National Pollutant Inventory

Emission Estimation Technique Manual

for

Mineral Sands Mining and Processing
Version 1.0

Environment Australia

Version 1.0 - published on 6 April 2001

ISBN: 06 4254 6924

www.npi.gov.au

This manual may be reproduced in whole or part for study or training purposes subject to the inclusion of an acknowledgment of the source. It may be reproduced in whole or part by those involved in estimating the emissions of substances for the purpose of National Pollutant Inventory (NPI) reporting. The manual may be updated at any time. Reproduction for other purposes requires the written permission of Environment Australia, GPO Box 787, Canberra, ACT 2601, e-mail npi@ea.gov.au, internet address www.npi.gov.au or phone 1800 657 945.

Disclaimer

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

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

Erratum for Mineral Sands Mining and Processing EET Manual (Version 1.0 - 6 April 2001).

Page	Outline of alteration
	None to date

EMISSION ESTIMATION TECHNIQUES
FOR
MINERAL SANDS MINING AND PROCESSING

TABLE OF CONTENTS

APPENDICES

Mineral Sand Mining and Processing
List of Figures, Tables, Equations and Examples

FIGURES

TABLES

EQUATIONS

EXAMPLES

1.0 Introduction

1.1 The NPI

The National Pollutant Inventory (NPI) is an Internet database, providing information on the types and amounts of identified substances emitted to air, land and water environments. The data, or subsets of it, are available in other medium such as an annual summary report and CD. In order to provide useful and reliable information to the community, industry, and Government, Emission Estimation Techniques (EETs) used to generate data for the NPI must be consistent, and the process for developing these techniques needs to be transparent. This EET manual has been developed, reviewed, and finalised in this context.

Users of this EET manual may refer to the NPI National Environmental Protection Measure (NEPM) document, Memorandum of Understanding and the *NPI Guide* for further information concerning the NEPM or NPI.

1.2 Purpose and Scope of this Manual

The purpose of all EET Manuals is to assist Australian manufacturing, industrial, and service facilities to estimate, and report emissions of NPI listed substances. This Manual describes the procedures, and recommended approaches for estimating emissions from facilities engaged in mineral sands mining and processing operations.

This EET manual is one of many that form an NPI Industry Handbook for the Mineral Sands Mining and Processing Industry. Together these manuals provide the EETs necessary for the quantification of emissions of NPI substances required to achieve NPI reporting.

The activities covered in this Manual include mineral sands mining, dry separation of mineral sands from Heavy Mineral Concentrate (HMC), and synthetic rutile processing.

EET MANUAL:	Mineral Sands Mining and Processing
HANDBOOK:	Mineral Sands Mining and Processing
ANZSIC CODE:	1315

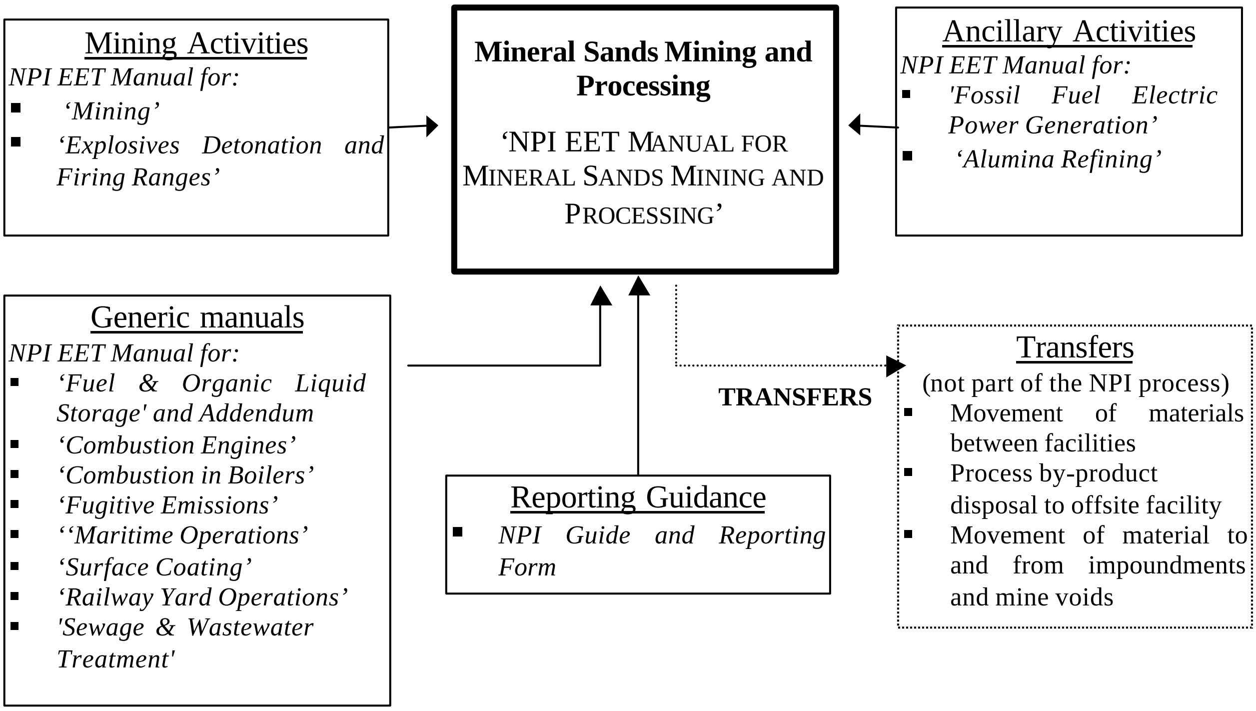
This Manual was drafted by PPK Environment and Infrastructure Pty Ltd, in conjunction with the Titanium Minerals Committee, and the NPI Unit of the Western Australian Department of Environmental Protection (DEP), on behalf of the Commonwealth Government. It has been developed through a process of national consultation involving State and Territory environmental authorities, and key industry stakeholders.

It is recognised that the data generated by the NPI process will have varying degrees of accuracy with respect to the actual emissions from mineral sands mining and processing facilities. In some cases there will be a large potential for error due to the inherent assumptions incorporated in EETs and/or a lack of available information concerning chemical processes. In light of this it is necessary to understand that for the purposes of NPI reporting the concept of “best endeavours” will be applicable in some cases.

This EET Manual aims to provide the most effective EETs available at the time of publication for the NPI substances relevant to the mineral sands mining and processing industry. However, the absence in this manual of an EET for a specific substance or source does not necessarily indicate that any known emissions should not be reported to the NPI. The obligation to report all relevant substance emissions exists where NPI reporting thresholds have been exceeded and it is reasonable to assume that a reportable substance has been emitted.

The scope of this manual is presented diagrammatically in Figure 1. The latest version of the EET Manuals and the NPI Guide that make up Industry Handbooks is on the NPI Internet site, www.npi.gov.au.

Figure 1 Mineral Sands Mining and Processing Manual' relationship with other EET manuals



1.3 Structure of Manual

The manual is structured to allow facilities to address NPI issues in a logical and coherent manner.

Section 2 presents an overview of mineral sands mining and processing and indicates the likely emission sources involved.

Section 3 describes the NPI reporting process, and lists likely sources of NPI reportable emissions associated with mineral sands mining and processing activities.

Section 4 provides background data on the various types of EETs and principles of their application

Section 5 lists emission estimation techniques for emissions to air.

Section 6 lists emission estimation techniques for emissions to water.

Section 7 lists emission estimation techniques for emissions to land.

Section 8 Glossary of technical terms and abbreviations.

Section 9 References

Background information concerning both the NPI process, and the mineral sands mining and processing industry, is available in the appendices as follows:

Appendix A provides generic assay data for various materials that may be present at mineral sands mining and processing facilities.

Appendix B details sources of existing data that may be used in the NPI reporting process.

Appendix C describes the use of emission controls and their impact on emission estimation.

Appendix D describes the substance thresholds and their application.

Appendix E provides information regarding the application and limitation of the EETs available.

Appendix F provides guidance to possible errors associated with different EETs.

Appendix G defines variables and symbols used in this manual.

This manual was developed for use in conjunction with other NPI EET Manuals and, where appropriate, specific manuals have been referred to in the text. Since publication of the various manuals, some EETs provided have been superseded. Where relevant the updated EETs have been provided in this manual.

