National Pollutant Inventory

Emission Estimation Technique Manual

for

Iron and Steel Production

Environment Australia

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EMISSION ESTIMATION TECHNIQUES
FOR
IRON & STEEL PRODUCTION

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EMISSION ESTIMATION TECHNIQUES
FOR
IRON & STEEL PRODUCTION

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1.0 Introduction

The purpose of all Emission Estimation Technique (EET) Manuals in this series is to assist Australian manufacturing, industrial, and service facilities to report emissions of listed substances to the National Pollutant Inventory (NPI). This Manual describes the procedures and recommended approaches for estimating emissions from facilities engaged in basic iron and steel production.

This Manual does not cover the manufacture of steel products from raw steel. In addition, this Manual does not cover alternative iron making technologies, such as direct ore reduction.

EET MANUAL : Iron & Steel Production

HANDBOOK : Basic Iron & Steel Manufacturing

ANZSIC CODE : 2711

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This Manual has been developed through a process of national consultation involving State and Territory environmental authorities. Particular thanks are due to BHP Steel for their comments, advice and information.

2.0 Process Description

Iron & steel production consists of the following main activities:

A: Iron Production

- Cokemaking;
- Sinter or pellet making;
- Blast furnace iron production; and
- Casting and storage.

B: Steel Production

- Raw material handling;
- Electric arc or basic oxygen furnace steel making;
- Refining and alloying; and
- Continuous casting and storage

Figure 1 identifies potential sources of emissions to the environment as a result of iron & steel production.

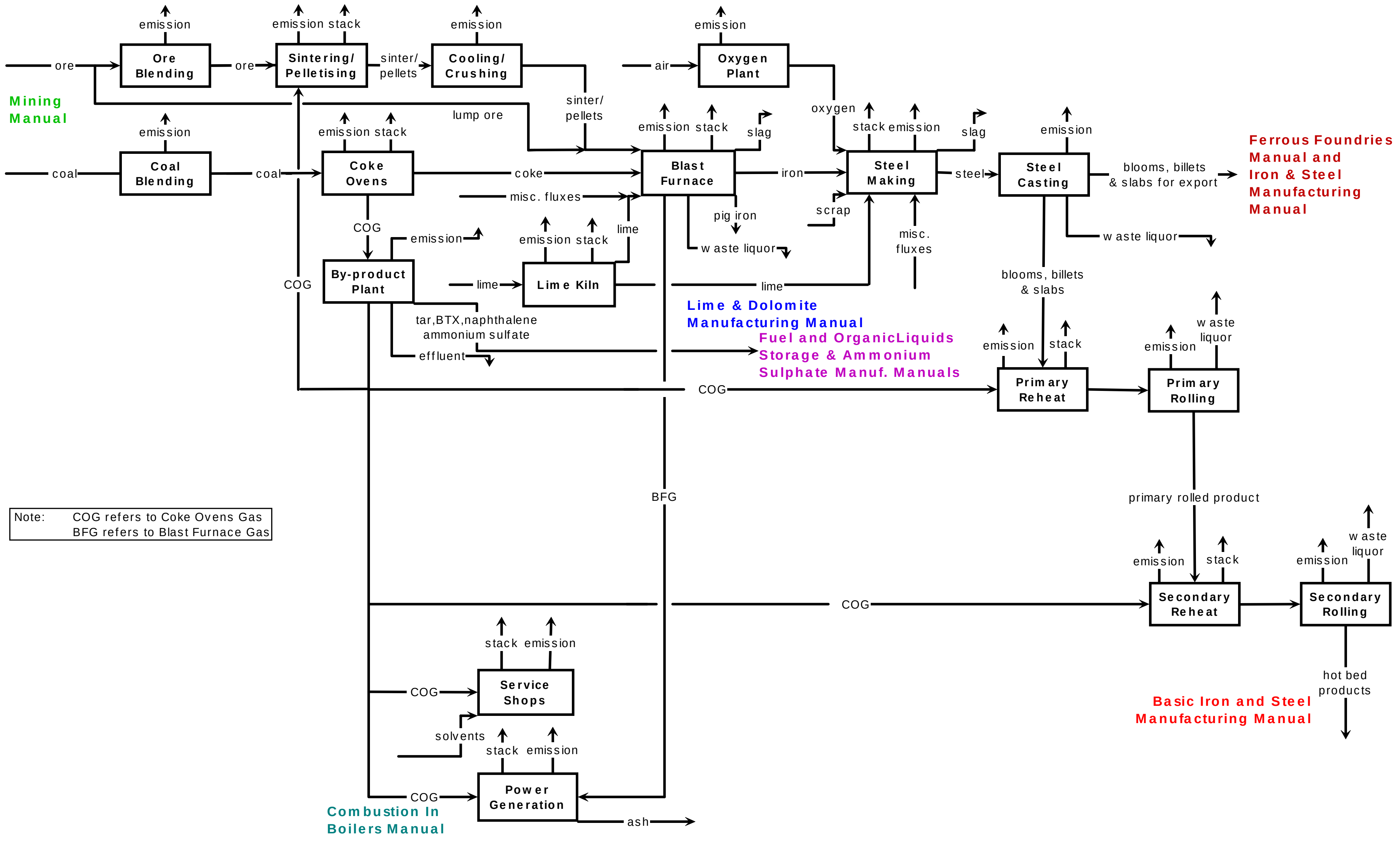

Figure 1 - Potential Emission Sources from Iron & Steel Making Operations

3.0 Emission Sources

3.1 Emissions to Air

Air emissions may be categorised as either fugitive emissions or point source emissions.

Fugitive emissions are those not released through a flare, vent or stack. Examples of fugitive emissions include volatilisation and vapour emission from open vessels, equipment leaks from valves and flanges, losses from oven and furnace doors and releases from materials handling (eg. stockpiling).

Point source emissions include flares, vents and stacks.

3.2 Emissions to Water

Emissions of substances to water include discharges to:

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

In most cases, the most accurate method of determining emissions to the environment via wastewater is to use direct measurement techniques. However, you may use other EETs for the purposes of reporting to the NPI.

3.3 Emissions to Land

Emissions of substances to land include solid wastes, slurries, sediments, spills and leaks from processing activities and the storage and distribution of raw materials and products. There may also be emissions from the use of chemicals to control various elements of the environment (eg. dust) where these emissions contain listed substances. The discharge of listed substances **to** a sewer, landfill or tailings dam does not require you to report to the NPI, but emissions **from** these or other sources are reportable (See Section Three of *The NPI Guide*).

It is the responsibility of operators to analyse their own processes and determine which (if any) thresholds of substances on the NPI reporting list are exceeded.

4.0 Do I Need to Report?

The NPI Guide, which accompanies this Manual, provides guidance to help you determine:

- whether you are required to report under the NPI; and
- which substances are to be reported.

Section Two of *The NPI Guide* at the front of this Handbook, details the necessary steps taken to assess if your facility triggers any of the thresholds for the substances listed under the NPI. A series of worksheets is provided in *The NPI Guide* to assist with this.

Sections 4.1 to 4.4 below provide additional guidance on the NPI substances for which iron and steel production facilities will be required to report. It should be noted that this information is provided for guidance only. It is the responsibility of individual facilities to determine whether or not they are required to report and which substances are required to be reported. Please check the current edition of the NPI guide for reporting thresholds.

4.1 Category 2a and 2b Substances

According to the 1998 edition of the NPI Guide, the reporting threshold for Category 2a substances would be exceeded if 400 or more tonnes of fuel or waste is burned in a reporting period. Or, 1 tonne or more of fuel or waste is burned in any hour of a period. To trigger the reporting thresholds for Category 2b substances, 2000 tonnes or more of fuel must be burned, 60 000 megawatt hours or more of energy must be consumed, or the facility must have a maximum power consumption rated at 20 megawatts or more.

In the iron and steel industry, reporting of Category 2a and 2b substances is likely to be triggered by coking and iron making, as well as combustion processes. From our discussions with BHP Steel, we expect that all iron and steel production facilities will be required to report on emissions of Category 2a and 2b substances. Table 1 lists these substances.

Table 1 - Category 2a and 2b Substances from Iron and Steel Production Likely to Trigger NPI Reporting Thresholds

Substances	
Arsenic & compounds	Lead & compounds
Beryllium & compounds	Magnesium oxide fume
Cadmium & compounds	Mercury & compounds
Carbon monoxide (CO);	Nickel & compounds
Chromium (III) compounds	Oxides of nitrogen (NO_x)
Chromium (VI) compounds	PM_{10}
Copper & compounds	Polychlorinated dioxins and furans
Fluoride compounds	Polycyclic Aromatic Hydrocarbons (PAHs)
Hydrochloric acid	Sulfur dioxide (SO_2)
	Total Volatile Organic Compounds (VOCs)

Source: NSW Environment Protection Authority

4.2 Category 1 Substances

According to the 1998 edition of the NPI Guide, the reporting threshold for Category 1 substances is exceeded if the activities of a facility involve the use (eg. handling) of 10 tonnes or more of the substance in a reporting period. It is expected that iron and steel production facilities will trigger reporting thresholds for the following Category 1 Substances listed in Table 2 (note that the Category 2a and 2b Substances listed in Table 1 which are also Category 1 substances are not included in the Table 2):

Table 2 - Category 1 Substances from Iron and Steel Production Likely to Trigger NPI Reporting Thresholds

Substances	
Ammonia	Manganese & compounds
Antimony & compounds	Methyl ethyl ketone
Benzene	Phenol
Biphenyl(1,1-biphenyl)	Phosphoric acid
Boron & compounds	Selenium & compounds
Cobalt & compounds	Sulfuric acid
Cumene	Toluene
Cyanide (inorganic compounds)	Xylenes
Ethylene glycol	Zinc & compounds
Hydrogen sulfide	

Source: NSW Environment Protection Authority

The total amount of each Category 1 substance ‘used’ must be estimated in order to determine whether the threshold is exceeded. For all NPI substances, consideration of whether or not reporting is triggered depends upon the concentration of each substance in the feedstock materials.

