$3.11 * 10^{-8}$
Cobalt & compounds	$1.36 * 10^{-8}$
Cumene	$1.72 * 10^{-7}$
1,2-Dibromoethane	-[f]
Dibutyl Phthalate	$7.52 * 10^{-8}$
1,2-Dichloroethane	-[f]
Ethylbenzene	$2.11 * 10^{-7}$
n-Hexane	$3.7 * 10^{-6}$
Methyl Isobutyl Ketone	$1.21 * 10^{-6}$
Methylene bis 2,4 aniline	-[f]
Nickel & compounds	$5.57 * 10^{-8}$
Styrene	$9.91 * 10^{-8}$
1,1,1,2-Tetrachloroethane	-[f]
Tetrachloroethylene	$2.11 * 10^{-7}$
Toluene	$1.48 * 10^{-6}$
Total VOCs[c]	$2.47 * 10^{-5}$
1,1,2-Trichloroethane	-[f]
Vinyl Chloride Monomer	$1.98 * 10^{-8}$
Xylenes[d]	$8.75 * 10^{-7}$

Source: USEPA, 1999. The emission factors presented in this section are taken from a draft document published by the USEPA (USEPA, 1999). This document presents emission factors for a number of NPI-listed substances from the processing of 23 separate compounds. The composition of each of these compounds is listed in **Appendix D** of this Manual. If a facility would like to refer to emission factor data for any of the individual compounds, it should consult USEPA (1999).

[a] The sum of 2,4,5-trichlorophenol and 2,4,6-trichlorophenol data.

[b] USEPA data does not distinguish between Chromium (III) and Chromium (VI) compounds.

[c] Taken from Total Method 25A Organic Data. Method 25A organics are those that may be measured with a flame ionisation detector (FID) according to USEPA *Method 25A* (EMTIC, 1997).

[d] The sum of m-xylene, o-xylene and p-xylene data.

[e] The mean of the emission factor data for 23 compounds which are listed in **Appendix D** of this Manual.

[f] Below the lower limit of the measurement technique. In the absence of other data, assume zero emissions.

3.5 Calendering

3.5.1 General Description

Calendering involves the application of a rubber coat onto synthetic steel or fibres using a number of hollow rolls. A common example is the manufacture of radial tyres where synthetic fibres are rubber-coated and then combined with rubber stock.

3.5.2 Emission Factors

Emission factors for calendering operations may be found in Table 8.

Table 8 - Emission Factors for Calendering

Substance	Emission Factor[e] (kg substance/kg rubber processed)
Acetaldehyde[a]	$5.735 * 10^{-8}$
Acetonitrile	$1.461 * 10^{-8}$
Acrylonitrile	$4.275 * 10^{-7}$
Benzene	$7.379 * 10^{-8}$
Biphenyl	$3.476 * 10^{-9}$
1,3-Butadiene	$7.474 * 10^{-8}$
Carbon disulfide	$6.072 * 10^{-6}$
Chloroform	$2.222 * 10^{-8}$
Chlorophenols[b]	-[f]
Cumene	$2.337 * 10^{-7}$
Dibutylphthalate	$3.351 * 10^{-8}$
Ethyl benzene	$1.993 * 10^{-7}$
n-Hexane	$4.976 * 10^{-6}$
4,4-Methylene bis 2,4aniline	-[f]
Methyl ethyl ketone	$7.452 * 10^{-7}$
Methyl isobutyl ketone	$2.503 * 10^{-6}$
Phenol	$1.176 * 10^{-7}$
Styrene	$2.256 * 10^{-7}$
1,1,1,2-Tetrachloroethane	-[f]
Tetrachloroethylene	$1.154 * 10^{-7}$
Toluene	$1.643 * 10^{-6}$
Total VOCs[c]	$9.215 * 10^{-5}$
1,1,2-Trichloroethane	-[f]
Trichloroethylene	$6.992 * 10^{-9}$
Vinyl chloride Monomer	$4.15 * 10^{-10}$
Xylenes[d]	$1.154 * 10^{-7}$

Source: USEPA, 1999. The emission factors presented in this section are taken from a draft document published by the USEPA (USEPA, 1999). This document presents emission factors for a number of NPI-listed substances from the processing of 23 separate compounds. The composition of each of these compounds is listed in **Appendix D** of this Manual. If a facility would like to refer to emission factor data for any of the individual compounds, it should consult USEPA (1999).

[a] The sum of acetaldehyde and (acetaldehyde + isobutane data). This is a conservative estimate of acetaldehyde emissions.

[b] The sum of 2,4,5-trichlorophenol and 2,4,6-trichlorophenol data.

[c] Taken from Total Method 25A Organic Data. Method 25A organics are those that may be measured with a flame ionisation detector (FID) according to USEPA *Method 25A* (EMTIC, 1997).

[d] The sum of m-xylene, o-xylene and p-xylene data.

[e] The mean of the emission factor data for 23 compounds which are listed in **Appendix D** of this Manual.

[f] Below the lower limit of the measurement technique. In the absence of other data, assume zero emissions.

3.6 Curing

3.6.1 General Description

There are three widely used methods of curing, namely press mould curing, autoclave curing, and hot air curing. Press mould curing uses high temperature and pressure and is often used for tyre and engineered products manufacture. Autoclave curing utilises saturated steam and high pressure and is often used for non-tyre rubber manufacturing facilities. Hot air curing involves the passing of uncured products through a chamber with a heated atmosphere. VOCs may be released any time heat is applied to rubber compounds.

3.6.2 Emission Factors

3.6.2.1 Platen Press Curing

The platen press curing process is a general approach to pressure curing engineered rubber products in moulds. Most emissions occur during mould release at the end of the curing cycle. Emission factors for platen press curing are listed in Table 9.