1.4 Location of Information

EETs presented in this manual have been categorised according to the source equipment, activity, or process. A variety of techniques including mass balance, engineering calculations, direct monitoring, and emission factors may be applicable to each emission source. For more information on the different types and accuracy of available EETs, see Appendix E and Appendix F.

A quick reference guide to the relevant section/s corresponding to different EETs covered in this manual is provided in Table 1.

Table 1 Location of emission estimation techniques in this manual

Emission Source	Emission type	Section in this Manual
Emissions to Air		5.0
Dust		5.2
Mining		5.3
Fuel combustion in mining equipment	Fugitive	5.3.1
Blasting	Fugitive	5.3.2
Dredging	Fugitive/Point	5.3.3
Hydrocycloning and wet concentrating	Fugitive/Point	5.3.4
Burning of cleared vegetation	Fugitive	5.3.5
HMC separation		5.4
Dust emissions	Fugitive	5.4.1
Dryers	Point	5.4.2
Acid washing and leaching	Fugitive	5.4.3
Synthetic Rutile processing		5.5
Dust from storage and handling of ore and coal	Fugitive	5.5.1
Reduction kiln	Point/Fugitive	5.5.2
Rotary Coolers	Fugitive	5.5.3
Separation	Fugitive	5.5.4
Aeration	Fugitive	5.5.5
Leaching	Point/Fugitive	5.5.6
Drying	Point/Fugitive	5.5.7
Spontaneous coal combustion	Fugitive	5.5.8
Gases from final product	Point/Fugitive	5.5.9
By-Product treatment and disposal		5.6
Product transportation and handling		5.7
Dust from product transfer	Fugitive	5.7.1
Combustion emissions	Fugitive	5.7.2
Spills	Fugitive	5.7.3
Maintenance activities		5.8
Solvent degreasing	Fugitive	5.8.1
Welding	Fugitive	5.8.2
Surface coating/painting	Fugitive	5.8.3
Spills and incidents		5.9
Storage tanks		5.10
Fossil fuel electric power generation		5.11
Stationary internal combustion engines		5.12
Emissions to Water		6.0
Runoff and erosion		6.2
Discharge of treated waters		6.3
Spills to surface waters		6.4
Emissions to Land		7.0
Impoundment seepage		7.2
Spills and incidents		7.3
Surface applications		7.4

2.0 NPI Reporting Process

The following is a brief overview of the NPI reporting process including triggers calculation, emissions estimation, and reporting. Additional background information is available in the *NPI Guide*.

Step 1 – Define Facility

In the first instance operators must define the boundaries of the individual facilities to be reported on. When defining the number of facilities the following guidelines should be applied:

> *If two or more sites are less than 2 km apart they should be regarded as one facility unless residential areas are situated between the sites. For sites between 2 km and 10 km apart the occupier can choose to report as one or two facilities unless residential areas are situated between the sites. Sites more than 10 km apart should be treated as separate facilities. When determining the distance between sites, the shortest distance between the site boundaries should be used rather than the geographic centres of the sites. However, tailings storage facilities (TSFs) are deemed to be part of the facility for which the waste emanates irrespective of the distance between the TSF and the waste source. (DEP 2000)*

For the case of by-product impoundment process steps the same criteria for determining which NPI reporting facility they are included in is used as for TSFs.

Some operations may elect, or be required to report for a number of separate facilities (e.g, mining as one facility and processing as another). Emissions resulting from mobile activities occurring between separate facilities, such as ore haulage and other transportation, need not be reported (DEP 2000). Further clarification on defining facilities should be obtained from the relevant State or Territory NPI Unit.

Step 2 - Substance Identification

Identify and list all NPI substances and materials used, and/or produced in mining and mineral extraction processes at each facility during the reporting period. This will include determining the composition of some materials that may contain NPI substances. Remember to consider all associated auxiliary activities, and types of coincidental production.

Step 3 – NPI Substance Lists

Compare the substance list generated in step two with the NPI substance lists provided in the *NPI Guide*. Isolate any substances used or produced at the facility that are listed in NPI Categories 1, 1a and 3. These substances will need to be assessed against the category thresholds (see Appendix D) to identify those that trigger NPI reporting. Any NPI listed substance that exceeds the relevant category threshold at the facility will require emissions estimation and reporting.

Substances likely to trigger reporting at mineral sands mining and processing facilities are listed in Table 2.

Step 4 – Quantify Substance Use and/or Production

Determine the quantities of each listed substance used or produced at the facility, taking all activities into account.

Quantities of fuel and energy consumed are also required. When determining triggers or carrying out threshold calculations, calculate estimates for those areas representing the main bulk of handling of listed substances (reagents, ore and waste and fuels) first. These areas will often determine the majority of triggers exceeded and can lessen the amount of investigation into lesser substance usage. Once an NPI substance is triggered in one particular area of a facility other uses of that substance need not be investigated (until emissions determination). For example, a facility may use 3,200,000 litres (2675 tonnes) of diesel during a reporting year and trigger the category 2a and 2b threshold. Fuel consumption of over 2,000 tonnes triggers reporting to the NPI 21 substances some of which are category 1 substances also. Of these 21 substances 13 are from the Table 1 substances required to be reported for the first 3 years of the NPI, 1998-1999, 1999-2000, and 2000-2001. Facilities can report the full list of substances for these years of the program as it may decrease reporting costs for future years to put in place systems necessary for reporting. As these substances are triggered by threshold 2a/b they will require no further triggers (reporting threshold) investigation, but will probably need to be examined further when estimating emissions. These substances will require their emissions to be estimated and reported to the NPI.

Step 5 – Identify Threshold Exceedance ("triggers")

Compare the quantities of listed substances used or produced at the facility against the relevant NPI category thresholds. Category 2a and 2b thresholds refer specifically to fuel use and energy consumption. Where category thresholds are exceeded, substances are referred to as "triggers" or "triggered" substances, and require emissions estimation and reporting.

Step 6 – Emissions Estimation

Estimate emissions of each triggered substance from all facility sources using the most appropriate EETs. Sections 5.0, 6.0 and 7.0 list recommended techniques for estimating emissions of various substances from mineral sands mining and processing facility sources. Only triggered substances require reporting. However, if a substance is triggered it must be reported, even if emissions are zero.

Step 7 - Report

Complete the NPI Reporting Form (see Section 2.1 below) and return to the appropriate environmental authority. The reporting form is available from your State or Territory NPI Unit.

Remember

1. Only triggered substances require reporting.
2. Reporting facilities should apply a reasonable level of pragmatism regarding the level of detail or investigation applied when determining triggers and estimating emissions. Consideration should be given to the overall level of accuracy of estimates and the relative contribution of lesser sources. For example, some fugitive losses may be insignificant in comparison to the overall or main emission source (e.g. <1% of the total emissions of a substance); if so their omission will not alter the accuracy of the reported value significantly.
3. If a substance is below normal accepted analytical detection limits it may be assumed that it is not present and therefore not emitted.
4. If emissions of a triggered substance are believed to occur for which no EETs are provided in the relevant manuals, every reasonable effort should still be made to estimate those emissions.
5. Deposition/disposal of NPI substances to "purpose built" storage/containment facilities such as tailings storage facilities, are not reported under the NPI as emissions; these are considered to be transfers. However, releases from such facilities, such as seepage and wind blown dust, are emissions and should be reported as such.
6. The movement of materials without significantly altering them (e.g. concentrating, changing the chemical form or the addition of substances) is not reportable, providing they do not result in the emission of contained substances (through seepage, weathering or other such means).
7. Substances released under the context of "beneficial use" are not considered emissions (e.g, use of waste products as soil ameliorants). However, advice should be sought from relevant State or Territory Authorities regarding the classification of releases in this context prior to reporting (or not).

Wherever there is any doubt regarding NPI reporting, classification of emissions or otherwise, clarification and advice should be sought from your local NPI Unit members.

2.1 Reporting Requirements

Each facility is required to complete the appropriate section of the reporting form for each triggered substance (refer to *NPI Guide)*. This involves specifying the estimated quantity emitted (in kilograms per year) and the initial destination environment for each emission - air, water and/or land. The form also requires identification of the EET used to estimate these emissions.

For more detailed information concerning category thresholds and reporting requirements refer to the *NPI Guide*. (Appendix D also provides further guidance on the application of NPI reporting thresholds).

2.2 Likely Triggers and Determining Threshold Exceedance

Table 2 lists NPI substances likely to be relevant to Mineral Sands Mining and Processing facilities, and indicates appropriate methods for triggers determination. This table is intended as a guide only, and each facility should undertake a thorough substance inventory to provide a more accurate, facility specific list, and assess triggers determination methodology accordingly.

