



National Pollutant Inventory

Emission Estimation Techniques Manual

for

Railway Yard Operations

First published in July 1999

**EMISSION ESTIMATION TECHNIQUES
FOR
RAILWAY YARD OPERATIONS**

TABLE OF CONTENTS

1.0	INTRODUCTION	1
2.0	PROCESSES AND EMISSIONS	2
	2.1 Emissions Sources	2
	2.1.1 Emissions to Air.....	2
	2.1.2 Emissions to Water.....	3
	2.1.3 Emissions to Land	3
	2.2 Likely Emissions.....	3
	2.2.1 Maintenance Operations	3
	2.2.2 Refuelling (Diesel Engines) and Organic Liquid Storage Tanks	4
	2.2.3 General Yard Operations.....	4
3.0	EMISSION ESTIMATION TECHNIQUES.....	5
	3.1 Direct Measurement.....	6
	3.1.1 Sampling Data.....	6
	3.1.2 Continuous Emission Monitoring System (CEMS) Data.....	6
	3.2 Mass Balance.....	6
	3.3 Engineering Calculations.....	7
	3.3.1 Fuel Analysis	7
	3.4 Emission Factors.....	8
4.0	EMISSION ESTIMATION TECHNIQUES: ACCEPTABLE RELIABILITY AND UNCERTAINTY.....	9
	4.1 Direct Measurement.....	9
	4.2 Mass Balance.....	9
	4.3 Engineering Calculations	9
	4.4 Emission Factors.....	10
5.0	INDUSTRY-WIDE EMISSION FACTORS	11
	5.1 Emission Factors for Maintenance Operations.....	11
	5.2 Emissions from Fuel Storage and Refuelling.....	13
	5.3 Emission Factors for Transport Equivalents	13
	5.4 Estimating Emissions from Material Loading Operations.....	16
	5.5 Control Technologies.....	21
6.0	REFERENCES.....	22

RAILWAYS OPERATIONS HANDBOOK

LIST OF TABLES AND EXAMPLES

Table 1 - Possible Sources and Emissions of NPI-Listed Substances	4
2 - General Emission Factors for Railway Yards.....	11
3 - Ancillary Solvent Emission Factors	12
4 - PM₁₀ Emission Factors for Abrasive Blasting.....	12
5 - Typical Densities and Solids Contents of Coatings	13
6 - Emission Factors for Uncontrolled Line Haul Diesel Locomotives in Yard Operations.....	13
7 - Emission Factors for Uncontrolled Diesel Locomotives in Yard Operations.....	14
8 - On-Road Vehicle Emission Factors.....	14
9 - Off-Road Vehicle/Equipment Emission Factors	14
10 - Vehicle Equipment and Engine Data	15
11 - Saturation (S) Factors for Calculating Organic Liquid Loading Emissions	17
Example 1 - Using Fuel Analysis Data.....	7
2 - Calculating Material Loading Emissions	19

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).

Activities covered in this Manual apply to facilities primarily engaged in the operation of rail yards (including servicing, loading and unloading of freight), maintenance operations and general upkeep of locomotives and rolling stock.

EET MANUAL: Railway Yard Operations

HANDBOOK: Railway Equipment Manufacturing & Railway
Yard Operations

ANZSIC CODES : 2823 & 6200 and all codes within the 620 ANZSIC
code group.

This Manual was drafted by the NPI Unit of the Queensland Department of Environment and Heritage 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.

2.0 Processes and Emissions

Railway operations are designed primarily to cater for public transport and commercial transport and carrying. Within Australia the use of railways is quite extensive and the types of locomotives and haulage equipment varies from state to state. Generally the main locomotive types are electric or diesel fuel driven.

Within a rail yard and associated workshops, there are many possible emission sources and sinks. Many operations performed at these sites may trigger a reporting threshold of the National Pollutant Inventory (NPI). These operations include, but are not limited to, surface coating, machining of parts, surface refinishing, cleaning operations, maintenance and general transport operations. As with all operations there may be a need to identify all processes and eliminate any that do not require reporting before an exhaustive list is compiled. You should therefore try to identify all operations that are performed that may trigger reporting requirements, and not just those listed here.

2.1 Emissions Sources

2.1.1 Emissions to Air

Air emissions may be categorised as:

Fugitive Emissions

These are emissions that are not released through a vent or stack. Examples of fugitive emissions include dust from stockpiles, volatilisation of vapour from vats, open vessels, or spills and materials handling. Emissions emanating from ridgeline roof-vents, louvres, and open doors of a building as well as equipment leaks, and leaks from valves and flanges are also examples of fugitive emissions. Emission factor EETs are the usual method for determining losses through fugitive emissions.