Table 9 - Emission Factors for Platen Press Curing

Substance	Emission Factor[d] (kg substance/kg rubber processed)
Acetaldehyde	$6.00 * 10^{-6}$
Acetonitrile	$5.47 * 10^{-6}$
Acetophenone	$2.18 * 10^{-5}$
Acrylonitrile	$1.57 * 10^{-5}$
Benzene	$1.52 * 10^{-6}$
Biphenyl	$1.96 * 10^{-7}$
1,3-Butadiene	$9.04 * 10^{-6}$
Carbon Disulfide	$2.91 * 10^{-4}$
Chloroethane	$1.48 * 10^{-6}$
Chloroform	$6.52 * 10^{-6}$
Chlorophenols[a]	-[e]
Cumene	$4.10 * 10^{-7}$
1,2-Dibromoethane	-[e]
Dibutyl Phthalate	$1.74 * 10^{-6}$
1,2-Dichloroethane	-[e]
Ethylbenzene	$2.82 * 10^{-6}$
n-Hexane	$2.61 * 10^{-5}$
Methyl Isobutyl Ketone	$1.57 * 10^{-4}$
Methylene bis 2,4 aniline	-[e]
Styrene	$1.74 * 10^{-5}$
1,1,1,2-Tetrachloroethane	-[e]
Tetrachloroethene	$3.40 * 10^{-6}$
Toluene	$8.34 * 10^{-6}$
Total VOCs[b]	$1.46 * 10^{-3}$
1,1,2-Trichloroethane	-[e]
Vinyl Chloride Monomer	$2.57 * 10^{-7}$
Xylenes[c]	$1.30 * 10^{-5}$

Source: USEPA, 1999. The emission factors presented in this section are taken from a draft document published by the USEPA (USEPA, 1999). This document presents emission factors for a number of NPI-listed substances from the processing of 23 separate compounds. The composition of each of these compounds is listed in **Appendix D** of this Manual. If a facility would like to refer to emission factor data for any of the individual compounds, it should consult USEPA (1999).

[a] The sum of 2,4,5-trichlorophenol and 2,4,6-trichlorophenol data.

[b] Taken from Total Method 25A Organic Data. Method 25A organics are those that may be measured with a flame ionisation detector (FID) according to USEPA *Method 25A* (EMTIC, 1997).

[c] The sum of m-xylene, o-xylene and p-xylene data.

[d] The mean of the emission factor data for 23 compounds which are listed in **Appendix D** of this Manual.

[e] Below the lower limit of the measurement technique. In the absence of other data, assume zero emissions.

3.6.2.2 Autoclave Curing

Autoclave curing utilises saturated steam at an elevated pressure to cure the rubber mix and is the predominant curing method in non-tyre rubber manufacturing facilities. Emission factors for autoclave curing are presented in Table 10.

Table 10 - Emission Factors for Autoclave Curing

Substance	Emission Factor[d] kg substance/kg rubber processed
Acetaldehyde	$9.00 * 10^{-7}$
Acetonitrile	$4.43 * 10^{-6}$
Acrylonitrile	$1.08 * 10^{-4}$
Benzene	$5.35 * 10^{-6}$
Biphenyl	$1.82 * 10^{-7}$
1,3-Butadiene	$1.86 * 10^{-6}$
Carbon Disulfide	$6.17 * 10^{-4}$
Chloroethane	$1.31 * 10^{-5}$
Chloroform	$5.58 * 10^{-6}$
Chlorophenols[a]	-[e]
Cumene	$2.7 * 10^{-6}$
1,2-Dibromoethane	-[e]
Dibutyl Phthalate	$5.63 * 10^{-7}$
1,2-Dichloroethane	-[e]
Ethylbenzene	$6.04 * 10^{-6}$
n-Hexane	$1.04 * 10^{-4}$
Methyl Isobutyl Ketone	$2.35 * 10^{-5}$
Methyl Methacrylate	-[e]
Methylene bis 2,4 aniline	-[e]
Styrene	$9.49 * 10^{-7}$
1,1,1,2-Tetrachloroethane	-[e]
Tetrachloroethylene	$8.36 * 10^{-6}$
Toluene	$3.29 * 10^{-5}$
Total VOCs[b]	$2.71 * 10^{-4}$
1,1,2-Trichloroethane	-[e]
Vinyl Chloride Monomer	-[e]
Xylenes[c]	$3.68 * 10^{-05}$

Source: USEPA, 1999. The emission factors presented in this section are taken from a draft document published by the USEPA (USEPA, 1999). This document presents emission factors for a number of NPI-listed substances from the processing of 23 separate compounds. The composition of each of these compounds is listed in **Appendix D** of this Manual. If a facility would like to refer to emission factor data for any of the individual compounds, it should consult USEPA (1999).

[a] The sum of 2,4,5-trichlorophenol and 2,4,6-trichlorophenol data.

[b] Taken from Total Method 25A Organic Data. Method 25A organics are those that may be measured with a flame ionisation detector (FID) according to USEPA *Method 25A* (EMTIC, 1997).

[c] The sum of m-xylene, o-xylene and p-xylene data.

[d] The mean of the emission factor data for 23 compounds which are listed in **Appendix D** of this Manual.

[e] Below the lower limit of the measurement technique. In the absence of other data, assume zero emissions.

3.6.2.3 Hot Air Curing

This process is used to final cure preformed products. Emission factors for hot air curing are presented in Table 11.

Table 11 - Emission Factors for Hot Air Curing

Substance	Emission Factor[d] (kg substance/kg rubber processed)
Acetaldehyde	$1.49 * 10^{-5}$
Acetonitrile	$6.02 * 10^{-6}$
Acrylonitrile	$1.11 * 10^{-4}$
Benzene	$6.05 * 10^{-6}$
Biphenyl	$9.39 * 10^{-7}$
1,3-Butadiene	$4.29 * 10^{-6}$
Carbon Disulfide	$4.21 * 10^{-4}$
Chloroethane	$1.91 * 10^{-5}$
Chloroform	$4.33 * 10^{-6}$
Chlorophenols[a]	-[e]
Cumene	$7.25 * 10^{-6}$
1,2-Dibromoethane	-[e]
Dibutyl Phthalate	$2.01 * 10^{-6}$
1,2-Dichloroethane	-[e]
Ethylbenzene	$1.04 * 10^{-5}$
n-Hexane	$1.62 * 10^{-4}$
Methyl Isobutyl Ketone	$1.07 * 10^{-4}$
Methylene bis 2,4 aniline	-[e]
Styrene	$1.04 * 10^{-5}$
1,1,1,2-Tetrachloroethane	-[e]
Tetrachloroethylene	$1.03 * 10^{-5}$
Toluene	$4.74 * 10^{-5}$
Total VOCs[b]	$5.29 * 10^{-3}$
1,1,2-Trichloroethane	-[e]
Vinyl Chloride Monomer	$3.24 * 10^{-7}$
Xylenes[c]	$5.66 * 10^{-5}$

Source: USEPA, 1999. The emission factors presented in this section are taken from a draft document published by the USEPA (USEPA, 1999). This document presents emission factors for a number of NPI-listed substances from the processing of 23 separate compounds. The composition of each of these compounds is listed in **Appendix D** of this Manual. If a facility would like to refer to emission factor data for any of the individual compounds, it should consult USEPA (1999).