Table 2 NPI listed substances likely to trigger reporting, and proposed methodology for determining if the NPI threshold is exceeded.

SUBSTANCE	TRIGGER TYPE	THRESHOLD CATEGORY	METHOD
Ammonia (total)	Use (processing reagent)	1	INV
Antimony & compounds	Use (ore and coal content)	1	DM, GF
Arsenic & compounds*	Use (ore and coal content)	1	DM, GF
	Fuel or power use	2b	INV, C
Benzene*	Use (fuel content)	1	INV, GF
Beryllium & compounds	Use (ore and coal content)	1	DM, GF
	Fuel or power use	2b	INV
Boron & compounds	Use (ore and coal content)	1	DM, GF
Cadmium and compounds*	Use (ore and coal content)	1	DM, GF
	Fuel or power use	2b	INV, C
Carbon monoxide*	Fuel or power use	2a	INV, C
Chromium (III) compounds	Use (ore and coal content)	1	DM, GF
	Fuel or power use	2b	INV, C
Chromium (VI) compounds*	Fuel or power use	2b	INV, C
Cobalt & compounds*	Use (ore and coal content)	1	DM, GF
Copper & compounds	Use (ore and coal content)	1	DM, GF
	Fuel or power use	2b	INV, C
Cumene (1-methylethylbenzene)	Use (fuel content)	1	DM, GF
Ethylbenzene	Use (fuel content)	1	DM, GF
Fluoride compounds*	Use (ore and coal content)	1	DM, GF
	Fuel or power use	2a	INV
Hydrochloric acid	Use (processing reagent)	1	INV

Table 2 cont'

SUBSTANCE	TRIGGER TYPE	THRESHOLD CATEGORY	METHOD
Hydrogen sulfide	Use (coincidental production)	1	DM, EC
Lead & compounds*	Use (ore and coal content)	1	DM, GF
	Fuel or power use	2b	INV
Magnesium oxide fume	Fuel or power use	2b	INV, C
Manganese & compounds	Use (ore and coal content)	1	DM, GF
Mercury & compounds*	Use (ore and coal content)	1	DM, GF
	Fuel or power use	2b	INV
Nickel & compounds	Use (ore and coal content)	1	DM, GF
	Fuel or power use	2b	INV, C
Nickel carbonyl*	Fuel or power use	2b	INV, C
Nickel subsulfide*	Fuel or power use	2b	INV, C
Oxides of nitrogen (NOx)*	Fuel or power use	2a	INV, C
Particulate matter (<10um)*	Fuel or power use	2a	INV, C
Polychlorinated dioxins and furans	Fuel or power use	2b	INV, C
Polycyclic aromatic hydrocarbons*	Fuel or power use	2a	INV, C
Selenium & compounds	Use (ore and coal content)	1	INV, GF
Styrene (ethenylbenzene)	Use (fuel content)	1	INV, GF
Sulfur dioxide*	Use (coincidental production)	1	DM, EC
	Fuel or power use	2a	INV, C
Sulfuric acid*	Use (processing reagent)	1	INV
Toluene (methylbenzene)*	Use (fuel content)	1	INV, GF
Total Nitrogen*	Discharge to surface waters	3	DM, EF
Total Phosphorus*	Discharge to surface waters	3	DM, EF
Total volatile organic compounds	Use (fuel)	1a	INV, C
	Fuel or power use	2a	INV
Xylenes (individual or mixed isomers)*	Use (fuel content)	1	INV, GF
Zinc & compounds	Use (ore and coal content)	1	DM, GF

* Substances included in Table 1 of the *NPI Guide*

Notes:

DM:	Direct Measurement	→	Direct measurement of NPI reportable emissions in the discharge stream (total N and P) , or characterisation of the material;
INV:	Inventory	→	Inventory or material use (chemicals, fuel), with NPI content of materials identified;
GF:	Generic Factor	→	Generic factor applies to default concentrations to be used in the absence of facility-specific data;
EF:	Emission Factor	→	Emission factor to determine content in discharge stream (e.g. total N and P);
C:	Capacity	→	Capacity applies to the storage capacity of a facility, maximum combustion rate, consumption of energy or potential maximum power consumption; and
EC:	Engineering Calculation	→	Engineering calculations may be used for a number of substances such as sulfur dioxide.

Please note that while the reporting threshold for a substance may not be triggered during one reporting period, it may be triggered in a following reporting period. It is important to review NPI reporting requirements each reporting period.

3.0 Industry Description

Heavy mineral sands deposits are made up of various assemblages of titanium-bearing minerals, such as rutile, leucoxene, ilmenite, xenotime and monazite (containing rare earth metals), and the industrial minerals zircon, kyanite, and garnet. Mineral sands mining operations are currently located on Australia's east coast in northern NSW and southern Queensland, and in the south west of Western Australia. Dry mills and synthetic rutile plants are located in Western Australia at Geraldton, Eneabba, Muchea, Bunbury and Capel.

Titanium is mainly used in white paints and dyes, and in some alloys where properties of high heat resistance and high corrosion resistance are required. Zircon, because of its high melting point (>2,500 degrees Celsius), is used for manufacturing refractory bricks, ceramics and glazes. Monazite is mainly used in visual electronics.

The production of mineral sands generally follows a three-stage process:

- Mining – dredge or dry mining;
- Concentration and separation – using gravitational, magnetic and electrostatic processes; and
- Synthetic rutile production – involving chemical reduction, leaching, aeration and physical separation.

Representative processes are discussed below, and example flow diagrams are provided as a source of reference. Facilities are advised to use their own specificprocess flow diagrams to assist in structuring and addressing the NPI reporting process and requirements.

Some facilities do not produce synthetic rutile, undertaking physical separation processes only. Other facilities may need to divide their mining and synthetic rutile production operations into separate facilities for the purpose of NPI reporting because of their physical separation (see Section 2.0, Step 1). As such, not all sections of this manual will be relevant to each facility.

The Mineral Sands and other mining and mineral processing operations produce various waste material streams which are generically called tailings. Tailings are the sludge, mineral residue and wastewater (apart from final effluent) resulting from ore extraction and processing. Tailings vary widely in properties and constituents depending on the mineral being processed and the extraction process used. In turn the environmental impact and human health effects that tailing have vary widely. Some sectors of the Mineral Sands industry are using terms other than tailings to reflect more accurately the nature of the various process streams in their operations. In future the terminology used by the NPI may be altered, where appropriate, to reflect changes in terminology used and understood by various sectors of the community.

3.1 Mining

Mining begins with the removal of vegetation (and subsequent burning or use in land rehabilitation) from the mine site, and the removal and stockpiling (or transfer to previously disturbed sites) of topsoil and sub-soil. Orebodies are often interspaced by non-mineralised material (overburden and interburden) which must be removed to gain access to the ore. This is either stockpiled or backfilled into voids from previously mined areas. Revegetation is often part of the operations at mineral sand mining and processing facilities. Replanting of removed vegetation often occurs for embankment stabilisation and as a seed resource for future revegetation.

Mineral sands bearing ores (and the associated soils and overburden) are recovered by either wet dredging or dry mining techniques. The technique used is largely dependent on the location of the orebody in relation to the local groundwater.

Dredge mining involves the recovery of ore from a void filled with groundwater. The dredge utilises a cutting head to disturb the ore, which is then recovered as a slurry, and pumped to a wet separation plant via a floating pipeline. Water is often added to the dredge pond to maintain optimum water levels for operation.

Dry mining uses conventional mining equipment, generally scrapers for overburden removal and loaders for ore recovery, although excavators and haul trucks may also be used. The recovered ore is screened to remove oversized material, slurried, and then passed through a trommel to remove any remaining oversized material.

3.2 Concentrating

Recovered ore is passed through a heavy mineral recovery plant to yield heavy mineral concentrate (HMC). The heavy mineral sands are separated from the lighter tailings (waste material) using gravity spirals. Tailings are then either returned directly to the mine void, or placed in drying ponds from which water may be recovered for re-use. Solids are later returned to the mine void, or sealed and rehabilitated. Flocculants are often used on tailings prior to release, to allow for better decant recovery and void fill ratios.