Point Source Emissions

These emissions are exhausted into a vent (excluding roof vents) or stack and emitted through a single point source into the atmosphere. Air emission control technologies, such as electrostatic precipitators, fabric filters or baghouses, and wet scrubbers, are commonly installed to reduce the concentration of particulates in process off-gases before stack emission in many process industries (ie. surface coating operations and heat treatment). Where such emission abatement equipment has been installed, and where emission factors from uncontrolled sources have been used in emission estimation, the collection efficiency of the abatement equipment needs to be considered. Guidance on applying collection efficiencies to emission factor equations is provided in later sections.

With regards to emission controls for PM₁₀, in the absence of measured data, or knowledge of the collection efficiency for a particular piece of equipment, an efficiency of 90% should be used in the emission factor equation to calculate actual mass emissions. This default should only be used if there is no other available control efficiency.

2.1.2 Emissions to Water

Emissions of substances to water can be categorised as discharges to:

- Surface waters (eg. lakes, rivers, dams, and estuaries);
- Coastal or marine waters; and
- Stormwater.

Because of the significant environmental hazards posed by emitting toxic substances to water, most facilities emitting NPI-listed substances to waterways are required by their relevant State or Territory environment agency to closely monitor and measure these emissions. This existing sampling data can be used to calculate annual emissions.

If no wastewater monitoring data exists, emissions to process water can be calculated based on a mass balance or using emission factors. The discharge of listed substances to a sewer or tailings dam does not require you to report to the NPI. However leakage and other emissions (including dust) from a tailings storage facility are reportable. (See also Section Three of *The NPI Guide*).

2.1.3 Emissions to Land

Emissions of substances to land on-site include solid wastes, slurries, sediments, spills and leaks, storage and distribution of liquids and may contain listed substances. These emission sources can be broadly categorised as:

- surface impoundments of liquids and slurries; and
- unintentional leaks and spills.

2.2 Likely Emissions

Within a railway workshop or rail yard there are many sources of emissions from operations as listed in Section 2. When identifying these emissions it is necessary to isolate the process and material inputs used in that process. From a stock inventory or a flow diagram, if available, it is possible to isolate the processes where NPI-listed substances are used and where subsequent emissions are possible. The following sections describe some of the most common emissions and points of emission within a rail yard and workshop facility.

2.2.1 Maintenance Operations

Maintenance operations encompass a variety of applications from surface coating of rail cars and locomotives to the degreasing of bearings or other weathered components. Table 1 illustrates some of the inputs and possible emissions that can be expected from maintenance operations.

Table 1 - Possible Sources and Emissions of NPI-Listed Substances

Process	Material Inputs	Possible Emissions
Oil and grease removal.	Degreasers, solvents, other cleaning aids, acids.	Spent solvents, waste acids, VOCs
Car and locomotive cleaning.	Degreasing agents, solvents, acids.	spent solvents, VOCs, waste acids
Rust removal.	Acids, abrasive blasting materials.	waste acids, PM ₁₀ .
Paint preparation.	Solvents (thinners), white spirits, enamel reducers.	spent solvents, VOCs.
Surface coating and finishing.	Enamels, paints, electroplating substances, galvanising metals, acids.	spent solvents, VOCs, NPI listed metals. Waste acids.
Spray booths and cleaning operations.	Solvents, thinners, white spirits.	spent solvents, VOCs.

USEPA - Sector Notebook Project (1997)

The operations listed in Table 1 are not complete and should only serve as a guide to help identify all possible uses of NPI-listed substances and possible emissions. Section 5 describes techniques available for estimating these emissions.

2.2.2 Refuelling (Diesel Engines) and Organic Liquid Storage Tanks

In today's modern facilities, refuelling is generally an easy operation with minimal spills or open-air transfers. Although not 100% failsafe, the possible emissions from refuelling facilities can be considered negligible or none at all.

Storage of fuels is another matter that needs to be addressed and can lead to high fugitive losses or spills and leaks. Within any facility there is the possibility of storage tanks holding fuels and other organic based liquids if required. Possible emissions from these sites are primarily volatile organic compounds (VOCs) such as toluene, xylene and benzene.

For more information on the storage of organic liquids, please refer to the *Fuel and Organic Liquid Storage EET Manual*.

2.2.3 General Yard Operations

In all operations there needs to be movement of vehicles within the facility. In rail yards these vehicles can be cars, utility vehicles or locomotives themselves. Specific emissions sources arise from the combustion of fuel and possibly fugitive dust (particulate matter) emissions. Depending on the nature of cargo on freight services, other sources of emissions can arise from possible leaks and spills, and disposal of NPI-listed substances on-site and storage of these substances on site.

3.0 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 EET, (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 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*** 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.

* Usage is defined as meaning the handling, manufacture, import, processing, coincidental production or other uses of the substances.

3.1 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.

3.1.1 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.

3.1.2 Continuous Emission Monitoring System (CEMS) Data

A continuous emission monitoring system 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.