Example 1 - Do You Trip the Reporting Threshold for Category 1 Substances?

An integrated iron and steel facility processes 2 000 000 tonnes of coal, iron ore and limestone per annum. What mean concentration of a Category 1 substance (either an element or compound) in the feedstock materials would trip the current reporting threshold (10 tonnes per annum) and therefore require reporting?

$$\begin{aligned}\text{mean concentration of substance} &= \text{quantity of substance / quantity processed}\\ &= 10\ \text{(tonnes / year)} / 2 * 10^{6}\ \text{(tonnes / year)}\\ &= 5 * 10^{-6}\\ &= 5\ \text{ppm}\end{aligned}$$

Therefore, reporting would be required if the mean concentration of the substance in the feedstock material is equal to or exceeds 5 ppm.

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.

4.3 Category 1a Substances

The only Category 1a substance associated with iron and steel production is Volatile Organic Compounds (VOCs). The most appropriate method of calculating whether the reporting threshold for Total VOCs is exceeded for a facility is to sum the consumption and/or production streams containing VOCs.

The NPI threshold will be exceeded if the throughput of total VOCs exceeds 25 tonnes/year.

4.4 Category 3 Substances

Category 3 substances are reportable if emissions to water (excluding groundwater) exceed the following scheduled amounts:

- 15 tonnes per year of total nitrogen; and
- 3 tonnes per year of total phosphorus.

5.0 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. Each of these methods is discussed briefly in Sections 5.1 to 5.3 of this Manual. 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 emission estimation techniques 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 Manual does not necessarily imply that an emission should not 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.

In general, direct measurement is the most accurate method for characterising emissions and, where available, such data should be used in preference to other EETs presented in this Manual. However, additional direct measurement is not required under the NPI Measure. Direct monitoring may be undertaken as an element of other EETs.

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.

In developing an inventory of emissions, it is important to utilise the best information available to develop emission estimates. Ideally, this data is obtained through source testing of emission points, although it is recognised that in many situations sampling data is not available. Examples of how source emission monitoring data can be used for calculating emissions are shown in Section 6 of this Manual.

5.1 Use of Emission Factors

Emission factors are generally developed through the testing of a particular source population (eg. various boilers burning a particular fuel type). (The implicit assumption in using an emission factor is that all members of the source population perform in the same manner with little variation between members.)

This information is used to relate the quantity of a pollutant emitted to some measure of activity rate or throughput. For example, boiler emission factors are typically expressed as emissions per unit quantity of fuel consumed. To determine the emission rate for that boiler, a measure of the fuel consumption rate is necessary.

The generic formula is:

Equation 1

Emission Rate = **Emission Factor** * **Activity Rate**
(mass per time) (mass per unit of throughput) (throughput per time)

Appropriate conversion factors for units may need to be applied. For example, if the emission factor has units of '*kg pollutant/m^3 of fuel burned*' then the throughput or activity rate data required would be '*m^3 fuel burned/hr*', thereby generating an emission estimate of '*kg pollutant/hr*'.

5.2 Mass Balance Techniques

Mass balance involves the quantification of total materials into and out of a process, with the difference between inputs and outputs being accounted for in terms of releases to the environment as part of the facility waste, as an emission or as a transfer. Mass balance is particularly useful when the input and output streams can be quantified. This is most often the case for individual process units and operations.

Mass balance techniques can be applied across individual unit operations or across an entire facility. These techniques are best applied to systems prescribed inputs, defined internal conditions and known outputs. Section 7 of this Manual provides more guidance as well as a worked example on the application of mass balance techniques.

The estimates derived from mass balances are only as reliable as the values used in performing the calculations. Small errors in data or calculation parameters can result in large errors in the final emissions estimates. Additionally, if sampling of input and output materials is conducted, failure to use representative samples will also contribute to the uncertainty of the result.

5.3 Modelling

Emission models are available that predict emission rates for fugitive releases, landfills, lagoons, open dumps, waste piles, land treatment operations and other source areas. These can be used either as a “screening” tool or for in-depth investigations, which require site-specific data.

A range of other information is typically also required to utilise such software packages (eg. for the chemical and/or physical characterisation of specific substances). Where relevant in this Manual, the use of such software packages for the purposes of characterising and estimating emissions is discussed.

While software models frequently require an initial investment of time, they can provide long term benefits as they can be used relatively easily and quickly to re-estimate emissions.

5.4 Applying EETs

It is important to remember that the NEPM for the NPI defines an emission as an emission of a substance to the environment whether in pure form or contained in other matter and whether in solid, liquid or gaseous form. It includes emissions of a substance to the environment from landfill, sewage treatment plants and tailings dams but does not include:

- deposit of a substance into landfill;
- discharge of a substance to a sewer or a tailings dam; or
- removal of a substance from a facility for destruction, treatment, recycling, reprocessing, recovery or purification.

The NPI Guide lists all of the reportable substances and the associated reporting thresholds. This Guide should be consulted to ascertain whether your facility handles, manufactures, or otherwise uses any of the substances presented in the list and determine whether any thresholds are exceeded. If the facility is found to trigger any thresholds then releases to air, water and land must be quantified. Note, however, that although a particular substance may be triggered, an emission estimation technique may not be found in this Manual due to lack of emission estimation data.

Estimation methods applicable to particular processes in iron and steel production are detailed in Table 3a and Table 3b of this Manual. These Tables list the NPI substances of relevance or potentially of relevance to iron and steel production. It should be noted that not all of the activities and operations listed in the tables are relevant to all facilities. In such situations, you should only consider the set of activities that are of relevance to your operations.

The EETs shown in Table 3a and Table 3b have been discussed with the iron and steel industry and it has been agreed that these methods are the most likely to be used widely in the industry.

It should be noted that even if emission factors are not available, it is your responsibility to report emissions from the facility of any NPI substances that exceed NPI reporting thresholds. Other methods or a combination of existing emission factors and other methods, (such as direct measurement and engineering calculations) can be used.

For example, engineering calculation techniques such as speciation of total particulate emissions could be used to characterise emissions for metals.

Table 3a - Emission Estimation Techniques for NPI-Listed Substances Potentially Associated with Iron & Steel Production