3.3 Dry/Wet Separation of HMC

HMC is passed though various separation processes to recover the minerals present. Separation exploits the physical properties of each different mineral, including conductivity (electrostatics), magnetism (magnetic), and density (gravity) to isolate the various minerals. This produces the saleable product for the majority of mineral sands. Only zircon and ilmenite receive further treatment. Zircon processing may include acid washing to improve the cosmetic value of the product. Some ilmenite may be further processed to produce high-grade synthetic rutile as described in 3.4 below.

The non-valuable tailings process streams are generally stockpiled before being returned to the mine void, or used in waste pond construction.

3.4 Synthetic Rutile Production

In some cases ilmenite product may be processed further to yield a higher-grade synthetic rutile product. This is achieved using reduction kilns to remove iron from the mineral matrix by reducing it to metallic iron. Coal is used as the fuel source and sulfur or boron compounds as reducing agents; the ilmenite ore is passed through a reduction kiln.

The ilmenite is separated from any char and aggregates that may have formed during reduction, and is passed through an aeration phase. During this phase ammonium chloride is used as a catalyst to oxidise the iron, which can then be separated from the synthetic rutile using cyclones. Prior to drying and shipment the product is passed through a leaching stage using sulfuric acid to remove any remaining impurities (Mulligan 1996).

Wastes produced during this process are dewatered either in tailings storage ponds or using filtration systems and are then sealed in mine voids or remain in the ponds and are rehabilitated.

Most wastewaters are reclaimed and returned to the process although some are treated and released to the environment.

The following figures (Figure 2 to Figure 4) are generic flow charts showing processes and main associated emissions. They are intended as a guide only. Each facility may differ from these and should assess their own processes for potential emission sources.