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 your relevant environmental authority's requirement for NPI emissions estimations.

3.2 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 can also be used for estimating emissions of organic liquids. Please refer to the *Surface Coating EET Manual* for more information regarding mass balance.

3.3 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).

3.3.1 Fuel Analysis

Fuel analysis is an example of an engineering calculation and can be used to predict SO₂, 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, which may be converted into other compounds during the combustion process.

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

Equation 1

$$E_{kpy,i} = Q_f * \text{pollutant concentration in fuel}/100 * (MW_p / EW_f) * \text{OpHrs}$$

where:

$$\begin{aligned} E_{kpy,i} &= \text{annual emissions of pollutant i, kg/yr} \\ Q_f &= \text{fuel use, kg/hr} \\ \text{OpHrs} &= \text{operating hours, hr/yr} \\ MW_p &= \text{molecular weight of pollutant emitted, kg/kg-mole} \\ EW_f &= \text{elemental weight of pollutant in fuel, kg/kg-mole} \\ &= \text{Concentration of pollutant i in fuel expressed as weight percent, \%} \end{aligned}$$

For instance, SO₂ emissions from oil combustion can be calculated based on the concentration of sulfur in the oil. This approach assumes complete conversion of sulfur to SO₂. Therefore, for every kilogram of sulfur (MW = 32) burned, two kilograms of SO₂ (MW = 64) are emitted. The application of this EET is shown in Example 1.

Example 1 - Using Fuel Analysis Data

This example illustrates how SO₂ emissions can be calculated for diesel combustion based on fuel analysis results and the fuel flow information from a diesel engine. The engine is assumed to operate 1500 hours per year. The annual emissions of sulfur may be calculated using Equation 1 and given the following:

$$\begin{aligned} \text{Fuel flow (Q}_f\text{)} &= 2000 \text{ kg/hr} \\ \text{Weight percent sulfur in fuel} &= 1.18 \% \end{aligned}$$

$$\begin{aligned} E_{kpy,SO_2} &= Q_f * \text{pollutant concentration in fuel}/100 * (MW_p / EW_f) * \text{OpHrs} \\ &= (2000) * (1.18/100) * (64/32) * 1500 \\ &= 47.2\text{kg/hr} * 1500 \text{ hr/yr} \\ &= 70\ 800 \text{ kg/yr} \end{aligned}$$

3.4 Emission Factors

An emission factor is a tool that is 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 2

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

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 for 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. As previously mentioned, you are required to have the emission factor reviewed and approved by State or Territory environment agencies prior to its use for NPI estimations.

4.0 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 railway yard operations. The technique chosen is dependent on available data, 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 3.4.1. of this Manual.

4.1 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 railway yard operations. 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 would need to be collected over a period of time. 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.

4.2 Mass Balance

Calculating emissions from railway yard operations using mass balance can be a straightforward approach to emission estimations. Australian railway yard operations may consistently track material usage and waste generation and hence overall accuracy needed for application of this method can be attained. However, inaccuracies associated with individual material tracking or other activities inherent in each material handling stage can often result in large deviations of 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.

4.3 Engineering Calculations

Theoretical and complex equations or *models* can be used for estimating emissions from railway yard operations. EET equations are available for the following types of emissions found at railway yard operations.

Use of emission equations to estimate emissions from railway yard operations 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.

4.4 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 Section 6.0 of this Manual. 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

5.0 Industry-Wide Emission Factors

The following sections present emission factors to assist you in estimating emissions from various processes throughout your facility. These emission factors can be categorised into three specific areas:

- Emission factors for maintenance operations;
- Emission factors for fuel storage and refuelling operations; and
- Emission factors for transport equivalents and locomotives.

Emission estimation can be accomplished by using monitoring data or other techniques/models available.

5.1 Emission Factors for Maintenance Operations.

Table 2 - General Emission Factors for Railway Yards

Process Description	Origin of Emissions	Emission Factor	Emission Factor Rating
From Point Sources			
Discarded raw materials containers	materials remaining in discarded containers, bags, and vessels	1% of vessel contents (10kg/tonne)	E
Equipment cleaning	VOCs, metals, and other listed substances	1 percent of vessel contents/clean (10kg/tonne)	E
Spills	Accidental discharge	Total volume of spillage less recovered volume	C
Waste solvents	Equipment cleaning using solvent	1% of vessel contents per clean (10kg/tonne)	U
Wastewater sludge	Contaminated sludges removed from waste water		
From Fugitive Sources			
Flanges	Solvent with vapour pressure >5mm Hg 37°C	0.00082 kg/hr	C
Valves	Solvent with vapour pressure >5mm Hg 37°C	0.0073 kg/hr	C
Pump seal	Solvent with vapour pressure >5mm Hg 37°C	0.050 kg/hr	C
Sample connection	Solvent with vapour pressure >5mm Hg 37°C	0.015 kg/hr	C