[a] The sum of 2,4,5-trichlorophenol and 2,4,6-trichlorophenol data.

[b] Taken from Total Method 25A Organic Data. Method 25A organics are those that may be measured with a flame ionisation detector (FID) according to USEPA *Method 25A* (EMTIC, 1997).

[c] The sum of m-xylene, o-xylene and p-xylene data.

[d] The mean of the emission factor data for 23 compounds which are listed in **Appendix D** of this Manual.

[e] Below the lower limit of the measurement technique. In the absence of other data, assume zero emissions.

3.6.2.4 Tyre Curing

Emission factors for tyre curing are shown in Table 12. If a tyre at your facility does not belong to any of the categories shown in Table 12, use the emission factor for original equipment tyres.

Table 12 - Emission Factors for Tyre Curing

Substance	Original Equipment Tyres[c] (kg substance/ kg rubber processed)	High Performance Tyres[d] (kg substance/ kg rubber processed)	Replacement Tyres[e] (kg substance/ kg rubber processed)
Acetonitrile	-[f]	-[f]	-[f]
Acrylonitrile	-[f]	-[f]	-[f]
Benzene	$2.51 * 10^{-7}$	$4.78 * 10^{-7}$	$3.62 * 10^{-7}$
Biphenyl	$6.78 * 10^{-8}$	$5.40 * 10^{-8}$	$5.96 * 10^{-8}$
1,3-Butadiene	-[f]	-[f]	-[f]
Carbon Disulfide	$8.94 * 10^{-6}$	$6.86 * 10^{-6}$	$4.60 * 10^{-6}$
Chloroform	-[f]	$6.50 * 10^{-8}$	-[f]
Cumene	$2.28 * 10^{-7}$	$4.75 * 10^{-7}$	$2.04 * 10^{-7}$
Dibutyl Phthalate	$4.47 * 10^{-7}$	$2.88 * 10^{-7}$	$4.52 * 10^{-7}$
Ethyl benzene	$9.13 * 10^{-6}$	$1.35 *10^{-5}$	$3.70 * 10^{-6}$
n-Hexane	$1.45 * 10^{-6}$	$5.97 * 10^{-6}$	$1.59 * 10^{-6}$
Methyl ethyl ketone	$9.40 * 10^{-7}$	$1.10 * 10^{-6}$	$5.37 * 10^{-7}$
Methyl isobutyl ketone	$1.20 * 10^{-5}$	$1.29 * 10^{-5}$	$1.26 * 10^{-5}$
Phenol	$1.04 * 10^{-7}$	$4.63 * 10^{-7}$	$3.87 * 10^{-7}$
Styrene	$1.55 * 10^{-6}$	$6.82 * 10^{-7}$	$4.71 * 10^{-7}$
1,1,1,2-Tetrachloroethane	$2.06 * 10^{-7}$	-[f]	-[f]
Toluene	$1.04 * 10^{-5}$	$1.65 *10^{-5}$	$6.90 * 10^{-6}$
Total VOCs[a]	$2.67 * 10^{-4}$	$2.10 * 10^{-4}$	$1.94 * 10^{-4}$
1,1,2-Trichloroethane	-[f]	-[f]	-[f]
Vinyl chloride Monomer	-[f]	-[f]	-[f]
Xylenes[b]	$4.50 * 10^{-5}$	$5.10 * 10^{-5}$	$1.56 * 10^{-5}$

Source: USEPA, 1999. The emission factors presented in this section are taken from a draft document published by the USEPA (USEPA, 1999). This document presents emission factors for a number of NPI-listed substances from the processing of 23 separate compounds. The composition of each of these compounds is listed in **Appendix D** of this Manual. If a facility would like to refer to emission factor data for any of the individual compounds, it should consult USEPA (1999).

[a] Taken from Total Method 25A Organic Data. Method 25A organics are those that may be measured with a flame ionisation detector (FID) according to USEPA *Method 25A* (EMTIC, 1997).

[b] The sum of m-xylene, o-xylene and p-xylene data.

[c] The average value for the data from three different original equipment tyres (USEPA, 1999).

[d] The average value for the data from three different high performance tyres (USEPA, 1999).

[e] The average value for the data from three different replacement tyres (USEPA, 1999).

[f] Below the lower limit of the measurement technique. In the absence of other data, assume zero emissions.

3.7 Grinding

3.7.1 General Description

Grinding is used to remove rough edges and other blemishes from the final product or sometimes to shape the product. Ground rubber may be recycled within the process. Particulate matter (PM_{10}) would normally be emitted as a result of grinding.

3.7.2 Emission Factors

Emission factors for grinding operations are presented in Table 13.