Figure 2 Mining and concentrating - processes and likely emissions

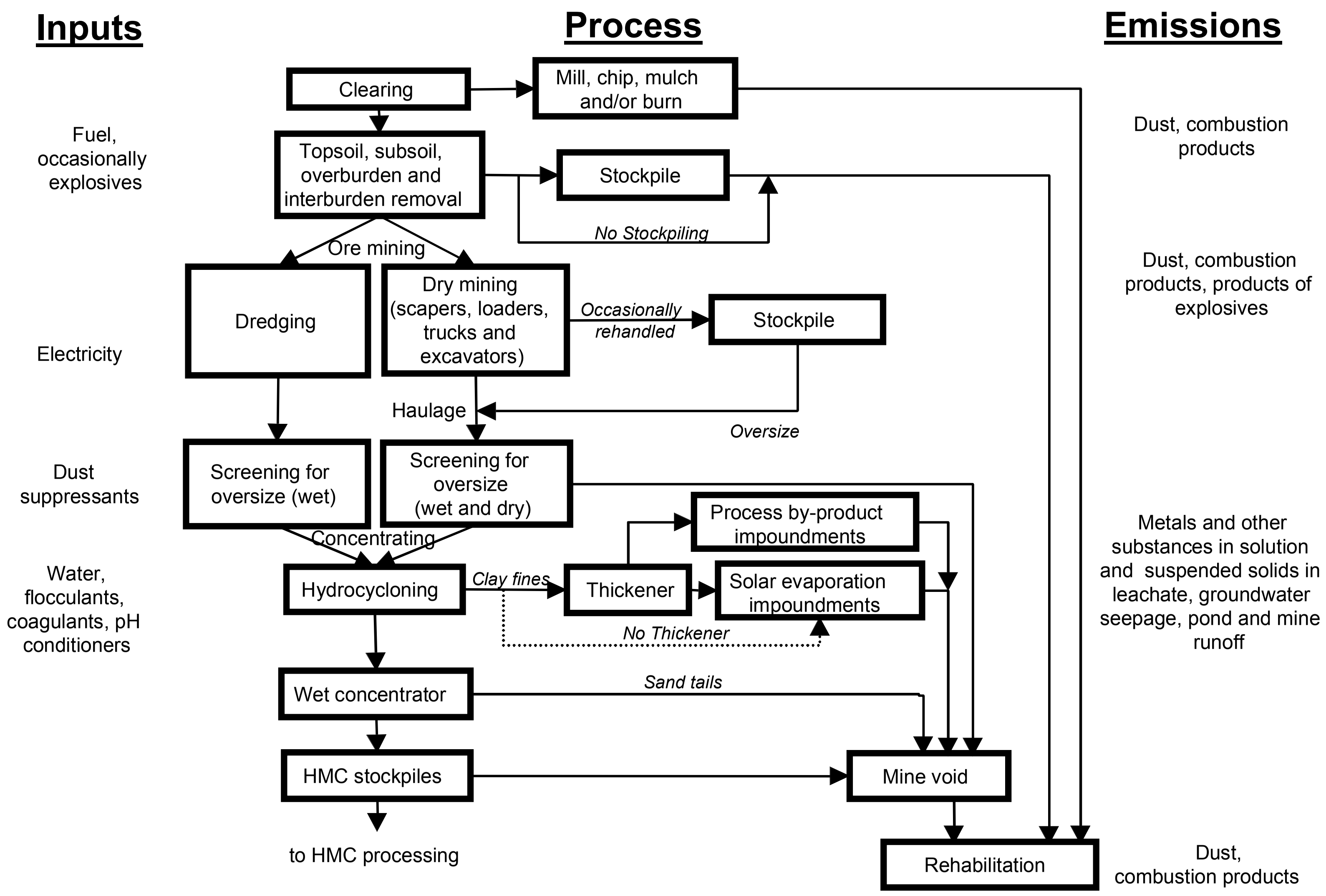


Figure 3 HMC separation - processes and likely emissions

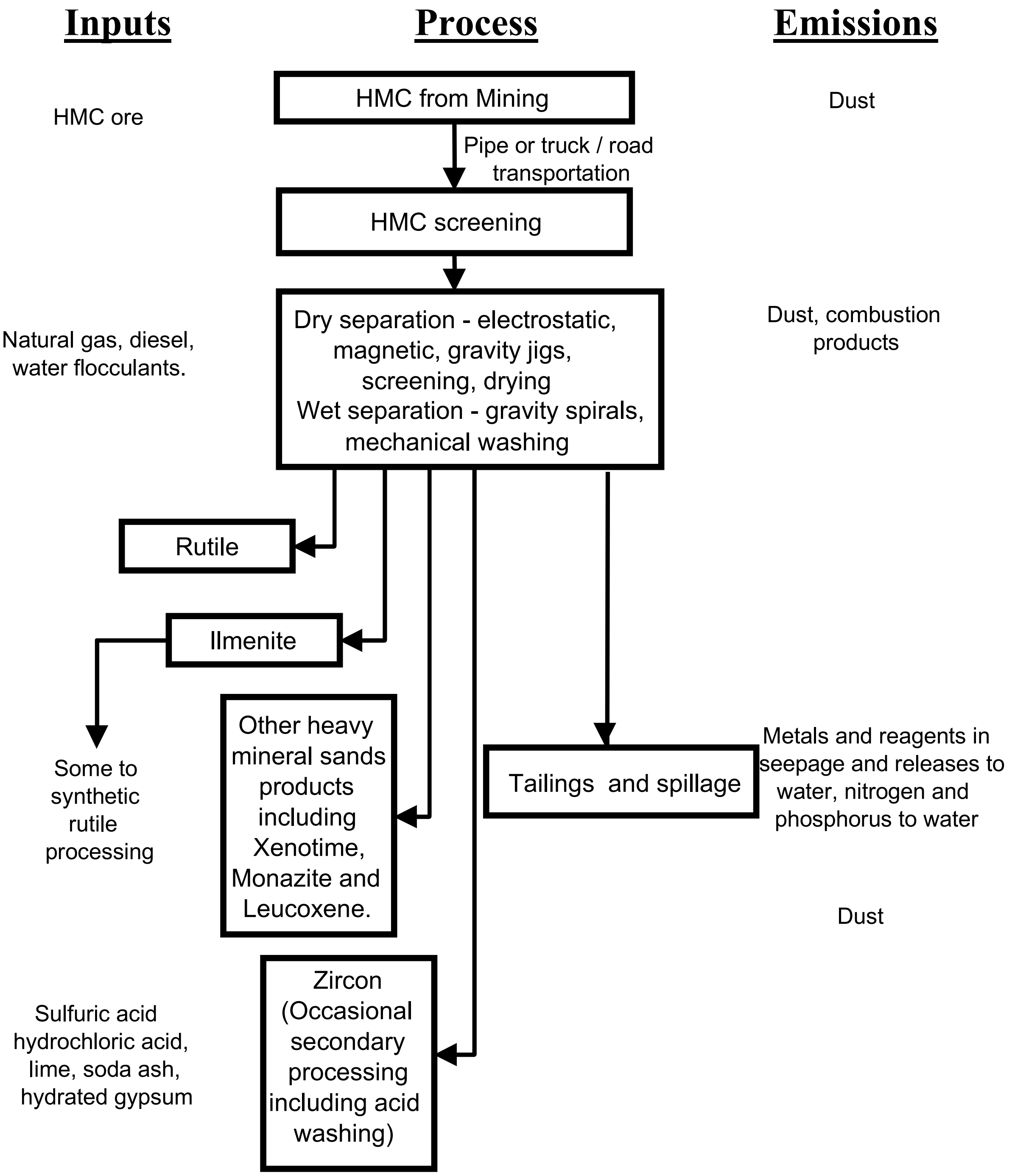
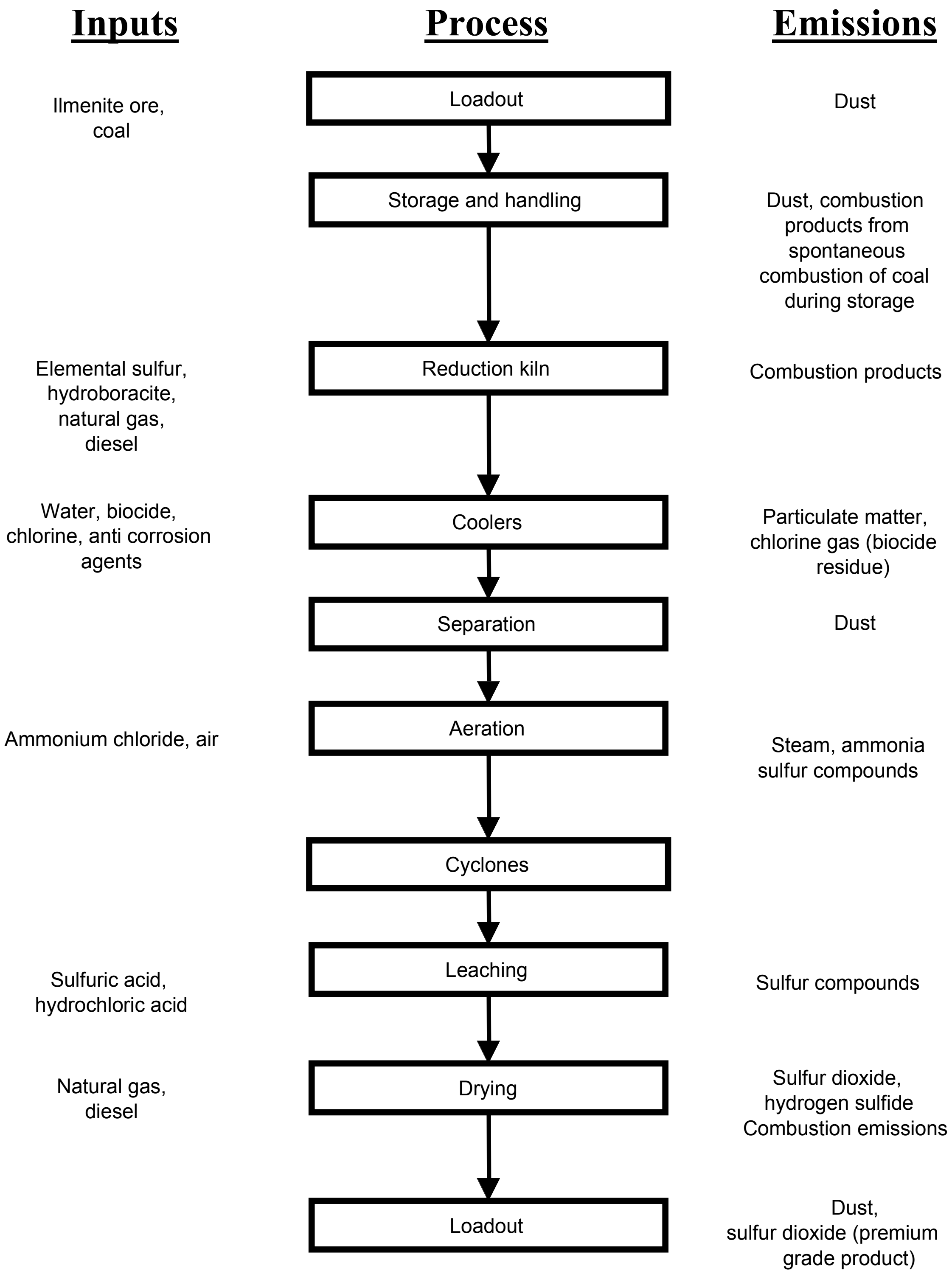


Figure 4 Synthetic rutile processing - processes and likely emissions



3.5 Associated Facilities

Activated carbon is a by-product of mineral sands processing which has commodity value. There are no known emissions associated with the production and handling of this product although it is possible they do occur. Activated carbon may contain residual trace, or occasionally elevated levels of NPI substances concentrated by the reduction process. The movement or sale of these materials within or from the facility is not considered as an emission.

3.6 Ancillary Activities

There are a number of ancillary activities associated with mineral sands mining and processing that result in emissions that may be reportable. Examples include fuel storage, power generation and maintenance activities. Generic manuals for these activities are available and listed in Figure 1.

3.6.1 Fuel and Organic Liquid Storage

Storage of fuel and other organic liquids is likely to occur at mineral sands mining and processing facilities. Bulk liquid fuels held on site may include gas fuels (LPG and LNG), diesel, petrol, or oil. Emissions resulting from the volatilisation of these fuels during storage, transfer and transport may need to be estimated for NPI reporting purposes. Small quantities of other organic materials may be used in processing operations, analytical procedures, or maintenance purposes, and may also require consideration.

3.6.2 Fossil Fuel Electric Power Generation

Fossil fuel electric power generation systems are delineated into steam plants, gas turbines, co-generation, and internal combustion generation. It is likely that most mineral sands facilities either draw power from the state electric power grid, or generate power from kiln waste heat or internal combustion engines. Petrol, natural gas, distillate and/or LPG internal combustion engines and generators are commonly used to provide electricity in remote areas, and for stand-by (emergency) purposes. Any emissions from fossil fuel electric power generation undertaken within facility boundaries must be considered in the NPI process.

3.6.3 Maintenance Activities

Materials used in maintenance activities often contain NPI substances that, during use, may be released to the environment. For example, maintenance activities involving the use of degreasers, likely to contain volatile organic compounds, may result in emissions to air, land and/or water during use, or at disposal.

Components of all washdown water streams need to be considered when calculating emissions to water and land, as this effluent may contain metals, volatile organic compounds, benzene, toluene, ethylbenzene and xylenes (BTEX) species, polycyclic aromatic hydrocarbons, sulfuric acid and descaling chemicals. Although these emissions are likely to be insignificant in comparison to those from other sources, each facility should investigate all chemicals used in maintenance activities to ensure that all relevant NPI emissions are captured.

Other emission sources associated with maintenance activities that may be present at mineral sands facilities include welding, painting, and sand blasting. Products used for these purposes, and any waste materials generated, may result in NPI emissions and should be investigated.

4.0 Definition of EETs and Background

This section provides an explanation of the types of EETs available for NPI reporting and their application. Examples in this section are given to illustrate the principles and application of the various types of EETs available. A listing and details of the actual EETs for mineral sands mining and processing are provided in the following secions:

- 5 – Emissions to Air;
- 6 – Emissions to Water; and
- 7 – Emissions to Land.

4.1 Emission Estimation

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

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

- sampling or direct measurement;
- mass balance;
- fuel analysis or other engineering calculations; and
- emission factors.

The most appropriate EETs (or combinations of EETs) should be selected for each of your individual facility operations.

Emission estimation techniques that are not outlined in this document may be used for NPI reporting purposes. However, you must seek the approval of your relevant environmental authority.

If emissions are estimated by correctly applying any of the EETs presented in this manual the resulting data will be displayed on the NPI database as being of 'acceptable reliability'. This is also true of data produced using EETs not outlined in this handbook but which have been approved for use by the relevant environmental authority.

The emission estimation techniques given in this manual should be regarded as a guide only, and each facility will need to investigate which sources of data are available and how this can be applied. Similarly, emission pathways given (i.e. to air, land, or water) are those commonly expected from common industry processes, however, it is possible that some facilities may emit substances via alternative pathways to those listed. Each facility should develop flowsheets detailing the pathways of reportable substances when assessing emission points for their particular facility.