USEPA 560/4-88-004c (1988)

Table 3 - Ancillary Solvent Emission Factors

Solvent Used	Use in industry	Emission Factor ¹ (kg / tonne used) ^a	Emission Factor Rating
Dichloromethane <i>Uncontrolled</i> <i>Controlled</i>	Vapour degreasing Cold Cleaners	930	E
		890	E
Tetrachloroethylene <i>Uncontrolled</i> <i>Controlled</i>	Vapour degreasing Cold Cleaners	890	E
		850	E
Trichloroethylene <i>Uncontrolled</i> <i>Controlled</i>	Vapour degreasing Cold Cleaners	910	E
		870	E

USEPA EPA- EPA 560/4-90-012. (1990)

^a Factor units are kg of substance emitted per tonne of substance used.

Table 4 - PM₁₀ Emission Factors for Abrasive Blasting

Source	Particle Size	Emission Factor kg/tonne	Factor Rating
Sand blasting of mild steel panels - uncontrolled	PM ₁₀		
	8 km/hr	27	E
	16 km/hr	55	E
	24 km/hr	91	E
Abrasive blasting of unspecified metal parts, controlled with fabric filter	PM ₁₀	0.69	E

USEPA AP-42 Section 13.2.6-1 (1997)

Factor units are kg of PM₁₀ emitted/tonne of material treated.

Table 5 below lists typical values for densities and solids content of various coating treatments. These values can be used where you are unsure of the density and solids content of your surface coating application.

Please refer to the *Surface Coating EET Manual* for guidance on estimating emissions from surface coating activities.

Table 5 - Typical Densities and Solids Contents of Coatings

Coating Information ^a	Coating Density (kg/L)	VOC Weight (%)
Enamel , air dry	0.91	39.6
Enamel, baking	1.09	42.8
Acrylic enamel	1.07	30.3
Alkyd enamel	0.96	47.2
Primer surfacer	1.13	49.0
Primer, epoxy	1.26	57.2
Varnish, baking	0.79	35.3
Lacquer, spraying	0.95	26.1
Vinyl, roller coat	0.92	12.0
Polyurethane	1.10	31.7
Stain	0.88	21.6
Sealer	0.84	11.7
Magnet wire enamel	0.94	25.0
Paper coating	0.92	22.0
Fabric coating	0.92	22.0
Typical Solvents ^b	0.88	-

USEPA AP-42 Section 4.2.2.1-1 (1995)

^a These values should be used when no data for coating densities are available.

^b This data should be used if the solvent densities are unknown.

5.2 Emissions from Fuel Storage and Refuelling

Railway workshops and refuelling depots will store large quantities of diesel fuel, and possible other types of fuel or organic liquids in on-site storage tanks and freight tanks. Evaporative hydrocarbon emissions from the tanks occur during fuel loading and unloading as well as during daily expansion and contraction of the tank contents due to ambient temperature changes. Emissions arising from fuel storage facilities are detailed in the *Fuel and Organic Liquid Storage EET Manual*, which is available from your local Environment Protection Agency.

5.3 Emission Factors for Transport Equivalents

The following table gives emission factors from diesel-powered locomotives in terms of the operation of the locomotive - either line haul or switch locomotives.

Table 6 - Emission Factors for Uncontrolled Line Haul Diesel Locomotives in Yard Operations

Operation ^d	VOC ^c kg/kL	CO kg/kL	NO _x kg/kL	SO ₂ ^b kg/kL	PM ₁₀ kg/Kl
Line Haul ^a	2.53	7.51	59.17	3.11	0.77

USEPA (1998) – Procedures for Emission Inventory Preparation – Volume IV : Mobile Sources

^a Line haul locomotives over the line haul duty cycle

^c Total VOC is considered to be all hydrocarbon emissions.

^b Sulfur content is assumed to be 0.18%. This sulfur content is accurate for Australian fuels.

^d Emission Factor in kilograms for every kilo litre of diesel.

Table 7 - Emission Factors for Uncontrolled Diesel Locomotives in Yard Operations

Operation ^d	VOC ^a kg/kL	CO kg/kL	NO _x kg/kL	SO ₂ ^b kg/kL	PM ₁₀ Kg/kL
Locomotives other than in Table 6	6.08	10.74	50.57	3.11	0.91

USEPA (1998) – Procedures for Emission Inventory Preparation – Volume IV : Mobile Sources

^a Total VOC is considered to be total hydrocarbon emissions

^b Sulfur content is assumed to be 0.18%. This sulfur content is accurate for Australian fuels.

^d Emission Factor in kilograms for every kilo litre of diesel.