Table 13 - Emission Factors for Grinding Operations

Substance	Belt[f] (kg substance /kg rubber removed)	Carcass[g] (kg substance /kg rubber removed)	Retread[h] (kg substance /kg rubber processed)	Sidewall / Whitewall[i] (kg substance /kg rubber removed)
Acetaldehyde	$1.53 * 10^{-5}$	-[j]	-[j]	-[j]
Acetonitrile	-[j]	-[j]	-[j]	-[j]
Acrylonitrile	-[j]	-[j]	-[j]	-[j]
Benzene	-[j]	$4.13 * 10^{-6}$	$9.96 * 10^{-6}$	$1.33 * 10^{-5}$
Biphenyl	-[j]	-[j]	$6.63 * 10^{-9}$	-[j]
1,3-Butadiene	$2.41 * 10^{-5}$	$2.65 * 10^{-5}$	$4.39 * 10^{-8}$	$2.40 * 10^{-5}$
Cadmium & compounds	$1.40 * 10^{-7}$	$8.58 * 10^{-7}$	-[j]	$7.38 * 10^{-7}$
Carbon Disulfide	$3.03 * 10^{-4}$	$2.58 * 10^{-6}$	$6.77 * 10^{-7}$	$1.90 * 10^{-5}$
Chloroethane	-[j]	-[j]	-[j]	-[j]
Chloroform	-[j]	-[j]	-[j]	-[j]
Chlorophenols[a]	-[j]	-[j]	-[j]	-[j]
Chromium (Cr) Compounds[b]	$2.58 * 10^{-6}$	$1.44 * 10^{-6}$	$3.79 * 10^{-8}$	$1.34 * 10^{-5}$
Cobalt & compounds	-[j]	-[j]	$8.74 * 10^{-9}$	-[j]
Cumene	-[j]	-[j]	-[j]	$1.13 * 10^{-6}$
1,2-Dibromoethane	-[j]	-[j]	-[j]	-[j]
Dibutyl Phthalate	$3.31 * 10^{-6}$	$2.24 * 10^{-6}$	$3.87 * 10^{-8}$	$2.54 * 10^{-6}$
1,2-Dichloroethane	-[j]	-[j]	-[j]	-[j]
Ethylbenzene	-[j]	-[j]	-[j]	$5.70 * 10^{-5}$
n-Hexane	$4.18 * 10^{-5}$	$1.60 * 10^{-5}$	-[j]	$1.24 * 10^{-4}$
Lead & compounds	$1.59 * 10^{-6}$	$2.02 * 10^{-6}$	-[j]	$1.55 * 10^{-5}$
Methyl Isobutyl Ketone	-[j]	$1.92 * 10^{-5}$	$8.44 * 10^{-7}$	-[j]
Methylene bis 2,4 aniline	-[j]	-[j]	-[j]	-[j]
Nickel & compounds	$9.13 * 10^{-6}$	$2.03 * 10^{-6}$	$1.78 * 10^{-8}$	$7.51 * 10^{-6}$
PM_{10}[c]	$2.26 * 10^{-4}$	$5.45 * 10^{-1}$	$9.09 * 10^{-7}$	$1.96 * 10^{-4}$
Styrene	-[j]	-[j]	$9.86 * 10^{-8}$	$1.69 * 10^{-5}$
1,1,1,2-Tetrachloroethane	-[j]	-[j]	-[j]	-[j]
Tetrachloroethylene	$1.39 * 10^{-4}$	-[j]	$7.58 * 10^{-9}$	-[j]
Toluene	$1.35 * 10^{-3}$	$9.59 * 10^{-3}$	$3.82 * 10^{-7}$	$1.86 * 10^{-4}$
Total VOCs[d]	$1.78 * 10^{-3}$	$5.21 * 10^{-4}$	$2.43 * 10^{-4}$	$1.59 * 10^{-2}$
1,1,2-Trichloroethane	-[j]	-[j]	-[j]	-[j]
Vinyl Chloride Monomer	-[j]	-[j]	-[j]	-[j]
Xylenes[e]	$1.39 * 10^{-5}$	$2.23 * 10^{-6}$	$9.53 * 10^{-8}$	$5.04 * 10^{-5}$

Source: USEPA, 1999. The emission factors presented in this section are taken from a draft document published by the USEPA (USEPA, 1999). This document presents emission factors for a number of NPI-listed substances from the processing of 23 separate compounds. The composition of each of these compounds is listed in **Appendix D** of this

Manual. If a facility would like to refer to emission factor data for any of the individual compounds, it should consult USEPA (1999).

[a] The sum of 2,4,5-trichlorophenol and 2,4,6-trichlorophenol data.

[b] USEPA data does not distinguish between Chromium (III) and Chromium (VI) compounds.

[c] The emission factor published by the USEPA (USEPA, 1999) is for Total Particulate Matter. In the absence of site-specific particle size distribution data, it can be conservatively assumed that Total Particulate Matter is equal to PM_{10}.

[d] Taken from Total Method 25A Organic Data. Method 25A organics are those that may be measured with a flame ionisation detector (FID) according to USEPA *Method 25A* (EMTIC, 1997).

[e] The sum of m-xylene, o-xylene and p-xylene data.

[f] Belt controlled by cyclone and ESP assuming 99.97% collection efficiency. Use a factor of 1.0 kg emitted per kg of rubber removed for uncontrolled PM_{10} emissions.

[g] Carcass controlled by cyclone assuming 97.8% collection efficiency. Emission factor is after control. Use a factor of 1.0 kg emitted per kg of rubber removed for uncontrolled PM_{10} emissions.

[h] Retread controlled by cyclone and baghouse assuming 97.9% collection efficiency. Emission factor is after control.

[i] Sidewall controlled by cyclone assuming 91.9% collection efficiency. Emission factor is after control. Use a factor of 1.0 kg emitted per kg of rubber removed for uncontrolled PM_{10} emissions.

[j] Below the lower limit of the measurement technique. In the absence of other data, assume zero emissions. Emission factor is after control.

4.0 Glossary of Technical Terms and Abbreviations

ANZSIC	Australian and New Zealand Standard Industrial Classification
CEMS	Continuous Emission Monitoring System
CO	Carbon Monoxide
EEA	European Environment Agency
EET	Emission Estimation Technique
EFR	Emission Factor Rating
NEPM	National Environment Protection Measure
NO_x	Oxides of Nitrogen
NPI	National Pollutant Inventory
PM	Particulate Matter
PM_{10}	Particulate matter with an equivalent aerodynamic diameter of 10 micrometres or less (ie. $\leq 10\mu m$)
SO_2	Sulfur Dioxide
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. Emissions classed as transfers are not required to be reported under the NPI.
TSP	Total Suspended Particulate
USEPA	United States Environmental Protection Agency
VOC	Volatile Organic Compounds

5.0 References

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ANZSIC, 1993, *Australian and New Zealand Standard Industrial Classification*, Australian Bureau of Statistics & NZ Dept of Statistics, Canberra, Australia.

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Perry, R. and D. Green, 1997, *Perry's Chemical Engineers' Handbook* (7th ed.), McGraw-Hill, New York, USA.

USEPA, July 1999, *Emission Factor Documentation for AP-42, Section 4.12, Manufacture of Rubber Products, Draft Section*, United States Environmental Protection Agency, Office of Air Quality Planning and Standards. Research Triangle Park, NC, USA.
http://www.epa.gov/ttn/chief/ap42.html

The following Emission Estimation Technique Manuals referred to in this Manual are available at the NPI Homepage (www.npi.gov.au), and from your local environmental protection agency:

- *Emission Estimation Technique Manual for Combustion in Boilers*;
- *Emission Estimation Technique Manual for Combustion Engines;*
- *Emission Estimation Technique Manual for Fuel and Organic Liquid Storage;*
- *Emission Estimation Technique Manual for Organic Chemical Processing Industries*;
- *Emission Estimation Technique Manual for Petroleum Refining;*
- *Emission Estimation Technique Manual for Sewage and Wastewater Treatment;* and
- *Emission Estimation Technique Manual for Fugitive Emissions.*

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.

The **usage**[a] 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.

[a] 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** of this Manual.

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 14. 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^3/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^3. 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 1.