Pollutant	**NPI Category**	**Coke Making**			**Sinter and Pellet Making**			**Blast Furnace Iron Making**				**Steel Making**				
		Coal Handling	Coke Ovens	By-Products	Materials Handling	Sintering & Pelletising	Cooling & Handling	Materials Handling	Furnace Operations	Iron Handling	Slag Handling	Basic Oxygen Steel Making	Electric Arc Steel Making	Liquid Steel Handling	Slag Handling	Bloom, Billet & Slab Cast
Ammonia (total)	1		**EC+DM**	**EC+DM**		**EC+DM**			**EF+DM**							
Antimony & compounds	1	**EC**	**EC+DM**		**EC**	**EC+DM**	**EC+DM**	**EC**	**EF+DM**	**EF**	**EC+DM**	**EC**	**EC**	**EC+DM**	**EC+DM**	**EF+DM**
Arsenic & compounds	1, 2b	**EC**	**EC+DM**		**EC**	**EC+DM**	**EC+DM**	**EC**	**EF+DM**	**EF**	**EC+DM**	**EC**	**EC**	**EC+DM**	**EC+DM**	**EF+DM**
Benzene	1		**EC+DM**	**EC+EC+ DM**		**EC+DM**			**EF+DM**							
Beryllium & compounds	1, 2b	**EC**	**EC+DM**		**EC**	**EC+DM**	**EC+DM**	**EC**	**EC+DM**	**EC**	**EC+DM**	**EC**	**EC**	**EC+DM**	**EC+DM**	**EC+DM**
Biphenyl (1,1 - biphenyl)	1		**EC+DM**	**DM**		**EC+DM**			**EC+DM**							
Boron & compounds	1	**EC**	**EC+DM**		**EC**	**EC+DM**	**EC+DM**	**EC**	**EC+DM**	**EC**	**EC+DM**	**EC**	**EC**	**EC+DM**	**EC+DM**	**EC+DM**
Cadmium & compounds	1, 2b	**EC**	**EC+DM**		**EC**	**EC+DM**	**EC+DM**	**EC**	**EC+DM**	**EC**	**EC+DM**	**EC**	**EC**	**EC+DM**	**EC+DM**	**EC+DM**
Carbon Monoxide	1, 2a		**EC+DM**	**EC+DM**		**EC+DM**			**EC+DM**			**EC**	**EC**			
Chromium (III) compounds	1, 2b	**EC**	**EC+DM**	**EC+DM**	**EC**	**EC+DM**	**EC+DM**	**EC**	**EC+DM**		**EC+DM**	**EC**	**EC**		**EC+DM**	**EC+DM**
Chromium (VI) compounds	1, 2b	**EC**	**EC+DM**	**EC+DM**	**EC**	**EC+DM**		**EC**	**EC+DM**			**EC**	**EC**		**EC+DM**	**EC+DM**
Cobalt & compounds	1	**EC**	**EC+DM**		**EC**	**EC+DM**	**EC+DM**	**EC**	**EC+DM**	**EC**	**EC+DM**	**EC**	**EC**	**EC+DM**	**EC+DM**	**EC+DM**
Copper & compounds	1, 2b	**EC**	**EC+DM**		**EC**	**EC+DM**	**EC+DM**	**EC**	**EC+DM**	**EC**	**EC+DM**	**EC**	**EC**	**EC+DM**	**EC+DM**	**EC+DM**
Cumene	1		**EC+DM**	**EC+DM**												
Cyanide (inorganic) compounds	1		**EC+DM**	**EC+DM**		**EC+DM**		**EC**	**EC+DM**							
Ethylene glycol	1		**DM**			**DM**			**EC+DM**			**EC**	**EC**			**EC+DM**
Fluoride compounds	1, 2a	**EC**	**EC+DM**		**EC**	**EC+DM**	**EC+DM**	**EC**	**EC+DM**		**EC+DM**	**EC**	**EC**		**EC+DM**	
Hydrochloric acid	1, 2a					**EC+DM**			**EC+DM**							
Hydrogen sulfide	1		**EC+DM**	**EC+DM**		**EC+DM**			**EC+DM**		**EC+DM**				**EC+DM**	
Lead & compounds	1, 2b	**EC**	**EC+DM**		**EC**	**EC+DM**	**EC+DM**	**EC**	**EC+DM**	**EC**	**EC+DM**	**EC**	**EC**	**EC+DM**	**EC+DM**	**EC+DM**
Magnesium oxide fume	1, 2b								**EF+DM**			**EF**	**EF**			
Manganese & compounds	1	**EF**	**EF+DM**		**EF**	**EF+DM**	**EF+DM**	**EF**	**EF+DM**	**EF**	**EF+DM**	**EF**	**EF**	**EF+DM**	**EF+DM**	**EF+DM**

Table 3a - Emission Estimation Techniques for NPI-Listed Substances Potentially Associated with Iron & Steel Production cont'

Pollutant	**NPI Category**	**Coke Making**			**Sinter and Pellet Making**			**Blast Furnace Iron Making**				**Steel Making**				
		Coal Handling	Coke Ovens	By-Products	Materials Handling	Sintering & Pelletising	Cooling & Handling	Materials Handling	Furnace Operations	Iron Handling	Slag Handling	Basic Oxygen Steel Making	Electric Arc Steel Making	Liquid Steel Handling	Slag Handling	Bloom, Billet & Slab Cast
Mercury & compounds	1, 2b	**EF**	**EF+DM**		**EF**	**EF+DM**	**EF+DM**	**EF**	**EF+DM**	**EF**	**EF+DM**	**EF**	**EF**	**EF+DM**	**EF+DM**	**EF+DM**
Methyl ethyl ketone	1															
Nickel & compounds	1, 2b	**EF**	**EF+DM**		**EF**	**EF+DM**	**EF+DM**	**EF**	**EF+DM**	**EF**	**EF+DM**	**EF**	**EF**	**EF+DM**	**EF+DM**	**EF+DM**
Oxides of nitrogen	2a		**EF+DM**			**EF+DM**			**EF+DM**			**EF**	**EF**			
Particulate Matter ≤10 µm (PM_{10})	2a	**EF**	**EF**		**EF**	**EF**	**EF**	**EF**	**EF**	**EF**	**EF+DM**	**EF**	**EF**	**EF**	**EF**	**EF**
Phenol	1		**EF+DM**	**EF+DM**		**EF+DM**										
Phosphoric acid	1			**DM**												
Polychlorinated dioxins and furans	2b					**EF**										
Polycyclic aromatic hydrocarbons	2a		**EF+DM**	**EF+DM**		**EF+DM**			**EF+DM**							
Selenium & compounds	1	**EF**	**EF+DM**		**EF**	**EF+DM**	**EF+DM**	**EF**	**EF+DM**	**EF**	**EF+DM**	**EF**	**EF**	**EF+DM**	**EF+DM**	**EF+DM**
Sulfur dioxide	1, 2a		**EF+DM**	**EF+DM**		**EF+DM**			**EF+DM**			**EF**	**EF**			
Sulfuric acid	1			**DM**		**EF+DM**			**EF+DM**			**EF**	**EF**			
Toluene	1		**EF+DM**	**EF+EC+ DM**		**EF+DM**			**EF+DM**							
Total Nitrogen	3		**DM**	**DM**					**EF+DM**							
Total Phosphorus	3		**DM**	**DM**					**EF+DM**							
Total Volatile Organic Compounds	1, 2a		**EF+DM**	**EF+DM**		**EF+DM**			**EF+DM**							
Xylenes (individual or mixed isomers)	1		**EF+DM**	**EF+EC+ DM**		**EF+DM**			**EF+DM**							
Zinc & compounds	1	**EF**	**EF+DM**	**EF+DM**	**EF**	**EF+DM**	**EF+DM**	**EF**	**EF+DM**	**EF**	**EF+DM**	**EF**	**EF**	**EF+DM**	**EF+DM**	**EF+DM**

EF = Emission Factor **DM = Direct Measurement** **EC = Engineering Calculations** **MB = Mass Balance**

While the NPI does not require facilities to conduct direct monitoring expressly for the purposes of NPI reporting, many facilities will have monitoring data relating to some of the substances required to be reported under the NPI. Direct monitoring (DM) is presented as an EET for those substances and activities for which monitoring is (or is likely to be) carried out for other purposes (eg. as part of licence conditions). In most situations, the use of monitoring data for the purposes of calculating emissions of NPI-listed substances is likely to provide a more accurate estimate of emissions than the use of emission factors.

Table 3b - Emission Estimation Techniques for NPI-Listed Substances Potentially Associated with Iron & Steel Production

Pollutant	**NPI Category**	**Primary Rolling Mills**			**Secondary Rolling Mills**			**Miscellaneous Operations**			
		Steel Handling	Reheat Furnace	Rolling Mill Operations	Steel Handling	Reheat Furnace	Rolling Mill Operations	Lime Kiln	Tonnage Oxygen Plant	Service Shops	Power Generation
Ammonia (total)	1		**EF**			**EF**		**EF+DM**		**EF+DM**	**EF+DM**
Antimony & compounds	1	**EF**	**EF**	**DM**	**EF**	**EF**	**DM**	**EF+DM**			**EF+DM**
Arsenic & compounds	1, 2b	**EF**	**EF**	**DM**	**EF**	**EF**	**DM**	**EF+DM**			**EF+DM**
Benzene	1		**EF**			**EF**		**EF+DM**		**EF+DM**	**EF+DM**
Beryllium & compounds	1, 2b	**EF**	**EF**	**DM**	**EF**	**EF**	**DM**	**EF+DM**			**EF+DM**
Biphenyl (1,1 - biphenyl)	1		**EF**			**EF**		**EF+DM**		**EF+DM**	**EF+DM**
Boron & compounds	1	**EF**	**EF**	**DM**	**EF**	**EF**	**DM**	**EF+DM**			**EF+DM**
Cadmium & compounds	1, 2b	**EF**	**EF**	**DM**	**EF**	**EF**	**DM**	**EF+DM**			**EF+DM**
Carbon Monoxide	1, 2a		**EF**			**EF**		**EF+DM**		**EF+DM**	**EF+DM**
Chromium (III) compounds	1, 2b			**DM**			**DM**	**EF+DM**	**DM**		**EF+DM**
Chromium (VI) compounds	1, 2b			**DM**			**DM**	**EF+DM**	**DM**		**EF+DM**
Cobalt & compounds	1	**EF**	**EF**	**DM**	**EF**	**EF**	**DM**	**EF+DM**			**EF+DM**
Copper & compounds	1, 2b	**EF**	**EF**	**DM**	**EF**	**EF**	**DM**	**EF+DM**			**EF+DM**
Cumene	1										
Cyanide (inorganic) compounds	1		**EF**			**EF**		**EF+DM**		**EF+DM**	**EF+DM**
Ethylene glycol	1			**DM**			**DM**			**EF+DM**	**EF+DM**
Fluoride compounds	1, 2a							**EF+DM**			**EF+DM**
Hydrochloric acid	1, 2a										**EF+DM**
Hydrogen sulfide	1		**EF**			**EF**		**EF+DM**		**EF+DM**	**EF+DM**
Lead & compounds	1, 2b	**EF**	**EF**	**DM**	**EF**	**EF**	**DM**	**EF+DM**			**EF+DM**
Magnesium oxide fume	1, 2b										
Manganese & compounds	1	**EF**	**EF**	**DM**	**EF**	**EF**	**DM**	**EF+DM**			**EF+DM**

Table 3b - Emission Estimation Techniques for NPI-Listed Substances Potentially Associated with Iron & Steel Production cont'