Table 8 - On-Road Vehicle Emission Factors^A

Vehicle Type	Engine Type	Emission Factors (kilograms per BHP-hour)				
		VOCs	NO _x	CO	PM ₁₀	SO ₂
Sedan, Ute, Van, and Light Commercial	Petrol	4.6 * 10 ⁻³	1.57 * 10 ⁻³	8.98 * 10 ⁻³	0.03 * 10 ⁻³	0.21 * 10 ⁻³
Light Duty Truck, Tray-Top, Tractors, Non –Articulated Trucks	Petrol	4.5 * 10 ⁻³	1.87 * 10 ⁻³	13.05 * 10 ⁻³	0.04 * 10 ⁻³	0.26 * 10 ⁻³
	Diesel	0.96 * 10 ⁻³	2.02 * 10 ⁻³	2.60 * 10 ⁻³	0.43 * 10 ⁻³	0.25 * 10 ⁻³

^A based on the average use per year in hours.

Table 9 - Off-Road Vehicle/Equipment Emission Factors

Engine Type	Coolant Type	BHP Range	Emission Factors (kilograms per BHP-hour)				
			VOCs	NO _x	CO	PM ₁₀	SO ₂
Petrol	Air	1 to 24	0.0109	0.002	0.360	0.0002	0.00021
		25 to 50	0.0084	0.003	0.400	0.0	0.00021
	Water	25 to 50	0.0043	0.004	0.240	0.0	0.00021
		≥ 51	0.0043	0.004	0.240	0.0	0.00026
Diesel	Water	1 to 50	0.0011	0.011	0.004	0.0007	0.00029
		≥ 51	0.0013	0.011	0.004	0.0005	0.00025
OEM Optimised CNG ^a	Water	1 to 24	0.0055	0.004	0.180	0.0	0.0
		25 to 50	0.0021	0.006	0.120	0.0	0.0
		≥ 51	0.0011	0.004	0.002	0.0	0.0
Existing CNG or LPG	Air	1 to 24	0.0055	0.004	0.180	0.0	0.0
		25 to 50	0.0044	0.006	0.200	0.0	0.0
LPG	Water	1 to 24	0.0055	0.004	0.180	0.0	0.0
		25 to 50	0.0022	0.006	0.120	0.0	0.0
		≥ 51	0.0022	0.006	0.120	0.0	0.0

^a OEM Optimised CNG refers to Original Equipment Manufacturer Optimised Compressed Natural Gas

Table 10 - Vehicle Equipment and Engine Data¹

Equipment Type	Fuel Type	Coolant	BHP	Fuel Usage² (litres/ BHP-hr)
Bus	Diesel	Water	180	0.360
	Petrol	Water	130	0.466
	CNG ⁴	Water	130	ND ⁵
Car	Petrol	Water	130	0.466
	LPG	Water	130	ND
	CNG	Water	130	ND
Cart	Petrol	Air	12	0.613
	LPG	Air	12	ND
	CNG	Air	12	ND
Forklift	Diesel	Water	52	0.242
	Petrol	Water	50	0.337
	LPG	Water	52	ND
	CNG	Water	52	ND
Ground Power Unit	Diesel	Water	145	0.231
	Petrol	Water	150	0.337
	CNG	Water	150	ND
Lift	Petrol	Water	100	0.337
	LPG	Water	100	ND
	CNG	Water	100	ND
Maintenance Truck	Diesel	Water	130	0.231
	Petrol	Water	130	0.337
	LPG	Water	130	ND
	CNG	Water	130	ND
Other ³	Diesel	Water	50	0.242
	Petrol	Water	50	0.337
	LPG	Water	50	ND
	CNG	Water	50	ND
Utility	Petrol	Water	130	0.466
	LPG	Water	130	ND
	CNG	Water	130	ND
Service Vehicle	Diesel	Water	170	0.231
	Petrol	Water	180	0.337
	LPG	Water	180	ND
	CNG	Water	180	ND
Tractor	Petrol	Water	100	0.337
	CNG	Water	100	ND
Water Tanker	Petrol	Water	130	0.337
	CNG	Water	130	ND

¹ Average use per year in hours.² Fuel consumption in litres per BHP-hour.³ Includes compressors, scrubbers, sweepers, and specialised units.⁴ CNG refers to 'compressed natural gas'.⁵ ND means 'no data'.

The following equation uses the above parameters in Table 9 and 10 to calculate emissions from the equipment listed.

Equation 3

$$E_{kpy,i} = \text{BHP} * (\text{LF}/100) * \text{OpHrs} * \text{EF}_i$$

where:

$E_{kpy,i}$	=	emissions per year of pollutant i, in kg, produced by support equipment type
BHP	=	average rated brake horsepower (BHP) of the engine for equipment type
LF	=	load factor utilised in operations for equipment type (% operation)
OpHrs	=	annual operational hours of use for equipment type, hr/yr
EF_i	=	emission factor for pollutant i, in kg per BHP-hr, which is specific to a given engine size (and engine vintage for diesel engines) and fuel type
i	=	pollutant type

5.4 Estimating Emissions from Material Loading Operations

Emissions of VOCs resulting from the addition of organic solvents to plating and storage tanks may be calculated using a loading loss equation. The equation, shown below as Equation 4 is related to tank loading but can be applied to any tank or vessel loading or unloading. This equation can only be used for organic materials and is not suitable for use in estimating emissions from adding mineral acids to plating baths.