Where alternative EETs are used, these should be substantiated by facility-specific factors and monitoring data to confirm the accuracy of the technique.

While particular EETs are generally more suited to certain operations, the selection of those appropriate to each facility will be dependent on a number of factors, including:

- the nature of the emission and emitted substance;
- the level of accuracy desired;
- the measurement or monitoring requirements;
- the existing monitoring practices in place and data availability; and
- the cost and effort required for additional data collection.

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 (for example spills) will also need to be estimated. The emission resulting from a spill is the net emission, that is the quantity of the NPI reportable substance spilled, less the quantity recovered during clean up operations.

While the NPI requires the reporting of metals and their compounds, only the mass of the metal emitted should be reported. For example, if arsenic trioxide were released to air, only the arsenic component would be reportable as an NPI emission. While the arsenic trioxide (As_2O_3) compound has a molecular weight of 197.8 the reportable arsenic component has a molecular weight of only 149.8. This means the reportable component, the element arsenic, of the release of arsenic trioxide, is actually 75.7 wt% of the total mass of As_2O_3 released.

Wherever practicable, facilities should ensure that only the reportable component of an emission is reported. In cases where accurate emissions are difficult to achieve, best estimates should be made.

The NPI has a commitment of not requiring facilities to undertake any additional monitoring to meet reporting requirements. A range of EETs that do not require direct monitoring are available. However, it should be noted that the accuracy of such emission estimations would generally be lower.

Where available monitoring data has indicated concentrations of NPI substances are below normal analytical limits, facilities may assume that such substances are not present.

A number of ancillary activities relating to the operation, maintenance and production of by-products are associated with the mineral sands mining and processing industry. This manual provides some guidance on the estimation of emissions from these activities; EET manuals have been developed specific to these operations, as outlined in Figure 1, and should also be referred to.

In all cases, when estimating emissions a facility should ensure that emissions are not “double accounted” between different processes.

4.2 Direct Measurement

While facilities are under no obligation to undertake additional monitoring for NPI reporting purposes, direct measurement is one of the more accurate methods of emissions estimation.

Facilities may wish to undertake direct measurement in order to:

- Provide more accurate estimations of the emissions of substances emitted in significant quantities;
- Verify estimations made using alternative EETs; or
- Provide supporting data for other EETs forwarded for approval.

For sampling data to be adequate and applicable for NPI reporting purposes, it should be collected over an extended period of time, and be representative of operations for the entire reporting period. Measurements should take into consideration standard and non-standard operating conditions. Often, the monitoring program for other purposes, such as licensing, can be used as a guideline when gathering valid NPI data. However, the purpose/intent of such monitoring should be taken into account to assess the appropriateness of such regimes for use in NPI reporting.

It is likely that some facilities have existing monitoring data suitable for NPI reporting purposes. Potential sources of existing data are discussed in Appendix B.

Estimations based on direct measurement data generally take the form of multiplying the concentration of the substance in an emission stream by the mass (or standard volume) of the final emission stream released as shown in Equation 1 below.

Equation 1 Application of monitoring data for emission estimation

$$M_i = C_i * V_T$$

Where:

M_i = mass of substance I emitted, (kg)
C_i = substance concentration, (kg/m^3)
V_T = volume of total emissions, (m^3)

Where direct measurement is to be undertaken, it is important that sampling and source monitoring procedures are established. The procedures should ensure that all sampling and analysis is undertaken in a standard (and traceable) manner and is in compliance with the appropriate Australian Standards.

Section 4.2.1 gives an example of this concept applied for the estimation of emissions from stack monitoring data.

4.2.1 Sampling Data

Stack sampling test reports often provide emissions data in kilograms per hour (kg/hr) or grams per cubic metre (g/m^3 dry standard). Annual emissions for NPI reporting can be calculated from this data providing that the sample is representative of normal operating conditions. Stack tests for NPI reporting should be performed under representative (i.e. normal) operating conditions. Some tests undertaken for a State or Territory licence condition may require testing to be undertaken during conditions of maximum emissions. This may provide data that can lead to the overestimation of emissions. It should also be noted that the following outlines various procedures for the calculation of emission estimates for normal operating conditions. They do not normally account for emissions resulting from abnormal events or operating conditions (such as during maintenance activities, or the breakdown of emission reduction equipment). Where these events are known to have occurred, facilities should make every attempt to include the resulting emission in the estimations.

An example of the application of stack monitoring data to calculate particulate emissions use Equation 2 to Equation 6 inclusive. These show the application of data on Total Particulate Matter (total PM) emitted in stack gases from a representative sample event. Each is different dependant on the sample data that may be available.

Total PM is also referred to as Total Suspended Particulates (TSP). Total PM in itself is not reportable for the NPI but some substances contained within total PM are. These include metals and particulate matter having an aerodynamic diameter of 10 microns (μm) or less (PM_{10}). To determine PM_{10} from total PM emissions and the metal fractions of total PM a size and composition analysis may need to be undertaken. The weight fraction of each relevant substance can then be multiplied by the total PM emission rate to produce the emissions of each substance.

As noted in Equation 1, monitoring data calculations are based on a concentration being multiplied by a flow rate. Often stack sampling will provide data regarding the volume of gas sampled and filter weight gain (determined gravimetrically). This must be converted to an emission rate (g/m^3) to facilitate NPI emission estimation.

Firstly the reported volume sampled must be corrected to STP (standard temperature and pressure = 273K and 101.325 kPa) using the ideal gas equation as shown in Equation 2.

Equation 2 Determination of volume sampled at STP

$$V_{m,\,STP} = (P * V_m * 273) / (T * 101.325)$$

Where

$V_{m,\,STP}$ = metered volume of sample at STP, m^3

V_m = actual metered volume at release temperature and pressure, m^3

T = temperature of gas sample, K (Kelvin)

P = pressure of gas sample,kPa

273 = 273K (standard temperature)

101.325 = 101.325kPa (standard pressure)

From this an emission rate can be calculated by dividing the filter weight gained by the volume sampled at STP (using the ideal gas equation of state), as shown in Equation 3.

Equation 3 Determination of PM concentration in stack exhaust from sample filter catch

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

where:

C_{PM} = concentration of PM or gram loading, g/m^3 dry

C_f = filter catch, g

$V_{m,STP}$ = metered volume of sample at STP, m^3 dry

The pollutant concentration is then multiplied by the volumetric flow rate to determine the emission rate in kilograms per hour as shown in Equation 4. Allowance is made for the difference between the sampled temperature (STP) and the actual temperature of the stack emissions.

Equation 4 Calculation of a time based emission factor for stack PM emission

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

where:

E_{PM} = hourly emissions of total PM, kg/hr

C_{PM} = concentration of total PM or gram loading, g/m^3 dry at temperature T

Q_d = stack gas volumetric flow rate, m^3/s, dry

3.6 = 3600 seconds per hour multiplied by 0.001 kilograms per gram

T = temperature of the gas sample, °C

The information from stack tests may be reported in grams of particulate per cubic metre of exhaust gas (wet). The difference in emissions between the flow rates as measured ‘wet’ and the calculated flow rates for ‘dry’ gas should be accounted for to provide an accurate estimation of emissions. Using Equation 5 dry particulate emissions in kg/hr may be calculated.

Equation 5 Adaptation of wet stack sampling data for the estimation of dry PM emissions

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

where:

E_{PM} = hourly emissions of total PM in kilograms per hour, kg/hr

Q_a = actual (i.e. wet) cubic metres of exhaust gas per second, m^3/s wet at STP

C_{PM} = concentration of PM or gram loading, g/m^3 dry at temperature T

3.6 = 3600 seconds per hour multiplied by 0.001 kilograms per gram

$moist_R$ = stack gas moisture content, vol %

273 = 273 K (0°C)

T = stack gas temperature, °C

To calculate moisture content use Equation 6.