Pollutant	**NPI Category**	**Primary Rolling Mills**			**Secondary Rolling Mills**			**Miscellaneous Operations**			
		Steel Handling	Reheat Furnace	Rolling Mill Operations	Steel Handling	Reheat Furnace	Rolling Mill Operations	Lime Kiln	Tonnage Oxygen Plant	Service Shops	Power Generation
Mercury & compounds	1, 2b	**EF**	**EF**	**DM**	**EF**	**EF**	**DM**	**EF+DM**			**EF+DM**
Methyl ethyl ketone	1									**EF+DM**	
Nickel & compounds	1, 2b	**EF**	**EF**	**DM**	**EF**	**EF**	**DM**	**EF+DM**			**EF+DM**
Oxides of nitrogen	2a		**EF**			**EF**		**EF+DM**		**EF+DM**	**EF+DM**
Particulate Matter ≤10µm (PM$_{10}$)	2a	**EF**	**EF**	**EF**	**EF**	**EF**	**EF**	**EF**			**EF**
Phenol	1		**EF**			**EF**		**EF+DM**		**EF+DM**	**EF+DM**
Phosphoric acid	1										
Polychlorinated dioxins and furans	2b										
Polycyclic aromatic hydrocarbons	2a		**EF**			**EF**		**EF+DM**		**EF+DM**	**EF+DM**
Selenium & compounds	1	**EF**	**EF**	**DM**	**EF**	**EF**	**DM**	**EF+DM**			**EF+DM**
Sulfur dioxide	1, 2a		**EF**			**EF**		**EF+DM**		**EF+DM**	**EF+DM**
Sulfuric acid	1		**EF**			**EF**		**EF+DM**		**EF+DM**	**EF+DM**
Toluene	1		**EF**			**EF**		**EF+DM**		**EF+DM**	**EF+DM**
Total Nitrogen	3										
Total Phosphorus	3										
Total Volatile Organic Compounds	1, 2a		**EF**			**EF**		**EF+DM**		**EF+DM**	**EF+DM**
Xylenes (individual or mixed isomers)	1		**EF**			**EF**		**EF+DM**		**EF+DM**	**EF+DM**
Zinc & compounds	1	**EF**	**EF**	**DM**	**EF**	**EF**	**DM**	**EF+DM**			**EF+DM**

EF = Emission Factor **DM = Direct Measurement** **EC = Engineering Calculations** **MB = Mass Balance**

While the NPI does not require facilities to conduct direct monitoring expressly for the purposes of NPI reporting. Many facilities will have monitoring data relating to some of the substances required to be reported under the NPI. Direct monitoring (DM) is presented as an EET for those substances and activities for which monitoring is (or is likely to be) carried out for other purposes (eg. as part of licence conditions). In most situations, the use of monitoring data for the purposes of calculating emissions of NPI-listed substances is likely to provide a more accurate estimate of emissions than the use of emission factors.

6.0 Monitoring

Many facilities conduct monitoring as part of existing regulatory requirements. Typically the monitoring is tied directly to the conditions on an environmental licence and will vary from site-to-site.

It is important to recognise that facilities also collect a range of other information, beyond stack or liquid effluent testing, which may be used in characterising emissions for the NPI. Typical data collected includes:

- volumetric flow rates (eg products, wastes, wastewater treatment);
- mass flowrates;
- stream composition;
- product and waste composition; and
- production and waste quantities.

In most situations, the use of such data as a basis for calculating emissions will provide the most representative emissions information for a facility and this data should be used, where available, to calculate emissions.

Monitoring data can be expressed in a range of units. The following discussion may be of assistance when converting monitoring results into annual emission estimates for the purposes of the NPI. It is important to remember that the calculation of annual emissions must also take account of the number of hours per year the source is discharging to the environment.

Stack data is typically presented in terms of either actual flow or a 'normalised' flow. The difference is that normalised data is standardised to a particular temperature and pressure, which are typically 0°C and 1 atm respectively. However, sometimes it may be referenced to 25°C and 1 atm. The following terms may be used when presenting data:

- acm - actual cubic metre (at actual temperature and pressure);
- scm - standard cubic metre (typically at 25°C and 1 atm, although sometimes it may be at 20°C or even 0°C); and
- Nm^3 - normal cubic metre (typically at 0°C and 1 atm).

It is essential to ascertain under what conditions the source test data is presented before determining annual emission estimates. However, typically the measured concentrations and flue gas flows are presented on source test reports at the same conditions (ie. temperature and pressure).

Two examples of the use of sampling data to characterise annual emissions are presented below. Example 2 is where the concentration of the compound is presented at the same conditions as the measured flow rate while Example 3 is where the concentration and flue gas flows are measured under different conditions.

Example 2 - Stack Sampling: Concentration and Flow Rate Measured at the Same Conditions

The following example relates to the situation where the concentration of the compound is presented at the same conditions as the measured flow rate.

The following data is known:

- the flue gas flow from a stack is measured at 30 Nm^3/sec;
- the measured concentration of cadmium in the flue gas is 0.01 mg/Nm^3; and
- the stack operates 24 hours per day for 300 days per year.

First of all, the number of seconds per year the stack is emitting is determined:

$$\begin{aligned}\text{No. seconds/year} &= (3600\ \text{sec/hour}) * (24\ \text{hours/day}) * (300\ \text{days/year}) \\ &= 2.6 * 10^7\ \text{seconds/year}\end{aligned}$$

Using this data the emission is derived from the generic formula shown in Equation 1:

$$\begin{aligned}\text{Emission} &= (0.01\ \text{mg/Nm}^3) * (30\ \text{Nm}^3\text{/sec}) * (2.6 * 10^7\ \text{sec/year})\ /\ 10^6\ \text{mg/kg} \\ &= 7.8\ \text{kg of cadmium per year.}\end{aligned}$$

Example 3 - Stack Sampling: Concentration and Flow Rate Measured at Different Conditions

If the concentration and flue gas flows are measured under different conditions then additional calculations are required. For example, the following data is known:

- the flue gas flow from a stack is measured at 100 acm/sec;
- the measured concentration of cadmium in the flue is 0.01 mg/Nm^3;
- the stack operates 24 hours per day for 300 days per year; and
- the conditions at the stack tip are approximately 150°C and 1 atm.

Using the actual stack data, the 'actual' flue gas flow can be converted to a normalised flow using a ratio of temperatures. Note however that the temperatures must be presented using the absolute temperature scale of Kelvin (ie. 0°C = 273 K). The conversion is then performed as follows (noting that the actual stack conditions are 150 + 273 = 423 K):

$$\begin{aligned}\text{Flue gas (Nm}^3\text{/sec)} &= 100\ \text{acm/sec} * (273/423) \\ &= 64.5\ \text{Nm}^3\text{/sec}\end{aligned}$$

The emission rate is then derived using the same methodology as outlined in Example 2 as follows:

$$\begin{aligned}\text{Emission} &= (0.01\ \text{mg/Nm}^3) * (64.5\ \text{Nm}^3\text{/sec}) * (2.6 * 10^7\ \text{sec/year})/10^6\ \text{mg/kg} \\ &= 16.8\ \text{kg of cadmium per year.}\end{aligned}$$

7.0 Mass Balance

Mass balance EETs 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; this most often is the case for small processes and operations. It can be applied across an entire facility or across individual unit operations. 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, and control efficiency) 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.

7.1 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 below). This involves 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:

Equation 2

$$\text{Total mass into process} = \text{Total mass out of process}$$

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

Equation 3

$$\text{Inputs} = \text{Products} + \text{Transfers} + \text{Emissions}$$

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 exported from the facility.

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

Equation 4

Input of substance ‘i’ = Amount of substance ‘i’ in product + amount of substance ‘i’ in waste + amount of substance ‘i’ transformed/consumed in process + emissions of substance ‘i’

The mass balance approach can be used for each NPI-listed substance for which the facility is responsible for reporting. Emissions can then be allocated to air, water and land. A simple example of the application of mass balance is presented below.

Example 4 - Using Mass Balance

A process uses 10 000 tonnes of raw material A, 5000 tonnes of raw material B and 20 000 tonnes of water to produce 22 000 tonnes of product and 4000 tonnes of by-product annually, where A and B are NPI-listed substances. (Note: You are required to quantify NPI-listed substances only). This process is shown schematically in Figure 2. What is the total amount of waste emitted from the process? How much of this should be reported under the NPI?