Equation 4

$$E_{kpy,VOC} = 0.1203 * (S * P * M * V) / T$$

where:

$E_{kpy,VOC}$	=	total VOC loading emissions, kg/yr
S	=	saturation factor (dimensionless); see Table 11.
P	=	vapour pressure of material loaded at temperature T, kPa
M	=	vapour molecular weight, kg/kg-mole
V	=	volume of material loaded, 1 000 litres/yr
T	=	temperature, K
0.1203	=	constant, {(kg-mole * K) / (kPa * 1000L)}

Calculation of VOC emissions using Equation 4 is based on the following assumptions:

- the vapours displaced from the process vessel are identical to the vapours from the materials being loaded;
- the volume of the vapour being displaced is equal to the volume of material being loaded into the vessel;
- the vapour within the headspace of the vessel is saturated at room temperature and remains at room temperature during loading; and
- all solvent additions are coincident at a constant temperature (in reality, solvents are generally added in stages).

Table 11 - Saturation (S) Factors for Calculating Organic Liquid Loading Emissions

Transport Carrier	Mode of Operation	S Factor
Road and Rail Tankers	Submerged loading of a clean cargo tank	0.50
	Submerged loading: normal service	0.60
	Submerged loading: vapour balance service	1.00
	Splash loading of a clean cargo tanker	1.45
	Splash loading : normal service	1.45
	Splash loading: vapour balance service	1.0
Marine Vessels	Submerged loading: ships	0.2
	Submerged loading: barges	0.5

Source: USEPA AP-42 Section 5.2 Transportation & Marketing of Petroleum, 1995.

If multiple NPI-listed solvents are used in a cleaning or degreasing formulation, the vapour pressure (P) will need to be calculated using Equation 5.

Equation 5

$$P = \sum P_i$$

where:

$$P = \text{vapour pressure of material loaded, kPa}$$

$$P_i = \text{partial pressure of VOC species i, kPa}$$

P_i may be calculated using Raoult's Law (for ideal solutions) or Henry's Law constants (when gases are dissolved at low concentrations in water). Raoult's Law is given in Equation 6.

Equation 6

$$P_i = m_i * VP_i$$

where:

$$P_i = \text{partial vapour pressure of VOC species i, kPa}$$

$$m_i = \text{liquid mole fraction of VOC species i, mole/mole}$$

$$VP_i = \text{true vapour pressure of VOC species i, kPa}$$

P_i may be calculated using Henry's Law constants and Equation 7.

Equation 7

$$P_i = m_i * H_i$$

where:

$$P_i = \text{partial vapour pressure of VOC species i, kPa}$$

$$m_i = \text{liquid mole fraction of VOC species i, mole/mole}$$

$$H_i = \text{Henry's Law constant for VOC species i, kPa}$$

The liquid mole fraction of VOC species i (m_i) may be calculated if the liquid weight fractions of all species are known using Equation 8.

Equation 8

$$m_i = (z_i / MW_i) / \Sigma (z_i / MW_i)$$

where:

$$\begin{aligned} m_i &= \text{liquid mole fraction of VOC species } i, \text{ mole/mole} \\ z_i &= \text{liquid mass fraction of VOC species } i, \text{ kg/kg} \\ MW_i &= \text{molecular weight of VOC species } i, \text{ kg/kg-mole} \end{aligned}$$

The vapour molecular weight (M) will also need to be calculated if multiple solvents are used and is shown by Equation 9.

Equation 9

$$M = \Sigma (y_i * MW_i)$$

where:

$$\begin{aligned} M &= \text{vapour molecular weight, kg/kg-mole} \\ y_i &= \text{vapour mole fraction of VOC species } i, \text{ mole/mole} \\ MW_i &= \text{molecular weight of VOC species } i, \text{ kg/kg-mole} \end{aligned}$$

The vapour mole fraction is calculated using Equation 10.

Equation 10

$$y_i = P_i / P$$

$$\begin{aligned} y_i &= \text{vapour mole fraction of VOC species } i, \text{ mole/mole} \\ P_i &= \text{partial pressure of VOC species } i \text{ (calculated using} \\ &\quad \text{Equation 6 or Equation 7, kPa)} \\ P &= \text{vapour pressure of the material loaded (calculated using} \\ &\quad \text{Equation 5)} \end{aligned}$$

Speciated VOC emissions are calculated using Equation 11.