Equation 6 Calculation of moisture content of stack exhaust

$$\text{moist}_{R} = 100\% * \left(\frac{\left(\frac{V_{lc} * \rho_{w}}{M_{w}}\right) * \left(\frac{R * T_{STP}}{P_{STP}}\right) * 1000}{V_{MV,STP}} \right)$$

where:

moist_R = moisture content, vol%

V_{lc} = volume of moisture collected, litres at STP

ρ_w = density of liquid water (0.9982 kg/l)

$V_{MV,STP}$ = wet metered volume of sample at STP, m^3

R = ideal gas constant (8.314 J /K/ g-mol)

T_{STP} = standard temperature (273 K)

P_{STP} = standard pressure (101 300 Pa (i.e. 1 atm))

M_W = molecular weight water (18.0 g/g-mol)

1000 = conversion factor from g to kg (i.e. 1kg = 1000g)

Emission rates (kg/hr) can then be multiplied by the total number of hours operated during the reporting period to give a total loading to the environment or reportable emission in kg.

4.2.2 Continuous Emission Monitoring System Data

A continuous emission monitoring system (CEMS) provides a continuous record of emissions over time, usually by reporting pollutant concentration. Emission calculation is based on the same principles as for stack sample as detailed in Section 4.2.1 except, rather than there being one sample event, there are multiple events. As with stack sampling, the measured pollutant concentrations are converted to emission rates by multiplying the pollutant concentration by the volumetric gas or liquid flow rate of that pollutant. This is particularly applicable to emissions of sulfur dioxide from synthetic rutile process stack emissions.

Unlike stack sampling, CEMS often report real-time hourly emissions automatically, and it is necessary to estimate annual emissions from hourly concentration data manually. This section describes how to calculate emissions for the NPI from CEMS concentration data.

Initially a protocol for collecting and averaging the data should be developed in order that the estimate satisfies the local environmental authority's requirement for NPI emission estimations. Averaging should aim to provide representative emission rates and conditions for each monitored pollutant.

It is possible to determine total emissions of an individual pollutant over a given time period from 'snapshot' or limited data, assuming the CEM operates reliably throughout the period. A generally more accurate emission estimate can be made for the full year by totalling the hourly emission estimates (emission calculated for each hourly sample), providing the CEMS data is representative of typical operating conditions.

Monitoring should provide data regarding the:

- concentration of pollutants in emission stream which may be given in either volume of pollutant emitted per volume of total flow (e.g, parts per million volume by volume) or mass of substance emitted per volume of gas released (g/m^3);
- properties of emitted stream such as temperature, flow rate (m^3/s)

Equation 7 below shows the application of CEMS data for NPI reporting of gaseous substances to air. It illustrates the use of data regarding a pollutant concentration in parts per million by volume dry air (ppm_{vd} = volume of pollutant gas/10^6 volumes of dry air) and stack volumetric flow rates to generate an emission rate in kg/hr.

Equation 7 Calculation of hourly emissions using CEMS data

$$E_i = (C * MW * Q * 3\,600) / [22.4 * (T+273/273) * 10^6]$$

where:

E_i = emissions of pollutant i, kg/hr

C = pollutant concentration, $ppm_{v,d}$

MW = molecular weight of the pollutant, kg/kg-mole

Q = stack gas volumetric flow rate, m^3/s at T

3 600 = conversion factor, s/hr

22.4 = volume occupied by one mole of gas at standard temperature and pressure (0°C and 101.3 kPa), m^3/kg-mole

T = temperature of gas sample, °C

Annual emissions can then be calculated by multiplying the emission rate in kg/hr by the number of actual operating hours per year (OpHrs) as shown in Equation 8 for each typical time period and summing the results.

Equation 8 Calculation of annual emissions from emission rate and operation time data

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

where:

$E_{kpy,i}$ = annual emissions of pollutant i, kg/yr

E_i = emissions of pollutant i, kg/hr (from Equation 7 for example)

OpHrs= operating hours, hr/yr

4.3 Using Mass Balance

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

Mass balance calculations for estimating emissions to air of NPI-listed substances can be represented conceptually by Equation 9.

Equation 9 Simple mass balance approach

$$E_{kpy,i} = PL_i - Q_{out} - Acc$$

where:

$E_{kpy,i}$ = emissions of pollutant i, kg/yr

PL_i = amount of pollutant i entering the process, kg/yr

Q_{out} = amount of pollutant i leaving the process as a discharge stream, article or product, kg/yr

Acc = amount of pollutant accumulating within the process, kg/yr

The term “Q_{out}” may actually involve several different fates for an individual pollutant. This could include the amount recovered or recycled, the amount leaving the process in the manufactured product, the amount leaving the process in wastewater, the amount emitted to the atmosphere, or the amount of material transferred off-site as (or associated with) hazardous waste or to a purpose built facility. Knowledge of the different fates for the pollutant is necessary for an accurate emission estimate to be made using the mass balance approach. It is necessary to know the fates of the pollutant to all other destinations, including accumulation in the process, to determine emission to a particular destination. If more than one emission destination is to be determined by mass balance then the distribution of the substance has to be known.

The amount of a particular substance entering or leaving a facility is often mixed within a solution as a formulation component or as a trace element within the raw material. To determine the total weight of the substance entering or leaving the process, the concentration of the substance within the material is required.

Where a facility uses a listed mineral acid or base, with this acid or base being effectively neutralised in use or during wastewater treatment (to a pH of 6 to 8, as required by most State and Territory effluent standards), no emission quantities should be reported. If the acid or base is itself transformed into another listed substance, however, the quantity of this formed substance coincidentally produced must be determined to assess if a NPI reporting threshold has beenexceeded. For example, sulfuric acid can often yield hydrogen sulfide in effluent streams, and hydrogen sulfide is itself a NPI listed substance and requires reporting where annual use total 10 tonnes or more. In this case use is coincidental production of hydrogen sulfide.

For many reagents used during processing, some degradation may occur during treatment so that the total amount of the reagent is not transferred into the waste stream. As such, the total amount emitted will be reduced by the amount removed.

It should be remembered that reagents may generate NPI substances when they degrade during use (coincidental production). If this is the case, and the NPI substances are emitted , then the mass emitted must be determined.

4.4 Engineering Calculations

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

4.4.1 Fuel Analysis

Fuel analysis is an example of an engineering calculation that can be used to predict SO_2, metals, and other emissions based on application of mass conservation laws. The presence of certain elements in fuels may be used to predict their presence in emission streams. This includes elements such as sulfur that may be converted into other compounds during the combustion process. Equation 10 below is used in fuel analysis emission calculations.

Equation 10 Emission estimation using fuel analysis data

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

where:

$E_{kpy,i}$ = emissions of pollutant i, kg/yr

Q_f = fuel use, kg/hr

MW_p = molecular weight of pollutant emitted, kg/kg-mole

EW_f = elemental weight of substance in fuel, kg/kg-mole

OpHrs= operating hours, hr/yr

For instance, SO_2 emissions from coal combustion can be calculated based on the concentration of sulfur in the feed coal. This approach assumes complete conversion of sulfur to SO_2. Therefore, for every kilogram of sulfur (elemental weight, EW_i = 32) burned, two kilograms of SO_2 (molecular weight, MW = 64) are emitted.

Example 1 Using fuel analysis data

This example shows how SO_2 emissions can be calculated from fuel combustion based on fuel analysis results, and the known fuel flow of the engine. E_{SO2} may be calculated using Equation 10 and given the following:

Q_f	=	20 900 kg/hr
Fuel (coal) sulfur	=	1.17 %
Operating hours	=	1 500 hr/yr

$$\begin{aligned} E_{SO2} &= Q_f * \text{pollutant concentration in fuel} * (MW_p / EW_f) * OpHrs \\ &= (20\,900) * (1.17 /100) * (64 / 32) * 1\,500 \\ &= 733\,590 \text{ kg/yr} \end{aligned}$$

It must be noted that this method does not account for emission control devices or the generation of alternative species (such as hydrogen sulfide in the case for sulfur). Similarly, the initial form of the sulfur in the feed stock may affect which sulfur containing substances are emitted.

4.5 Emission Factors

An emission factor is a tool used to estimate emissions to the environment. In this manual, it relates the quantity of substances emitted to some common activity associated with those emissions. Emission factors 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 (e.g. kilograms of sulfur dioxide emitted per tonne of coal consumed).

These may take the form of a generic emission factor as described above or an emission factor equation that, when applied using local operating parameters, calculates a location/facility specific emission factor.

Emission factors are used to estimate a facility's emissions using the general expression in Equation 11.

Equation 11 Generic emission factor equation

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

where :

$E_{kpy,i}$ = emission rate of pollutant i, kg/yr

A = activity rate, t/hr

$OpHrs$= operating hours, hr/yr

EF_i = uncontrolled emission factor of pollutant i, kg/t

CE_i = overall control efficiency of pollutant i, %.