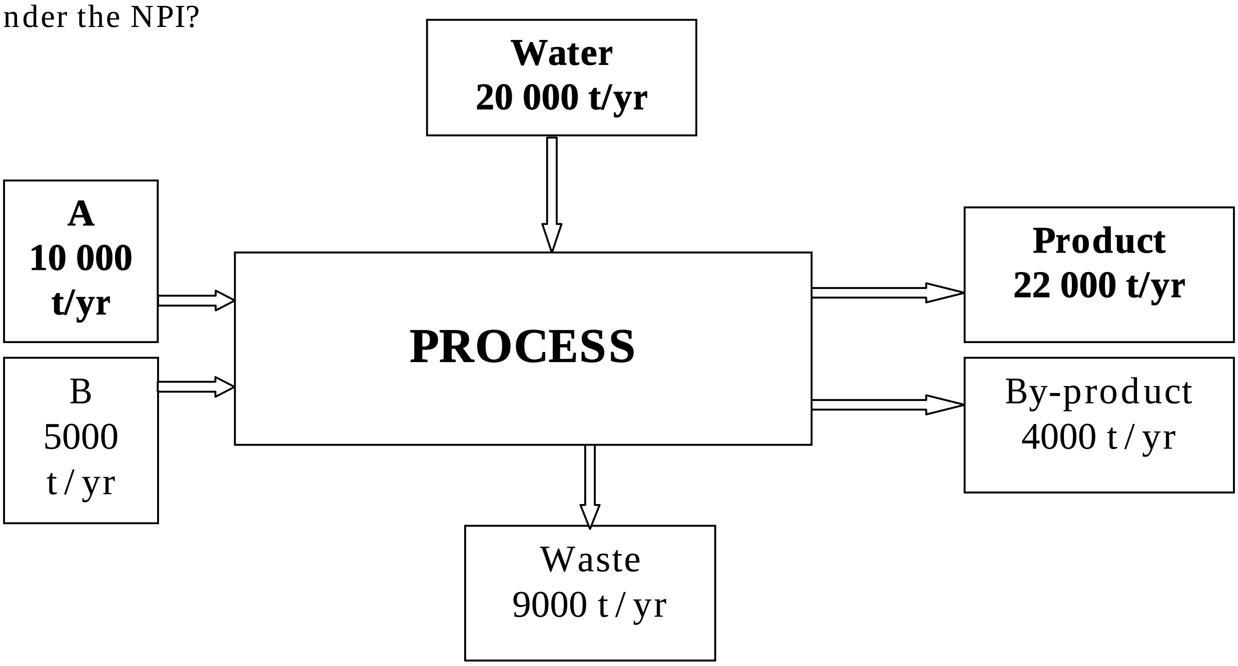

Figure 2 - Mass Balance Process

Example 4 - Using Mass Balance cont'

The general calculation process is presented as a series of steps:

Step 1: Calculate Total Inputs to Process

Total inputs:
= mass of A + mass of B + mass of water
= 10 000 + 5000 + 20 000
= 35 000 tonnes

Step 2: Calculate Total Outputs from Process

Total outputs:
= mass of product + mass of by-product
= 22 000 + 4000
= 26 000 tonnes

Step 3: Calculate Total Amount of Waste Produced

Total quantity of waste produced:
= mass of inputs - mass of outputs
= 35 000 - 26 000
= 9000 tonnes per annum.

Step 4: Identify Transfers and Spills

The facility will need to identify those wastes that are classed as transfers under the NPI. For example, of the 9000 tonnes per annum of waste produced, 2800 tonnes may be collected and sent for off-site disposal (ie. reporting not required), while approximately 6000 tonnes may be sent to an on-site water treatment facility prior to discharge to sewer (ie. reporting not required).

This would then indicate that 200 tonnes of waste has been released into the environment (in the present example, the release is to atmosphere but could also be, for example, a release direct to a water body). If the approximate proportions of substances A and B in the waste stream are known, the quantity of A and B released to the atmosphere may be determined.

It is important to note that account must be taken of any pertinent emission controls (eg. the waste may be routed through an incinerator which destroys most or all of substances A and B before they are released to the atmosphere).

7.2 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 5 can be used (note that scm is an abbreviation for standard cubic metres - refer to Section 6 - Monitoring).

Equation 5

$$E_i = \Sigma Q_a W_{a,i} \rho_a - \Sigma Q_o W_{o,i} \rho_o$$

where:

E_i = emission rate of component i (kg/hr)
Q_a = volumetric flow rate of inlet stream a (scm/hr)
Q_o = volumetric flow rate of outlet stream o (scm/hr)
$W_{a,i}$ = weight fraction of component i in inlet stream a
$W_{o,i}$ = weight fraction of component i in outlet stream o
ρ_a, ρ_o = density of streams a 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_i 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.

8.0 Air Emissions

8.1 Sources

Emissions to the atmosphere from an integrated iron and steel production facility arise from a range of sources and activities. These include:

- Coke making (see Section 8.4);
- Sinter and pellet making (see Section 8.5);
- Iron making (see Section 8.6);
- Steel making (see Section 8.7);
- Steel casting and steel rolling mill operations (see Section 8.8);
- Lime kilns (see Section 8.9);
- Power generation (see Section 8.10);
- Service shops (see Section 8.11);
- Oxygen plant (see Section 8.11); and
- Miscellaneous sources (see Section 8.11).

Many of the potential sources of emission within an integrated iron and steel facility are extremely difficult to measure directly and emissions must be estimated using other techniques. Emissions such as those from coke battery charging and pushing operations, blast furnace charging and steel making operations in particular will be heavily dependent upon the emission reduction technology employed and the age and condition of the equipment. Consequently, emission factors are provided in this Manual for different control technologies. The emission factors chosen should be those which correspond most closely to the technology in place.

Section 8.3 describes how to estimate emissions of volatile organic compounds (VOCs, on a facility-wide basis). Sections 8.4 to 8.11 describe the emissions to air from each of the above-mentioned activities, and the techniques that are applicable for estimating each type of airborne emission.

8.2 Particulate Speciation

Metals can be speciated based on trace analysis data or Material Safety Data Sheets (MSDS) provided by the vendor. This data can be combined with particulate emissions data (ie. collected as source test results and/or calculated by other estimation techniques) using the Equation 6 below.

Equation 6

$$E_{kpy,i} = (m)(c_i)$$

where:

$E_{kpy,i}$ = mass emission of component i (kg/yr)
m = mass emission rate of total particulate (kg/yr)
c_i = mass fraction of component i (dimensionless, eg. kg/kg)

This methodology is most applicable to emissions from low temperature sources, such as stockpiles. This is because it intrinsically assumes that the released particulate matter contains all metals. While this may be a reasonable assumption for metals with very low vapour pressures, more volatile metals such as mercury are likely to be partially present in vapour form. However, insufficient information is currently available to produce better estimates other than through source testing.

8.3 Estimating VOC Emissions

VOCs are generated during the coking process and can be extracted from coke oven gas as commercial by-products. BTX (nominal cut of benzene, toluene and xylene) is such a product stream.

VOCs produced (not necessarily emitted) in coking operations are estimated by dividing the annual light oil make (light oil production, L_{ORG}) by the recovery efficiency (expressed as a decimal fraction). Recovery efficiency is calculated by the following equation:

Equation 7

$$\text{Recovery Efficiency} = (L_{ORG} - L_{OS}) / L_{ORG}$$

where:

L_{ORG} = light oil content of raw coke ovens gas
L_{OS} = light oil slip (ie losses of light oil)

VOCs emitted from coking operations come from various sources. Gas losses, combustion processes, organic liquid storage etc all contribute to total VOC emission.

VOCs emitted from gas losses in the gas processing plant can be estimated using standard loss factors for flanges and fittings, published in the *Emission Estimation Technique Manuals for Organic Chemical Processing Industries* or *for Fugitive Emissions.*

VOCs emitted from combustion processes can be estimated by applying standard emission factors for fuels per the *Emission Estimation Technique Manual for Combustion in Boilers*.

The other major source of VOC emissions from any iron and steel production facility will be from the handling and storage of organic liquids. EETs for VOC emissions from these sources are provided in the *Emission Estimation Technique Manual for Fuel and Organic Liquid Storage.*

8.4 Coke Making

8.4.1 Sources of Emissions

The air emissions from a typical coke making operation would generally include:

- coal dust at discharge;
- coal dust windage from stock piles;
- coal dust losses at transfer points;
- coke oven gas emission from charging, pushing, door leakage, wall and flue leakage and oven top operations;
- coke dust from pushing and quenching;
- coke dust from transfer and screening operations;
- combustion products from the main stack and interworks coke ovens gas consumers;
- fume and vapours from quenching operations;
- fugitive emissions in the by-products plant; and
- vapours from by-products plant operations.

8.4.2 Emission Estimation Techniques

Applicable emission estimation techniques for coke making and associated activities are summarised in Table 3a. Direct measurement would be possible for wall and flue leakage, combustion products from the main stack and coke dust emission from quenching operations.

Coal Handling

EETs for coal storage, preparation and handling are provided in the *Emission Estimation Technique Manual For Mining*.

Coke Ovens

Table 4 provides emission factors for PM_{10} (particulate matter with an equivalent aerodynamic diameter of 10 micrometres or less ie. $\leq 10\mu m$), carbon monoxide, sulfur dioxide, total VOCs and oxides of nitrogen, for coke ovens operations. In addition, other NPI substances are likely to be emitted, for which no emissions factors may be available.