Equation 11

$$E_{kpy,i} = E_{kpy,VOC} * x_i$$

where:

$$\begin{aligned} E_{kpy,i} &= \text{loading emissions of VOC species } i, \text{ kg/yr} \\ E_{kpy,VOC} &= \text{total VOC loading emissions (calculated using} \\ &\quad \text{Equation 4), kg/yr} \\ x_i &= \text{vapour mass fraction of VOC species } i, \text{ kg/kg} \end{aligned}$$

The vapour mass fraction of VOC species i (x_i) is calculated by Equation 12.

Equation 12

$$x_i = y_i * MW_i / M$$

where:

- x_i = vapour mass fraction of VOC species i , kg/kg
- y_i = vapour mole fraction of VOC species i (calculated using Equation 10), mole/mole
- MW_i = molecular weight of VOC species i , kg/kg-mole
- M = vapour molecular weight (from Equation 9), kg/kg-mole

Example 2 illustrates the use of Equation 4 through to Equation 12. Emissions are calculated by following Steps 1 through 8.

Example 2 - Calculating Material Loading Emissions

A rail yard cleans a degreasing tank in its workshop with a standard cleaning solvent. The following data is available:

- the yearly consumption of the solvent (Q) is 6 000 litres;
- the cleaning solvent is a 50/50 mixture (by weight) of toluene and n -heptane;
- the solvent mixture is splash loaded into the vessel ($S = 1.45$ from Table 11.); and
- the temperature of the solvent is 298 K (25°C).

The following Steps 1 through 8 below calculate emissions.

Step 1: Apply Equation 8 - Calculation of Liquid Mole Fraction (m_i)

Component i	Liquid Mass Fraction, z_i (kg of i /kg of liquid)	Molecular Weight, M_i (kg of i /kg-mole of i)	Liquid Mole Fraction, m_i (mole of i /mole of liquid)
Toluene	0.50	92	$(z_i / MW_i) / \sum (z_i / MW_i)$ $(0.5/92) / [(0.5/92) + (0.5/100)]$ $= 0.52$
n -Heptane	0.50	100	$(z_i / MW_i) / \sum (z_i / MW_i)$ $(0.5/100) / [(0.5/92) + (0.5/100)]$ $= 0.48$

Step 2: Apply Equation 6 - Calculation of Partial Vapour Pressure (P_i)

Component i	Liquid Mole Fraction, m _i (mole of i/mole of liquid)	True Vapour Pressure, VP _i (kPa)	Partial Vapour Pressure, P _i (kPa)
Toluene	0.52	4.0	m _i * VP _i = 0.52 * 4.0 = 2.08
n-Heptane	0.48	6.2	m _i * VP _i = 0.48 * 6.2 = 2.98

Step 3: Apply Equation 5 - Calculation of Vapour Pressure (P)

$$\begin{aligned}
 P &= \Sigma P_i \\
 &= 2.08 + 2.98 \\
 &= 5.06 \text{ kPa}
 \end{aligned}$$

Step 4: Apply Equation 10 - Calculation of Vapour Mole Fraction (y_i)

Component i	Partial Vapour Pressure, P _i (kPa)	Total Vapour Pressure, P (kPa)	Vapour Mole Fraction, y _i (mole of i/mole of vapour)
Toluene	2.08	5.06	P _i / P = 2.08 / 5.06 = 0.41
n-Heptane	2.98	5.06	P _i / P = 2.98 / 5.06 = 0.59

Step 5: Apply Equation 9 - Calculation of Vapour Molecular Weight (M)

$$\begin{aligned}
 M &= \Sigma (y_i * MW_i) \\
 &= (0.41 * 92) + (0.59 * 100) \\
 &= 97 \text{ kg/kg-mole}
 \end{aligned}$$

Step 6: Apply Equation 12 - Calculation of Vapour Mass Fraction (x_i)

Component i	Vapour Mole Fraction, y _i (mole of i/mole of vapour)	Molecular Weight, M _i (kg of i/kg-mole of i)	Vapour Molecular Weight, M (kg of vapour /kg mole of vapour)	Vapour Mass Fraction, x _i (kg of i/kg of vapour)
Toluene	0.41	92	97	y _i * MW _i / M = 0.41 * 92/97 = 0.39
n-Heptane	0.59	100	97	y _i * MW _i / M = 0.59 * 100/97 = 0.61

Step 7: Apply Equation 4 - Calculate Total VOC Emissions ($E_{kpy,VOC}$)

$$\begin{aligned} E_{kpy,VOC} &= 0.1203 * (S * P * M * V) / T \\ &= 0.1203 * (1.45 * 5.06 * 97 * 6) / 298 \\ &= 1.724 \text{ kg/yr} \end{aligned}$$

Step 8: Apply Equation 11 - Calculate Speciated VOC Emissions ($E_{kpv,i}$)