Equation 1

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

where:

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

Equation 2

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

where:

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

Table 14 - Stack Sample Test Results

Parameter	Symbol	Test 1	Test 2	Test 3
Total sampling time (sec)		7200	7200	7200
Moisture collected (g)	g_{MOIST}	395.6	372.6	341.4
Filter catch (g)	C_f	0.0851	0.0449	0.0625
Average sampling rate (m^3/s)		$1.67 * 10^{-4}$	$1.67 * 10^{-4}$	$1.67 * 10^{-4}$
Standard metered volume (m^3)	$V_{m, STP}$	1.185	1.160	1.163
Volumetric flow rate (m^3/s), dry	Q_d	8.48	8.43	8.45
Concentration of particulate (g/m^3)	C_{PM}	0.0718	0.0387	0.0537

Example 1 - 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 14, and an exhaust gas temperature of 150°C (423 K)). This is shown below:

$$\begin{aligned} C_{PM} &= C_f / V_{m, STP} \\ &= 0.0851 / 1.185 \\ &= 0.072 \text{ g/m}^3 \end{aligned}$$

$$\begin{aligned} E_{PM} &= C_{PM} * Q_d * 3.6 * [273/(273 + T)] \\ &= 0.072 * 8.48 * 3.6 * (273/423 \text{ K}) \\ &= 1.42 \text{ kg/hr} \end{aligned}$$

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

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

where:

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

Total suspended particulates (TSP) are also referred to as total particulate matter (total PM). To determine PM_{10} from total PM emissions, a size analysis may need to be undertaken. The weight PM_{10} fraction can then be multiplied by the total PM emission rate to produce PM_{10} emissions. Alternatively, it can be assumed that 100% of PM emissions are PM_{10}; 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 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.

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

where:

$moist_R$ = moisture content, %
g_{moist} = moisture collected, g
$V_{m,STP}$ = metered volume of sample at STP, m^3
ρ_{STP} = dry density of stack gas sample, kg/m^3 at STP
{if the density is not known a default value of 1.62 kg/m^3 may be used. This assumes a dry gas composition of 50% air, 50% CO_2}

Example 2 - Calculating Moisture Percentage

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

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

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

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_2, NO_x, 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_{vd} = volume of pollutant gas/10^6 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 15 presents example CEMS data output for three periods for a hypothetical furnace. The output includes pollutant concentrations in parts per million dry basis (ppm_{vd}), diluent (O_2 or CO_2) 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 15 - Example CEMS Output for a Hypothetical Furnace Firing Waste Fuel Oil

Time	O_2 content	Concentration				Gas Flow Rate (Q_{st})	Production Rate of Product (A)
	% by volume	SO_2 (ppm_{vd})	NO_x (ppm_{vd})	CO (ppm_{vd})	VOC (ppm_{vd})	m^3/s	tonnes/hour
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

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

Equation 5

$$E_i = (C * MW * Q_{st} * 3600) / [22.4 * ((T + 273)/273) * 10^6]$$

where:

E_i = emissions of pollutant i, kg/hr
C = pollutant concentration, $ppm_{v,d}$
MW = molecular weight of the pollutant, kg/kg-mole
Q_{st} = actual stack gas volumetric flow rate, m^3/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^3/kg-mole
T = temperature of gas sample, °C
10^6 = conversion factor, ppm.kg/kg

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

Example 3 - Using CEMS Data

This example shows how SO_2 emissions can be calculated using Equation 5 based on the CEMS data for Time Period 1 shown in Table 15, and an exhaust gas temperature of 150°C (423 K).

$$\begin{aligned} E_{SO2,1} &= (C * MW * Q_{st} * 3600) / [(22.4 * (T + 273/273) * 10^6] \\ &= (150.9 * 64 * 8.52 * 3600) / [22.4 * (423/273) * 10^6] \\ &= 296\,217\,907 / 34\,707\,692 \\ &= 8.53 \text{ kg/hr} \end{aligned}$$

For Time Period 2, also at 150°C
$E_{SO2,2}$ = 8.11 kg/hr

For Time Period 3, also at 150°C
$E_{SO2,3}$ = 7.23 kg/hr

Say representative operating conditions for the year are:

Period 1 = 1500 hr
Period 2 = 2000 hr
Period 3 = 1800 hr

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

$$\begin{aligned} E_{kpy,SO2} &= E_{SO2,1} * OpHrs + E_{SO2,2} * OpHrs + E_{SO2,3} * OpHrs \\ &= (8.53 * 1500) + (8.11 * 2000) + (7.23 * 1800) \text{ kg} \\ &= 42\,021 \text{ kg/yr} \end{aligned}$$

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

$$\begin{aligned} E_{kpt,SO2} &= E_{SO2} / A \\ &= 8.53 / 290 \\ &= 2.94 * 10^{-2} \text{ kg } SO_2 \text{ emitted per tonne of product produced} \end{aligned}$$

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

A.2 Mass Balance

Mass balances involve examining a process to determine whether emissions can be characterised based on an analysis of operating parameters, material composition, and total material usage. Mass balance involves the quantification of total materials into and out of a process, with the difference between inputs and outputs being accounted for as a release to the environment (to air, water, land) or as part of the facility's waste. Mass balance is particularly useful when the input and output streams can be readily characterised and this is most often the case for small processes and operations.

Mass balance can be applied across individual unit operations (see **Appendix A.2.2**) or across an entire facility (see **Appendix A.2.1**). Mass balance techniques and engineering estimates are best used where there is a system with prescribed inputs, defined internal conditions, and known outputs.

It is essential to recognise that the emission values produced when using mass balance are only as good as the values used in performing the calculations. For example, small errors in data or calculation parameters (eg. pressure, temperature, stream concentration, flow, or control efficiencies) can result in potentially large errors in the final estimates. In addition, when sampling of input and/or output materials is conducted, the failure to use representative samples will also contribute to uncertainty. In some cases, the combined uncertainty is quantifiable and this is useful in determining if the values are suitable for their intended use.

A.2.1 Overall Facility Mass Balance

Mass balances can be used to characterise emissions from a facility providing that sufficient data is available pertaining to the process and relevant input and output streams. Mass balances can be applied to an entire facility (see Example 4). This involves the consideration of material inputs to the facility (purchases) and materials exported from the facility in products and wastes, where the remainder is considered as a 'loss' (or a release to the environment).

The mass balance calculation can be summarised by:

Total mass into process = Total mass out of process

In the context of the NPI, this equation could be written as:

Inputs = Products + Transfers + Emissions

where:

Inputs	=	All incoming material used in the process.
Emissions	=	Releases to air, water, and land (as defined under the NPI). Emissions include both routine and accidental releases as well as spills.
Transfers	=	As defined under the NPI NEPM, transfers include substances discharged to sewer, substances deposited into landfill and substances removed from a facility for destruction, treatment, recycling, reprocessing, recovery, or purification.
Products	=	Products and materials (eg. by-products) exported from the facility.