Table 4 - Emission Factors for Coke Ovens Battery Operations

Operation	PM_{10} (kg/t coke)	Emission Factor Rating	Carbon Monoxide (kg/t coke)	Emission Factor Rating	SO_2 (kg/t coke)	Emission Factor Rating	VOCs (kg/t coke)	Emission Factor Rating	NO_x (kg/t coke)	Emission Factor Rating	Ammonia (kg/t coke)	Emission Factor Rating
Charging												
uncontrolled	0.12	D	0.3	D	0.01	D	1.25	D	0.015	D	0.01	D
Oven Doors												
uncontrolled	0.27	D	0.3	D			0.75	D	0.005	D	0.03	D
Pushing												
uncontrolled	0.25	B	0.035	D			0.1	D			0.05	D
venturi scrubber	0.08	D	0.035	D			0.1	D				
baghouse	0.045	D	0.035	D			0.1	D				
Quenching												
uncontrolled dirty water	0.6	D										
uncontrolled clean water	0.17	D										
baffled dirty water	0.21	B										
baffled clean water	0.03	B										
Main Stack												
uncontrolled raw COG[a]	0.22	A			2.0	D						
uncontrolled BF gas[b]	0.085	A			0.54	D						

Source: USEPA 1995. Where a factor is not included in the table, it is either not applicable or considered negligible.

[a] COG: coke ovens gas. [b] BF gas: blast furnace gas.

Coke Ovens By-product Plant

Emissions from chemical plant which strips out benzene, toluene and other volatile NPI substances from the by-products section of the coke ovens can be estimated by techniques published in the *Emission Estimation Technique Manual For Organic Chemical Processing Industries. Emission Estimation Technique Manual For Fuel and Organic Liquid Storage, Emission Estimation Technique Manual For Ammonium Sulfate Manufacturing* and the *NPI Industry Handbook for Fertiliser Manufacturing.*

Interworks Coke Oven Gas Combustion

The simplest way of estimating emissions resulting from coke oven gas combustion is to derive emission factors from typical waste gas composition for a particular plant and apply these factors to the entire coke oven gas make (ie. production). An engineering calculation technique that uses source monitoring data, such as the particulate speciation method described in Section 8.2, could be used to do this.

8.5 Sinter and Pellet Making

8.5.1 Sources of Emissions

Emissions to air from a typical iron ore sintering or pelletising operation generally include:

- material dusts at discharge (ore, fluxes and coke breeze);
- material storage yard wind losses;
- ore, flux and coke breeze losses at transfer points;
- loss of sintering or pelletising plant feed from strand or hearth grate;
- combustion products from the main stack;
- combustion product fines lost in forced or convection coolers;
- uncaptured product fines generated by screening of sinter or pellets; and
- transfer point losses associated with handling of sinter or pellets.

8.5.2 Emission Estimation Techniques

Applicable emission estimation techniques for sinter and pellet making are summarised in Table 3a of this Manual. Direct measurement would be possible for unrecovered feed losses through the strand or hearth grate and combustion products discharging through the main stack.

Materials Handling

Table 5 provides emission factors for PM_{10}, for ore storage, preparation and handling activities. In addition, other NPI substances are likely to be emitted, for which no emissions factors may be available.

Table 5 - Emission Factors for Ore Storage, Preparation and Handling

Operation	PM_{10} (kg/t ore)
Transfer Point inc Stacker Ore	0.00055
Transfer Point inc Stacker Lump	0.000075

Source: USEPA 1995

Sintering and Pelletising

Table 6 provides emission factors for PM_{10} and carbon monoxide, for sintering and pelletising plants. In addition, other NPI substances are likely to be emitted, for which no emissions factors may be available.

Table 6 - Emission Factors for Sinter and Pellet Plant Operations

Operation	PM_{10} (kg/t sinter)	carbon monoxide (kg/t sinter)
Windbox		
cyclones	0.37	22.0
venturi scrubber	0.226	22.0
wet ESP[a]	0.05	22.0
baghouse	0.104	22.0
Discharge		
baghouse	0.016	
Transfer Points		
each	0.0065	

Source: USEPA 1995

Where a factor is not included in the table, it is either not applicable or considered negligible.

[a] ESP: electrostatic precipitator

8.6 Iron Making

8.6.1 Sources of Emissions

Emissions to air from a typical blast furnace iron making operation would include:

- sinter, pellet, ore, flux and coke breeze losses from material stock houses and transfer points;
- loss of blast furnace gas from furnace top;
- combustion products from stove heating and interworks blast furnace gas consumers;
- dust losses when clearing dust catchers;
- uncaptured emissions from cast house operations;
- emissions associated with rock slag quenching and / or handling operations;
- emissions associated with slag granulation; and
- kish and fume generated from molten iron transfer and handling.

8.6.2 Emission Estimation Techniques

Applicable emission estimation techniques for iron making are summarised in Table 3a. Direct measurement would be possible for combustion products from stove heating and uncaptured emissions from material stock houses and cast house operations.

Furnace Operations, Iron Handling and Slag Handling

Table 7 provides emission factors for PM_{10}, for blast furnace iron making operations. In addition, other NPI substances are likely to be emitted, for which no emissions factors may be available.

Table 7 - Emission Factors for Blast Furnace Iron Making Operations

Operation	PM_{10} (kg/t metal or slip)
Blast Furnace	
slips	39.5
cast house - uncontrolled	0.15
furnace	0.16
taphole and trough	0.15
Hot Metal Desulfurisation	
uncontrolled	0.1
baghouse	0.0033

Source: USEPA 1995

Note: Blast furnace PM_{10} emissions would be calculated as follows:

1. Sum the cast house, furnace and taphole and trough emission factors and multiply by the annual hot metal make.
2. Determine the number of stack slips that occurred in all furnaces through the year and multiply by the per slip PM_{10} emission factor in the table.

Interworks Blast Furnace Gas Combustion

The simplest way of estimating emissions resulting from blast furnace gas combustion is to apply a typical waste gas composition to the entire blast furnace gas make. An engineering calculation technique that uses source-monitoring data, such as the particulate speciation method described in Section 8.2 could be used to do this.

8.7 Steel Making

8.7.1 Sources of Emissions

The emissions to air from a typical basic oxygen steel making or electric arc furnace operation would generally include:

- ore, flux and coke breeze losses at transfer points;
- emission (kish and fume) from molten iron transfer (BOF only);
- combustion products and emission from hot metal desulfurisation plant;
- dust generated when charging scrap;
- uncaptured emissions from baghouses or electrostatic precipitators cleaning furnace off gases;
- combustion products in furnace off gases;
- emissions associated with tapping of steel and slag;

- generation of dust from dragline operations; and
- emission from slag quenching and handling operations.

8.7.2 Emission Estimation Techniques

Applicable emission estimation techniques for steel making are summarised in Table 3a. Direct measurement would be possible for combustion products in furnace off gases and uncaptured emissions from furnace off gas cleaning and dust-removing equipment.

Basic Oxygen Steel Making

Table 8 provides emission factors for PM_{10} and carbon monoxide, for basic oxygen steel making operations. In addition, other NPI substances are likely to be emitted, for which no emissions factors may be available.

Table 8 - Emission Factors for Basic Oxygen Steel Making Operations

Operation	PM_{10} (kg/t steel)	Carbon Monoxide (kg/t steel)
BOF Refining		
open hood with ESP	0.065	69.0
open hood with scrubber	0.045	69.0
closed hood with scrubber	0.0023	69.0
Charging	0.071	
Tapping	0.145	
Hot Metal Transfer	0.028	

Source: USEPA 1995

Where a factor is not included in the table, it is either not applicable or considered negligible.

Electric Arc Furnace (EAF) Steel Making

Table 9 provides emission factors for PM_{10} and carbon monoxide, for electric arc steel making operations. In addition, other NPI substances are likely to be emitted, for which no emissions factors may be available.

Table 9 - Emission Factors for EAF Steel Making Operations

Refining - All Operations	PM_{10} (kg/t steel)	Carbon Monoxide (kg/t steel)
uncontrolled	11.02	9.0
hood and baghouse	0.0163	9.0

Source: USEPA 1995

8.8 Steel Casting and Steel Rolling Mill Operations

8.8.1 Sources of Emissions

The air emissions produced by a typical steel casting or steel rolling mill operation include:

- emissions from molten steel transfer, pouring or teeming;
- combustion products and fume from oxy steel cutters;
- combustion products from gas fired reheat furnaces; and
- dust from miscellaneous sources.

8.8.2 Emission Estimation Techniques

Emission estimation techniques for steel casting and steel rolling mill operations are summarised in Table 3a and Table 3b respectively. Direct measurement would be possible for combustion products from reheat furnaces.

Steel Teeming and Casting

Table 10 provides emission factors for PM_{10} for teeming and casting of steel. In addition, other NPI substances are likely to be emitted, for which no emissions factors may be available.

Table 10 - Emission Factors for Steel Teeming and Casting Operations

Operation	PM_{10} (kg/t steel)
Teeming	
leaded steel uncontrolled	0.405
unleaded steel uncontrolled	0.035
Casting	
hot metal transfer uncontrolled	0.028
machine scarfing and cutting	0.05

Source: USEPA 1995

Teeming

Where the teeming of ingots is undertaken prior to primary rolling operations, steel make must be subdivided into leaded and unleaded and the total emissions calculated by summing the emissions produced for their respective tonnages (from the emission factors shown in Table 8).

Casting, Cutting and Scarfing

In general, casting involves a single hot metal transfer operation followed by a cutting and/or scarfing operation. For each casting operation, the cast steel tonnage is multiplied by the relevant emission factor to estimate total emissions.

Emissions from the casting operation itself are calculated by multiplying the emission factor shown in Table 10 by the steel throughput.