Component i	VOC Emissions, $E_{kpv,VOC}$ (kg VOCs)	Vapour Mass Fraction, x_i (kg of i/kg of VOCs)	Speciated VOC Emissions, $E_{kpv,i}$ (kg i)
Toluene	1.724	0.39	$E_{kpy,VOC} * x_i = 1.724 * 0.39$ $= 0.672$
<i>n</i> -Heptane	1.724	0.61	$E_{kpy,VOC} * x_i = 1.724 * 0.61$ $= 1.052$

5.5 Control Technologies

Abatement equipment and control technologies, such as baghouses, cyclones and afterburners are often used to reduce emissions. If you have installed these or other abatement equipment at your facility, or if you have implemented work practices at your facility that reduce emissions, you should multiply the control efficiency of the technology or the practice adopted, by the appropriate emission factors.

6.0 References

Australian Academy of Technological Sciences and Engineering. 1997. *Inquiry into Urban Air Pollution in Australia, Report of Task Group 4: Transport Vehicles*. Parkville, Victoria.

Eastern Research Group. July 1997. *Introduction to Stationary Point Source Emission Inventory Development Volume II: Chapter 1*. Morrisville, NC, USA.

Economopoulos A. P. 1993. *Assessment of Sources of Air, Water, and Land Pollution. A Guide to Rapid Source Inventory Techniques and their Use in Formulating Environmental Control Strategies. Part One: Rapid Inventory Techniques in Environmental Pollution*. World Health Organisation, Geneva, Switzerland.

Energy and Environmental Analysis Inc. December 1988. *Feasibility of Controlling Emissions From Off-Road, Heavy-Duty Construction Equipment*. Prepared for the Air Resources Board, Sacramento. Arlington, VA, USA.

Energy and Environmental Analysis Inc. January 1992. *Regulatory Strategies for Off-Highway Equipment*. Prepared for the Air Resources Board, Sacramento. Arlington, VA, USA.

USEPA. revised 1998. *Procedures for Emission Inventory Preparation – Volume 1V: Mobile Source, Chapter 6 - Locomotives*. United States Environmental Protection Agency. Washington, DC, USA.

USEPA. December 1997. *United States Environmental Protection Agency - Office of Mobile Sources : EPA420-F-97-051 Emission Factors for Locomotives*. United States Environmental Protection Agency, Office of Mobile Sources. Washington, DC, USA.

USEPA. September 1997. *EPA Office of Compliance Sector Notebook Project. Profile of the Ground Transportation Industry - Trucking, Railroad and Pipeline*. United States Environmental Protection Agency, Office of Enforcement and Compliance Assurance. Washington, DC, USA.

USEPA. October 1997. *Compilation of Air Pollutant Emission Factors, Volume 1: Stationary Point and Area Sources, fifth edition, AP-42. Section 13.2.6 Miscellaneous Sources - Abrasive Blasting*. 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>

USEPA. January 1995a. *Compilation of Air Pollutant Emission Factors, Volume 1: Stationary Point and Area Sources, fifth edition, AP-42. Section 5.2 Transportation and Marketing Of Petroleum Liquids*. United States Environmental Protection Agency, Office of Air Quality Planning and Standards. Research Triangle Park, NC, USA.

USEPA. July 1995. *Compilation of Air Pollutant Emission Factors, Volume 1: Stationary Point and Area Sources, fifth edition, AP-42. Section 4.2 Surface Coating*. United States Environmental Protection Agency, Office of Air Quality Planning and Standards. Research Triangle Park, NC, USA.

USEPA. January 1990. *Section 313 Reporting Issue Paper : Clarification and Guidance for the Metal Fabrication Industry, Office of Toxic Substances, EPA 560/4-90-012*. Washington, DC, USA.

USEPA. March 1988. *Title III Section 313 Release Reporting Guidance, Estimating Chemical Releases from Formulation of Aqueous Solutions, Office of Pesticides and Toxic Substances, EPA 560/4-88-004f*. Washington, DC, USA.

VICEPA. 1996. *Technical Report on the Air Emissions Trials for The National Pollutant Inventory Volume 2*. Commonwealth of Australia, Canberra, Australian Capital Territory.

The following Emission Estimation Technique Manuals are available at the NPI Homepage (<http://www.npi.gov.au>) and from your local environmental protection agency (see the front of the NPI Guide for details):

- Emission Estimation Technique Manual for Ferrous Foundries;
- Emission Estimation Technique Manual for Non-ferrous Foundries;
- Emission Estimation Technique Manual for Combustion in Boilers;
- Emission Estimation Technique Manual for Combustion Engines;
- Emission Estimation Technique Manual for Fuel & Organic Liquid Storage;
- Emission Estimation Technique Manual for Surface Coating; and
- Emission Estimation Technique Manual for Electroplating & Anodising.