Applying this to an individual NPI substance (substance 'i'), the equation may be written as:

Input of substance 'i' = amount of substance 'i' in product
+ amounts of substance 'i' in waste
+ amount of substance 'i' transformed or consumed in process
+ emissions of substance 'i'.

The mass balance approach can be used for each NPI-listed substance for which the facility has a responsibility to report. Emissions can then be allocated to air, water, and land.

Example 4 provides an example of the application of mass balance.

Example 4 - Overall Facility Mass Balance

A chemical facility receives 1000 tonnes of an NPI-listed solvent product per annum, that is stored on-site. It is known that this solvent product contains 2 percent water that settles during storage, and is drained to sewer. The solubility of the solvent in water is 100 g/kg (ie. 0.1 weight fraction). It is known that 975 tonnes of solvent per annum is utilised in the process, based on actual addition rate data. During the year, it was recorded that 1 tonne of solvent was lost due to spillage, of which 500 kg was recovered and sent for appropriate disposal, with the rest washed to sewer. What quantity of the NPI-listed substance is required to be reported under the NPI?

Considering the water content of the solvent and the solubility of solvent in water the following data can be derived:

Quantity of water received in the solvent annually:

Water = 1000 tonnes * (2/100) = 20 tonnes of water (containing 100 g/kg solvent)

The solubility of solvent in this water is 100 g/kg:

Therefore, solvent in water = 20 * (0.1) = 2 tonnes of solvent

Excluding the water component, the quantity of solvent received annually is:

Total solvent (excluding water) = 1000 * 0.98 = 980 tonnes

Incorporating the solvent contained within the water component:

Total solvent received at facility (including solvent in water) = 980 + 2 = 982 tonnes solvent

Once the above quantities have been ascertained, the quantity of solvent released to the environment can be determined as follows:

Example 4 - Overall Facility Mass Balance cont'

Solvent to sewer = drainage from solvent tank + uncaptured spillage
= 2000 kg + 500 kg
= 2500 kg

Captured spillage = 500 kg

As no solvent was spilled on unsealed ground, there are no emissions to land. Therefore, the emission of solvent to air is derived as follows:

Air Emission = Total solvent received - sewer release - captured spillage - solvent utilised in the process
= 982 - 2.5 - 0.5 - 975
= 4 tonnes

Therefore, 4 tonnes of solvent is lost to the atmosphere each year from storage and handling operations. For NPI reporting, it would then be necessary to determine the quantity of NPI substances present in the solvent and to determine the quantities of each of these substances emitted to atmosphere. It is important to note that any emission controls must be taken into account when determining your emissions (eg. the solvent released to air may be routed through an incinerator before being released to the atmosphere).

A.2.2 Individual Unit Process Mass Balance

The general mass balance approach described above can also be applied to individual unit processes. This requires that information is available on the inputs (ie. flow rates, concentrations, densities) and outputs of the unit process.

The following general equation can be used (note that scm is an abbreviation for standard cubic metres):

Equation 8

$$E_i = \Sigma Q_i W_{fi} \rho_i - \Sigma Q_o W_{oi} \rho_o$$

where:

E_i = flow rate of component i in unknown stream (kg/hr)
Q_i = volumetric flow rate of inlet stream, i (scm/hr)
Q_o = volumetric flow rate of outlet stream, o (scm/hr)
W_{fi} = weight fraction of component i in inlet stream i
W_{oi} = weight fraction of component i in outlet stream o
ρ_i, ρ_o = density of streams i and o respectively (kg/scm)

Information on process stream input and output concentrations is generally known as this information is required for process control. The loss E_x will be determined through analysis of the process. It should be noted that it is then necessary to identify the environmental medium (or media) to which releases occur.

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_2, 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 9

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

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_2 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_2. Therefore, for every kilogram of sulfur (EW = 32) burned, two kilograms of SO_2 (MW = 64) are emitted. The application of this EET is shown in Example 5.

Example 5 - Using Fuel Analysis Data

This example shows how SO_2 emissions can be calculated from fuel combustion based on fuel analysis results, and the known fuel flow of the engine. $E_{kpy,SO2}$ may be calculated using Equation 9 and given the following:

Fuel flow (Q_f) = 20 900 kg/hr
Weight percent sulfur in fuel = 1.17 %
Operating hours = 1500 hr/yr

$$\begin{aligned} E_{kpy,SO2} &= Q_f * C_i/100 * (MW_p / EW_f) * OpHrs \\ &= (20\,900) * (1.17/100) * (64 / 32) * 1500 \\ &= 733\,590 \text{ kg/yr} \end{aligned}$$

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^3 *of fuel burned'*, then the activity data required would be in terms of 'm^3 *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.

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

Equation 10

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

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 emission factor reviewed and approved by State or Territory environment agencies prior to its use for NPI estimations.

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 rubber product manufacturing 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. In general, site-specific data that is representative of normal operations is more accurate than industry-averaged data, such as the emission factors presented in **Section 3** of this Manual.

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 rubber product manufacturing 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 rubber product manufacturing 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 ± 5 percent in any one step of the operation can significantly skew emission estimations.

B.3 Engineering Calculations

Theoretical and complex equations, or models, can be used for estimating emissions from rubber product manufacturing production processes. EET equations are available for the following types of emissions common to rubber product manufacturing facilities.

Use of emission equations to estimate emissions from rubber product manufacturing 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
Annual emissions of pollutant i	E_{kpyi}	kg/yr
Total emissions of pollutant i per hour	E_i	kg/hr
Uncontrolled emission factor for pollutant i	EF_i	kg of pollutant/unit of weight, volume, distance or duration of activity emitting the pollutant
Overall control efficiency (Emission reduction control factor)	CE_i	% reduction in emissions of pollutant i
Fuel used	Q_f	kg/hr
Concentration of pollutant i	C_i	ppmv, kg/L
Total suspended particulates in exhaust gases or air	TSP	kg/hr
Operating hours	OpHrs	hr/yr
Activity rate	A	t/hr
Molecular weight of pollutant emitted	MW_i	kg/kg-mole
Elemental weight of pollutant in fuel	EW_f	kg/kg-mole
Concentration of PM or gram loading	C_{PM}	g/m^3
Filter Catch	C_f	g
Metered volume of sample at STP	V_{mSTP}	m^3
Hourly emissions of PM	E_{PM}	kg/hr
Stack gas volumetric flowrate	Q_{st}	m^3/s
Temperature	T	^{o}Celsius (^{o}C) or Kelvin (K)
Moisture collected	g_{moist}	g
Moisture content	$moist_R$	%
Dry density of stack gas sample at STP	ρ_{STP}	kg/m^3
Emissions per tonne	$E_{kpt,i}$	kg of pollutant i per tonne of fuel consumed
Volumetric flow rate of stack gas	Q_a	actual (ie. wet) cubic metres per second (m^3/s)
Material entering the process	Q_i	kg/hr
Material leaving the process	Q_o	kg/hr
Weight fraction of component i in inlet stream	W_{fi}	
Weight fraction of component i in outlet stream o	W_{oi}	
Density of stream i	ρ_i	kg/m^3
Density of stream o	ρ_o	kg/m^3

Appendix D - Rubber Compound Constituents

This document presents emission factors for a number of NPI-listed substances from the processing of the 23 compounds listed in Table 16 below (USEPA, 1999). The composition of each of these compounds is provided below.