To calculate emissions from cutting and scarfing operations, it is necessary to determine the proportion of time that the cutters are operating relative to the scarfing torches and multiply this time fraction by the scarfing emission factor

Thus, the overall PM_{10} emissions from casting, cutting and scarfing are calculated by:

Equation 8

$$\text{Emissions of } PM_{10} = 0.028 * \text{tonnes cast} + (1 + CT) * 0.05 * \text{tonnes cast}$$

where: CT = the proportion of time the oxy cutters are in operation relative to the scarfing torches

Primary and Secondary Rolling

The major source of emissions to air from primary and secondary rolling operations are the stack emissions from each reheat furnace. Where these furnaces are fired on coke ovens gas or blast furnace gas, the pollutant contribution has already been calculated (see Section 8.4) and does not need to be estimated separately. Where a reheat furnace utilises a fuel other than these gases, emissions can be calculated using the *Emission Estimation Technique Manual for Combustion in Boilers.*

8.9 Lime Kilns

8.9.1 Sources of Emissions

The emissions to air relevant to lime kiln operations generally include:

- material dusts at discharge (lime, dolomite);
- material storage yard wind losses;
- lime / dolomite losses at transfer points;
- combustion products from gas fired kilns; and
- generation of dust from miscellaneous sources.

8.9.2 Emission Estimation Techniques

Applicable emission estimation techniques for limekilns are summarised in Table 3b. Direct measurement would be possible for combustion products from the rotary kiln.

Where a kiln is fired on coke ovens gas or blast furnace gas, the pollutant contribution has already been calculated (see Section 8.4) and does not need to be estimated separately. EETs for kilns fired on other fuels are provided in the *NPI Industry Handbook for Cement and Lime Manufacturing* which includes the *Emission Estimation Technique Manual for Lime and Dolomite Manufacturing.*

8.10 Power Generation

8.10.1 Sources of Emissions

Within an iron and steel plant, steam raising capacity can be used for power generation, general interworks use, separation processes within the coke ovens by-products area and for supplying turbines driving centrifugal and positive displacement pumps, blowers and fans. For the purpose of this Manual, these steam users are grouped under Power Generation.

8.10.2 Emission Estimation Techniques

Where a boiler is fired on coke ovens gas or blast furnace gas, the pollutant contribution has already been calculated (See Sections 8.4 and 8.6) and does not need to be estimated separately. Emissions from boilers using other fuels can be calculated from EETs provided in the *Emission Estimation Technique Manual for Combustion in Boilers.*

8.11 Service Shops, Oxygen Plant and Miscellaneous Emissions.

8.11.1 Sources of Emissions

Emissions to air from service shop operations, tonnage oxygen plant operations and miscellaneous sources generally include:

- combustion processes in service shop furnaces;
- evaporation of organic solvents;
- evaporation of specialty solvents used in the oxygen plant;
- emissions from petrol and diesel road vehicles[a];
- dust generated by road traffic[a]; and
- emissions from diesel powered locomotives[a].

[a] on-site only, non-registered vehicles.

8.11.2 Emission Estimation Techniques

Applicable emission estimation techniques for the above-mentioned activities are summarised in Table 3b.

Service Shop Furnaces

Where a service shop furnace is fired on coke oven gas or blast furnace gas, the pollutant emissions have already been calculated (See Sections 8.4 and 8.7). Only the contribution to emissions from fuel sources other than coke ovens gas and blast furnace gas should be estimated for Service Shop Furnaces. These emissions can be estimated using EETs provided in the *Emission Estimation Technique Manual for Combustion in Boilers.*

Solvent Evaporation

It can be assumed that all solvents purchased eventually end up as emissions to the air. While this is a conservative approach, it provides a quick way to calculate emissions from solvent handling, for VOCs and individual NPI substances for which reporting is required.

Emissions from Diesel Fuelled Vehicles and Locomotives

EETs for vehicle emissions, resulting from the combustion of fuels, are provided in the *Emission Estimation Technique Manual for Combustion Engines.* Factors for estimating dust generation associated with vehicle movement, are provided in Table 11 below. More detailed EETs for estimating dust generation associated with vehicle movement are provided in the *Emission Estimation Technique Manual for Mining.*

Table 11 - Emission Factors for Dust Generation Associated with Vehicle Movements

Vehicle Movement/Type	**PM_{10} (kg/Vehicle km travelled)**
Unpaved Roads	
Light Duty Vehicle	0.28
Medium Duty Vehicle	1.2
Heavy Duty Vehicle	2.1
Paved Roads	
Light / Heavy Vehicle Mix	0.12

Source: USEPA 1995

9.0 Emissions to Water

The first stage in characterising emissions to water is to identify those emissions that are classed as transfers under the NPI. You are not required to report these emissions to the NPI. Other emissions (eg. discharges to surface water bodies such as streams and rivers) are required to be reported.

Integrated iron and steel plants may have a number of drains, each containing discharges from a number of sources. The smaller facilities may have only one drain.

For all facilities, only those drains discharging directly to the environment (including stormwater) need be reported under the NPI. Drains to sewer, trade waste, off-site or on-site treatment facilities and to storage facilities are classified as transfers and reporting is not required.

As discharges to water are highly process- and site-specific, most facilities perform some monitoring to characterise these emissions. While the NPI does not require facilities to conduct additional monitoring to characterise emissions, it is likely that most facilities which discharge to water will have at least some monitoring data which can be used to assist in the characterisation of emissions. Examples on the application of monitoring data to the calculation of emissions are provided below.

Where no monitoring information is available, guidance on the characterisation of process wastewater emissions is provided in the *Emission Estimation Technique Manual for Sewage and Wastewater Treatment.*

In general, estimation of emissions to water is best undertaken by aggregating the annualised contribution of all drain discharges, uncontained spills and uncollected emissions from on-site storage, to the environment.

The quantities of each reportable substance emitted from each drain would be estimated as follows:

Equation 9

$$\underset{(kg)}{\text{Quantity Emitted}} = \underset{(l)}{\text{Annualised Flow}} * \underset{(mg/l)}{\text{Concentration}} / \underset{(mg/kg)}{1000}$$

The quantities emitted from all drains would then need to be added together to give the total figure.

Examples

The following two examples will show how emissions can be estimated from point source discharges. The first example is relevant for wastewater streams that have a relatively constant daily flow rate and the measured concentration of the relevant compound in the stream does not vary greatly. The second example is relevant for streams that have more variable flow rates and composition (eg. stormwater).

Example 5 - Estimating Emissions from Stream with Constant Daily Flow Rates

The following information is known regarding the wastewater stream:

- the wastewater stream contains an average cadmium concentration of 500 mg/L;
- the stream is sent to an on-site wastewater treatment plant at a rate of 5 L/minute;
- after treatment, the stream leaving the plant contains 25 milligrams/L (and is discharged to a local water body); and
- the plant operates 24 hours per day for 330 days per year.

Using the data above, determine the quantity of cadmium emitted from the wastewater treatment plant.

STEP 1: Determine the annual quantity of wastewater discharged

$$\begin{aligned}\text{Volume} &= (5\text{ L/min}) * (60\text{ min/hour}) * (24\text{ hour/day}) * (330\text{ days/year}) \\ &= 2.4 * 10^{6}\text{ L/year}\end{aligned}$$

STEP 2: Determine the quantity of cadmium exiting the plant, using Equation 9

$$\begin{aligned}\text{Quantity emitted } E_{kpy,Cd} &= (2.4 * 10^{6}\text{ L/year}) * (25\text{ mg/L}) \;/\; 1 * 10^{6}\text{ mg/kg} \\ &= 60\text{ kg/year}\end{aligned}$$

Therefore, based on the calculations above, 60 kg/year of cadmium is discharged from the plant annually (and you are required to report this under the NPI as the discharge is to a water body).

Example 6 - Estimating Emissions from Streams with Variable Flow Rates and Composition

This example is a little more complex than the previous in that it requires the analysis of all monitoring data collated in a year from which an average can be derived. In this example, samples are taken fortnightly to measure the discharge flow from a site, as well as cadmium levels in the discharge. The data collected over a single year is presented in Table 12.

The daily emission is derived by multiplying the daily flow rate, by the measured level of cadmium. The annual emissions can be determined by combining the average daily emission shown in the table above by the number of days the wastewater treatment plant discharges per year.

For this example the plant is assumed to be operational for 300 days per year. Therefore, the annual emission estimate is derived as follows:

$$\begin{aligned}\text{Annual release} &= (1.17\text{ kg/day}) * (300\text{ days/year}) \\ &= 351\text{ kg.}\end{aligned}$$

Thus it is estimated that 351 kg of cadmium is emitted from the site annually

Table 12 - Measurement Data

Measured Flow (10^6 L/day)	Cadmium (µg/L)	Daily Release (kg)
1.660	918	1.52
1.576	700	1.10
1.668	815	1.36
1.760	683	1.20
1.456	787	1.15
1.360	840	1.14
1.828	865	1.58
1.696	643	1.09
1.852	958	1.77
1.656	681	1.13
1.904	680	1.29
1.724	628	1.08
1.476	807	1.19
1.568	729	1.14
1.292	964	1.25
1.208	722	0.87
1.432	566	0.81
1.288	510	0.66
1.320	630	0.83
1.288	630	0.81
1.632	652	1.06
1.768	649	1.15
1.424	695	0.99
1.560	758	1.18
1.692	658	1.11
1.948	970	1.89
Average Daily Release = 1.17		

10.0 Emissions to Land

Under the NPI facilities are required to report on their emissions to land. The NPI Implementation Working Group has defined emissions to land 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 substances, such receiving facilities are to be operating in accordance with any applicable State or Territory government requirements.