Table 16 - Index of Rubber Compounds used in Emission Factor Data

Compound 1	Tyre Inner Liner (BrIIR/NR)	**Compound 12**	CRW (Polychloroprene W type)
Compound 2	Tyre Ply Coat (Natural	**Compound 13**	CRG (Polychloroprene G Type)
Compound 3	Rubber/Synthetic Rubber	**Compound 14**	Paracryl OZO (NBR/PVC)
Compound 4	Tyre Belt Coat (Natural Rubber)	**Compound 15**	Paracryl BLT (NBR)
Compound 5	Tyre Base/Sidewall (Natural	**Compound 16**	Hypalon (CSM)
	Rubber/Polybutadiene Rubber)	**Compound 17**	Fluoroelastomer (FKM)
Compound 6	Tyre Apex (Natural Rubber)	**Compound 18**	AEM (Vamac)
Compound 7	Tyre Tread (Styrene Butadiene	**Compound 19**	Hydrogenated Nitrile (HNBR)
	Rubber /Polybutadiene Rubber)	**Compound 20**	Acrylate Rubber (ACM)
Compound 8	Tyre Bladder (Butyl Rubber)	**Compound 21**	Chlorinated Polyethylene (CPE)
Compound 9	EPDM 1 (EPDM Sulfur Cure)	**Compound 22**	Emulsion SBR (SBR 1502)
Compound 10	EPDM 2 (Peroxide Cure)	**Compound 23**	Epichlorohydrin (ECO)
Compound 11	EPDM 3 (Non-Black EPDM Sulfur Cure)		

Compound #1: Tyre Inner Liner (BrIIR/NR)

Constituent Compounds	Weight %
Brominated IIR X-2	45.7
SMR 20 Natural Rubber	8.06
GPF Black	32.3
Stearic Acid	0.538
Paraffinic Medium Process Oil	8.06
Unreactive Phenol Formaldehyde Type Resin (Arofene 8318, SP1068)	2.69
Zinc Oxide	1.61
Sulfur	0.269
MBTS	0.806

Compound #2: Tyre Ply Coat (Natural Rubber/Synthetic Rubber)

Constituent Compounds	Weight %
SMR-GP Natural Rubber	41.0
Duradene 707	17.6
N330	21.4
Sundex 790	11.7
Flectol H	0.879
Santoflex IP	1.35
Sunproof Super Wax	0.703
Zinc Oxide	2.93
Stearic Acid	0.586
Sulfur	1.35
CBS	0.469

Compound #3: Tyre Belt Coat (Natural Rubber)

Constituent Compounds	Weight %
#1RSS Natural Rubber	55.5
HAF Black (N330)	30.5
Aromatic Oil	2.77
N-(1,3 dimethylbutyl)-N-phenyl-P-pnenylene diamine (Santoflex 13)	0.555
Zinc Oxide	5.55
Stearic Acid	1.11
n-tertiary-butyl-2-benzothiazole disulfide (Vanax NS)	0.444
Sulfur	2.22
Cobalt Neodecanate (20.5% cobalt)	1.39

Compound #4: Tyre Base/Sidewall (Natural Rubber/Polybutadiene Rubber) Non-Productive Recipe

Constituent Compounds	Weight %
NR-SMR-5 CV	29.2
Taktene 1220	29.2
N330 Carbon Black	29.2
Zinc Oxide	0.875
Stearic Acid	1.17
Agerite Resin D	1.17
Vulkanox 4020	1.75
Vanwax H Special	1.75
Flexon 580 Oil	5.83

Productive Recipe

Constituent Compounds	Weight %
Non Productive Recipe	97.7
Zinc Oxide	0.855
Rubber Maker Sulfur	0.997
DPG	0.0570
CBS	0.342

Compound #5: Tyre Apex (Natural Rubber)

Constituent Compounds	Weight %
TSR 20 Natural Rubber	49.3
HAF Black (N330)	39.4
Aromatic Oil	3.94
Stearic Acid	0.493
Resorcinol	1.48
Hexamethylenetetramine	1.48
Zinc Oxide	1.48
N-tertiary-butyl-2-benzothiazole disulfide (Vanax NS)	0.740
n-cyclohexythiopthalimide (Santogard PVI)	0.148
Sulfur	1.48

Compound #6: Tyre Tread (Styrene Butadiene Rubber/Polybutadiene Rubber)
Non-Productive Recipe #1:

Constituent Compounds	Weight %
SBR 1712C	49.8
N299 Carbon Black	27.1
Taktene 1220	9.05
Zinc Oxide	0.679
Stearic Acid	1.36
Vulkanox 4020	0.905
Wingstay 100	0.905
Vanox H Special	1.13
Sundex 8125 Oil	9.05

Non-Productive Recipe #2:

Constituent Compounds	Weight %
Non-Productive Recipe #1:	89.8
N299 Carbon Black	8.13
Sundex 8125 Oil	2.03

Productive Recipe:

Constituent Compounds	Weight %
Non-Productive Recipe #2	97.5
Zinc Oxide	0.595
Rubber Maker Sulfur	0.634
TMTD	0.079
CBS	1.19

Compound #7: Tyre Bladder

Constituent Compounds	Weight %
BUTYL268	55.6
N330	30.6
Castor Oil	2.78
SP 1045 Resin	5.56
Zinc Oxide	2.78
Neoprene W	2.78

Compound #8: EPDM 1 (EPDM Sulfur Cure)
Non-Productive Recipe:

Constituent Compounds	Weight %
Vistalon 7000	10.6
Vistalon 3777	18.5
N650 GPF-HS Black	24.3
N762 SRF-LM Black	24.3
Process Oil Type 104B (Sunpar 2280)	21.1
Zinc Oxide	1.06
Stearic Acid	0.211

Productive Recipe:

Constituent Compounds	Weight %
Non-Productive Recipe	97.6
Sulfur	0.103
TMTDS	0.619
ZDBDC	0.619
ZDMDC	0.619
DTDM	0.412

Compound #9: EPDM 2 (Peroxide Cure)
Non-Productive Recipe:

Constituent Compounds	Weight %
Royalene 502	25.6
N 762 Carbon Black	51.2
Sunpar 2280 Oil	21.7
Zinc Oxide	1.28
Stearic Acid	0.256

Productive:

Constituent Compounds	Weight %
Non-Productive Recipe	97.9
DICUP 40C	1.50
SARET 500 (on carrier/2 parts active)	0.641

Compound #10: EPDM 3 (Non-black EPDM Sulfur Cure)

Constituent Compounds	Weight %
Vistalon 5600	9.35
Vistalon 3777	16.4
Hard Clay (Suprex)	33.6
Mistron Vapor Talc	18.7
Atomite Whiting	7.48
Process Oil Type 104B (Sunpar 2280)	11.2
Silane (A-1100)	0.280
Paraffin Wax	0.935
Zinc Oxide	0.935
Stearic Acid	0.187
Sulfur	0.280
Cupsac	0.0935
TMTD	0.561

Compound #11: CRW (Polychloroprene W Type)
Non Productive:

Constituent Compounds	Weight %
Neoprene WRT	65.2
N 550	8.60
N 762	10.2
Agerite Staylite S	1.30
Sunproof Super Wax	1.30
Santoflex IP	0.652
Magnesium Oxide	2.61
Stearic Acid	0.326
PlastHall Doz	9.78

Productive Recipe:

Constituent Compounds	Weight %
Non-Productive Recipe	95.9
Zinc Oxide	3.13
TMTD	0.313
Dispersed Ethylene Thiourea	0.625

Compound #12: CRG (Polychloroprene G Type)

Non-Productive Recipe:

Constituent Compounds	Weight %
Neoprene GN	59.9
SRF	29.9
Sundex 790	5.99
Octamine	1.20
Stearic Acid	0.599
Maglite D	2.40

Productive Recipe:

Constituent Compounds	Weight %
Non-Productive Recipe	96.0
TMTM	0.287
Sulfur	0.575
DOTG	0.287
Zinc Oxide	2.87

Compound #13: Paracryl OZO (NBR/PVC)

Constituent Compounds	Weight %
PARACRIL OZO	41.0
Zinc Oxide	2.05
OCTAMINE	0.821
Hard Clay	32.8
FEF (N-550) Black	8.21
Stearic Acid	0.410
MBTS	1.03
TUEX	0.616
ETHYLTUEX	0.616
DOP	6.16
KP-140	6.16
Spider Sulfur	0.0821

Compound #14: Paracryl BLT (NBR)

Constituent Compounds	Weight %
PARACRIL BLT	43.4
Zinc Oxide	2.17
SRF (N-774) Black	43.4
TP-95	6.51
Paraplex G-25	2.17
AMINOX	0.651
Stearic Acid	0.434
ESEN	0.217
MONEX	0.651
Sulfur	0.326

Compound #15: Hypalon (CSM)

Constituent Compounds	Weight %
Hypalon 40	25.6
CLS 4 PBD	0.768
Carbo wax 4000	0.768
PE 617A	0.768
Mag Lite D	1.28
PE 200	0.768
Whiting (Atomite)	25.6
N650	25.6
TOTM Oil	17.9
MBTS	0.256
Tetrone A	0.384
NBC	0.128
HVA-2	0.128

Compound #16: Fluoroelastomer (FKM)

Constituent Compounds	Weight %
Viton E60C	77.5
N990 Black	15.5
Calcium Hydroxide	4.65
Maglite D	2.33

Compound #17: AEM (Vamac)

Constituent Compounds	Weight %
VAMAC*B-124 Masterbatch	86.9
ARMEEN 18D	0.350
Stearic Acid	0.140
SRF Carbon Black (N-774)	7.01
DIAK #1	2.80
DPG	2.80

Compound #18: Hydrogenated Nitrile (HNBR)
Non-Productive Recipe:

Constituent Compounds	Weight %
HNBR Zetpol 2020	62.1
N650 Black	28.0
Flexone 7P	0.621
Agerite Resin D	0.621
ZMTI	0.621
Kadox 911 C	3.11
Stearic Acid	0.621
Trioctyl trimellitate (TOTM)	4.35

Productive Recipe:

Constituent Compounds	Weight %
Non-productive recipe	97.6
Sulfur	0.303
MBTS	0.909
TMTD	0.909
MTD Monex	0.303

Compound #19: Silicone (VMQ)

Constituent Compounds	Weight %
Silicone Rubber	41.2
Silastic NPC-80 silicone rubber	17.7
5 Micron Min - U - Sil	40.0
Silastic HT - 1 modifier	0.47
Vulcanizing agent: Varox DBPH 50	0.589

Compound #20: Acrylate Rubber (ACM)
Non-Productive Recipe:

Constituent Compounds	Weight %
Hytemp AR71	60.2
Stearic Acid	0.602
N 550	39.2

Productive Recipe:

Constituent Compounds	Weight %
Non-Productive Recipe	98.1
Sodium Stearate	1.33
Potassium Stearate	0.443
Sulfur	0.177

Compound #21: Chlorinated Polyethylene (CPE)

Constituent Compounds	Weight %
CM 0136	43.5
Maglite D	4.35
N 774 Black	13.0
Sterling VH	15.2
DER 331 DLC	3.04
Agerite Resin D	0.0869
TOTM Oil	15.2
Triallyl Isocyanurate Cure 5223 (provided by Gates)	1.26
Trigonox 17/40	4.35

Compound #22: Emulsion SBR (SBR 1502)
Non-Productive Recipe:

Constituent Compounds	Weight %
SBR 1502	54.9
N330 Carbon Black	32.1
Zinc Oxide	5.49
Stearic Acid	1.10
Agerite Resin D (Naugard Q)	1.10
Flexone 7P	0.549
Sunproof Super Wax	0.824
Sundex 790 Oil	3.85

Compound #23: Epichlorohydrin (ECO)

Constituent Compounds	Weight %
Hydrin 2000	62.9
N330 Carbon Black	31.4
Stearic Acid	0.629
Vulkanox MB-2/MG/C	0.629
Calcium Carbonate	3.14
Zisnet F-PT	0.629
Diphenylguanadine	0.314
Santogard PVI	0.314