Emissions to receiving facilities such as secure landfills, sewers and tailings dams do not need to be reported. Similarly you are not required to report removal of a substance for transfer to another facility for destruction, treatment, recycling, reprocessing, recovery or purification. This means, for instance, that if an accidental emission of a water-borne pollutant is directed to a temporary bund or into a watercourse then it must be reported, regardless of whether the emission is detectable at the boundary of the facility.

If the emission is directed to and stored in a purpose built facility, for instance a rubber lined dam, then it does not need to be reported. However, all other emissions of NPI-listed substances except those that are directed to, and contained by, purpose-built receiving facilities are to be reported under the NPI, irrespective of whether the substance's fate is within or outside the reporting facility's boundary.

To characterise emissions to land, three general EETs are discussed here:

- groundwater monitoring;
- spills; and
- on-site disposal.

10.1 Groundwater Monitoring

Some facilities conduct monitoring of groundwater to characterise emissions from the facility. Where available, this monitoring data may be used to assist in the characterisation of emissions. This involves determining upstream and downstream concentrations and using this information, in conjunction with groundwater flow information, to determine the contribution of the facility to pollutant levels in the groundwater.

In terms of meeting NPI reporting requirements, this approach is reasonable in situations where there is no loss of substances (eg. due to evaporation) prior to the substance entering the groundwater and where the time between the emission occurring and the substance entering the groundwater is minimal. Therefore, for those facilities where groundwater monitoring captures all emissions to land, such monitoring can be used as a reasonable measure of emissions to the environment.

If this is not the case, (eg. where the rate of transmission through the soil/clay is low, or where there are other routes whereby substances to land are carried off-site, (eg. evaporation or surface run-off)), it will be necessary to characterise such emissions using the other EETs presented in this Manual.

10.2 Spills

For many facilities the primary source of releases will be through spills (this may also include intentional spillage due to vessel washdown). Accidental spills can contribute to releases to land (directly), to water (through run-off) and to air.

Unless spilled material is routed to a secure containment facility, the quantity of material spilled less any material that is collected must be reported under the NPI. In practical terms, a log of spillages could be maintained, detailing the quantities spilled and the composition of the spill (in particular, the quantities of NPI substances spilled). This log could then form the basic information required to meet NPI reporting requirements.

If any spilled material enters a stream or dam, it must be reported as an emission to water. Note that if the spill is a volatile liquid, it may be suitable to assume that the entire light end fraction is volatilised and the remaining liquid is emitted into the ground or water. However, if the liquid is not volatile and no material is collected, it may be reasonable to assume that all material is emitted to the land or water. The time, quantity of spill, temperature and porosity of the soil all play an important part in the estimation of emissions.

Once losses to the atmosphere have been quantified, releases to land can be estimated using the following equation:

Equation 10

$$EF_i = 1.2 * 10^{-10} (MW_i (p^o_i) / T) U^{0.78} * X^{0.89} * Y$$

where:

EF_i = evaporation rate (Emission factor) of pollutant ‘i’ (g / s)
U = wind speed over the surface of the spill (cm / s)
X = downwind dimension (cm)
Y = crosswind dimension (cm)
MW_i = molecular weight of ‘i’ (can be obtained from Perry & Green (1997) or other standard chemical engineering reference texts)
p^o_i = vapour pressure of substance ‘i’ at spill temperature T (dyne / cm^2 = 0.0001 kPa)
T = temperature (K)

Total emission to air = time * EF_i (g / event)

Once losses to the atmosphere have been quantified, releases to land can be estimated using the following equation:

Equation 11

$$EL_i = (Qtty_{SPILL} - [(time) * (EF_i)]) / 1000 \ (g / kg)$$

where:

EL_i = emission to the land of compound ‘i’,
kg / spill event [a]
$Qtty_{SPILL}$ = quantity of compound in the liquid spilled
E_i = loss through evaporation of substance ‘i’
as estimated using the evaporation equation 10 above.
Time = time period between when the liquid
was initially spilled and the eventual clean up.

[a] If there is an emission to a stream or dam then EL_i must be subdivided and the fractions emitted to land and water must be reported separately.

10.3 On-Site Disposal

Facilities with on-site disposal of wastes will need to consider whether the disposal is classed as a transfer or as an emission to land under the NPI; see Section 10 Emissions to Land. If the disposal is not a transfer, reporting will be required under the NPI. In a similar manner to spills, the most effective EET would be to maintain a record of all such disposals to land and, in particular, the amount of NPI substances contained in the material disposed of in such a manner.

11.0 Glossary

Reference should be made to the National Pollutant Inventory and the *NPI Guide* for definitions of terms used within the NPI system.

Baghouse	Gas cleaning device where filter bags are used to effect particulate removal from a gas stream.
BF gas	Blast Furnace gas.
Blooms	Intermediate rolled or cast steel square/rectangular section. Cross sectional area is intermediate between that of an ingot and a billet ie. 150 mm to 300 mm in dimension.
BOF	Basic Oxygen steel making Furnace.
BTX	Nominal cut of benzene, toluene and xylene.
Cast House	Building where ingots are cast.
Charging	Loading of raw materials into a process.
COG	Coke Oven Gas.
Coke Battery	A series of coke ovens operated together
Coke Breeze	Size fraction of coke. Typically < 3 mm, it is used as a fuel in sintering and pelletising operations in particular
Cyclone	Gas cleaning device utilising centrifugal forces to remove particulate matter.
EAF	Electric Arc steel making Furnace.
EET	Emission Estimation Technique.
Emission	Any release of substances to the environment whether in a pure form or contained in other matter. Emissions may be solid, liquid or gaseous.
Emission Factor (EF)	A number that can be multiplied by an activity rate or throughput data from a facility to estimate emissions from that facility without the need for sampling or analysis. The technique is most often used to estimate gaseous emissions to the environment.
ESP	Electrostatic Precipitator used for removal of particles from a gas stream by inducing electrostatic charge.
Flare	Equipment for combustion of surplus gas via stack
kish	Fine graphite flake produced when iron saturated with carbon is cooled
slip	With reference to discussion regarding blast furnaces, it is an irregular burden stock movement within the furnace. With reference to discussion regarding coke ovens, it is the uncaptured quantity of a vapour species downstream of its corresponding removal process. (Typically light oil or ammonia).
Mass Balance Technique	Estimation of emissions to the environment through accounting of inputs, accumulations and outputs for a particular process or facility.
make	production.

MSDS	Material Safety Data Sheets.
Nominal Cut	With reference to discussion regarding coke ovens by-products, it is a term referring to the organic compound(s) within a particular boiling point range or molecular weight range distilled from a mixture of organic compounds.
PM_{10}	Particulate matter with an equivalent aerodynamic diameter of 10 micrometres or less ie. $\leq 10\mu$m).
Pushing	Coke ovens operation where coke is removed from the coking oven using a hydraulic ram mounted on a “Ram Car”.
Scarfing	Removal of surface impurities and imperfections using high temperature oxygen enriched flames.
Stock houses	Building for the housing of blended process feed material. Typically a stock house is employed to avoid wind losses from stockpiles or where the material or its properties are water sensitive.
Strand	Mobile continuous hearth on a sintering plant.
Teeming	Pouring of molten steel into moulds for solidification.
Venturi Scrubber	Gas cleaning device where an accelerated air stream containing particulate matter is violently and intimately contacted with a liquid (usually water). The violent contact wets the particles facilitating removal from the gas.
VOCs	Volatile Organic Compounds (will be defined on the NPI WebPages).
Windbox	A steel chute forming a close fit with a mobile grate or hearth. Connected to the suction side of a fan by the windmain, the close fit of the windbox to the hearth creates a suction drawing a flamefront down through the material bed above.
Windage	Material emission resulting from wind action on the surface of exposed stockpiles.

12.0 References

ANZSIC: Australian and New Zealand Standard Industrial Classification
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USEPA (1995) *Compilation of Air Pollutant Emission Factors AP-42, Volume I: Stationary Sources, Fifth Edition, 1995*, Office of Air Planning and Standards, Office of Air Quality Planning and Standards, US EPA, Research Triangle Park, 1995 (AirChief CD-ROM, 1997, Version 5.0)
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 Authority:

- Emission Estimation Technique Manual for Organic Chemical Processing Industries;
- Emission Estimation Technique Manual for Fuel and Organic Liquid Storage;
- Emission Estimation Technique Manual for Mining;
- Emission Estimation Technique Manual for Combustion Engines;
- Emission Estimation Technique Manual for Combustion in Boilers;
- Emission Estimation Technique Manual for Sewage and Wastewater Treatment;
- National Industry Handbook for Cement and Lime Manufacturing;
- Emission Estimation Technique Manual for Surface Coating;
- National Industry Handbook for Fertiliser Manufacturing, including Emission Estimation Technique Manual for Ammonium Sulfate Manufacturing;
- Emission Estimation Technique Manual for Fugitive Emissions; and
- Emission Estimation Technique Manual for Ferrous Foundries.