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

4.5.1 Predictive Emission Monitoring (PEM)

Predictive emission monitoring is based on developing a correlation between pollutant emission rates and process parameters. A PEM allows facilities to develop site-specific emission factors, or emission factors more relevant to their particular process.

Based on test data, a mathematical correlation can be developed that predicts emissions using various parameters. This is particularly applicable for facilities having extensive historical monitoring data.

This data may be used to correlate process input to emissions of NPI substances. From this relationship a predictive emission factor can be developed to predict future emissions.

Reliability of such emission prediction will be dependant on the amount of past data available and the degree of similarity there is between past, current and future processing conditions. For example, variations in ore and fuel characteristics and input rates, processunits used, and equipment alterations and replacement.

5.0 EETs for Emissions to Air

5.1 Background

Emissions to air are often the most significant NPI reportable emissions from minerals sands mining and processing facilities. Main emission sources include:

- Mining operations;
- Stockpiling, transport, and handling of ore and waste materials;
- Stack emissions from reduction kilns, sulfuric acid leaching, and product dryers; and
- Production of gases during wet processing, and from solid wastes.

Emissions to air should be estimated at their point of release. Emissions estimation for NPI purposes does not take into account the fate of emitted substances, such as the rate of decay within the atmosphere, or the rate of deposition.

Air emissions can be classified as:

- Fugitive source emissions; and
- Point, or stack source emissions.

Fugitive Emissions

Fugitive emissions are those not released via a vent or a stack. They include mobile and dispersed sources, and emissions associated with leaks and spills. Examples of fugitive emissions sources include wind erosion of ore, concentrate and by-product stockpiles (dust emissions), and emissions of dust and combustion products from vehicles. Dust emissions from seals, skirting and open crushing points, as well as vats and open vessels, flange and equipment leaks, are also considered fugitive. The majority of emissions resulting from mining, mineral processing and associated activities are classified as fugitive emissions.

EETs based on emission factors are the preferred method for estimating emissions from fugitive sources. In the absence of suitable emission factors alternative EETs such as mass balance, or engineering calculations based on design criteria may be applied. Facility-specific EETs may also be used.

Point Source Emissions

Point source emissions are released to the atmosphere from a single, stationary source. An air emission control device such as a scrubber, fabric filter, afterburner, or electrostatic precipitator may be fitted to a point source to remove or reduce particular components of emissions.

Most emissions to air from synthetic rutile processing operations are likely to be released via a main stack, and are classified as point source emissions. It is generally accepted that direct measurement is the most appropriate approach to be taken when estimating stack emissions. In the absence of reliable monitoring data other approved EETs may be used.

5.2 Dust (TSP)

A large proportion of NPI reportable emissions to air from mineral sands mining operations are likely to be associated with total suspended particulate matter (TSP). Substances contained in TSP may include metals and particulate matter with an equivalent aerodynamic diameter less than 10 μm (PM_{10}). The NPI substances contained within the TSP generated by a facility and the PM_{10}

component of the TSP have to be reported to the NPI if the substance's reporting thresholds are exceeded.

EETs for TSP and PM_{10} emissions are provided in the *NPI EET Manual for Mining.*

Sources of dust emissions that may require consideration include:

- drilling;
- blasting
- wheeled vehicle movement;
- grading;
- scrapers;
- dozers;
- ore and waste handling (truck, front end loader and excavator loading and unloading);
- processing (screening, separation, milling); and
- wind erosion of disturbed areas (stockpiles, pits, TSFs, product and waste/by-product stockpiles etc).

5.3 Mining

Most air emissions produced during mineral sands mining activities are associated with either dust generation, or fuel combustion. EETs or emission factors for these emission sources are provided in the *NPI EET Manual for Mining.* The *NPI EET Manual for Combustion Engines* provides some alternative emission factors relating to fuel combustion.

5.3.1 Fuel Combustion in Mining Equipment

Mining equipment used at a mineral sands mining and processing facility may include petrol and diesel industrial engines; petrol and diesel motor vehicles, commercial vehicles and trucks, and large stationary diesel and dual fuel engines.

Common products of combustion emitted to air from mining equipment and vehicles include: carbon monoxide (CO); oxides of nitrogen (NO_x); sulfur dioxide (SO_2); organic compounds - including volatile organic compounds (VOC), benzene, toluene, ethylbenzene, xylenes, polycyclic aromatic hydrocarbons (PAH), and polychlorinated dioxins and furans; and particulate matter of diameter 10 µm or less (PM_{10}). The following metals: arsenic, antimony, beryllium, boron, cadmium, chromium III & VI, cobalt, copper, lead, nickel, selenium, and zinc may also be emitted from some fuel types. Generally the composition of emissions may reflect the characteristics of the fuel.

Further guidance on the estimation of emissions from fuel combustion may be found in the following NPI EET manuals:

- Vehicles – *NPI EET Manual for Combustion Engines* or *NPI EET Manual for Mining*
- Boilers and furnaces – *NPI EET Manual for Combustion in Boilers*
- Stationary Internal Combustion Engines – *NPI EET Manual for Combustion Engines*
- Power generation – *NPI EET Manual for Fossil Fuel Electric Power Generation & NPI EET Manual for Combustion Engines*

Direct Measurement

Many facilities may undertake monitoring of combustion emissions on a regular basis under existing monitoring programs, and the application of this data for NPI reporting purposes may be appropriate. This is often the case for large stationary internal combustion engine sources, such as in some power generating units.

Direct measurement of combustion emissions must provide adequate, representative samples undertaken over an extended period of time, that account for normal and extreme operating conditions. While direct measurement is viewed as an accurate EET, the NPI does not require facilities to undertake additional monitoring to meet reporting obligations and alternative EETs are available as detailed below.

Additional information regarding the use of direct measurement monitoring data for the estimation of emissions from combustion engines can be found in Section 3.1 of the *NPI EET Manual for Combustion Engines*.

Engineering Equations

Data detailing the composition of fuels may be applied to estimate quantities of NPI substances present in emissions streams. Using the rate of fuel consumption, fuel analysis data, and engineering calculations (e.g. based on application of the laws of conservation of mass) emissions of NPI substances such as metals may be estimated. An explanation of this EET is provided in Section 4.4.1 and Equation 9 and Equation 10.

Further information, including a worked example of the calculation, is provided in Section 3.3 of the *NPI EET Manual for Combustion Engines*.

Emission Factors

EETs using emission factors for combustion engine emissions are available in the following manuals:

- *NPI EET Manual for Combustion Engines Version 2.1 or later*
- *NPI EET Manual for Mining Version 2.1*

The *NPI EET Manual for Mining* provides emission factors for a limited number of substances for the majority of common mining equipment. Emission factors for other equipment types and relevant substances are provided in the *NPI EET Manual for Combustion Engines*.

5.3.2 Blasting

EETs for the estimation of NPI substances emitted in dust from blasting events are provided in the *NPI EET Manual for Mining*.

Explosives Detonation

NPI substances emitted to air from the detonation of explosives commonly used at mining facilities include carbon monoxide (CO), oxides of nitrogen (NO_x), ammonia (NH_3), hydrogen cyanide (HCN), hydrogen sulfide (H_2S) and sulfur dioxide (SO_2). Emissions of various combinations of these substance from a range of different types of explosive may be estimated using EETs provided in the *NPI EET Manual for Explosives Detonation and Firing Ranges*.

5.3.3 Dredging

Emissions to air associated with dredging operations are primarily associated with fuel combustion, and may be estimated using the techniques as outlined in 5.3.1. Other emissions may result from maintenance activities (see 5.8) and spills (see 5.9).

5.3.4 Hydrocycloning and Wet Concentrating

Emissions to air associated with mineral sands hydrocycloning and concentrating processes are likely to be relatively minor. Some emissions of volatile organic compounds (VOCs) may result from the use of organic flocculants, and each facility should assess the use of such substances in these processes.

Where organic flocculants are used, it should be assumed that 100% of the volatile organic fraction in the flocculant is emitted to air, unless other information is available. Information concerning chemical composition and physical properties of various process chemicals, including flocculants, may be sourced from suppliers, or Materials Safety Data Sheets (MSDS). It is recommended that wherever practicable such information be used to provide a greater level of accuracy in mass balance emission estimation.

5.3.5 Burning of Cleared Vegetation

Some facilities may burn vegetation following its removal prior to mining. Emissions of NPI substances associated with the combustion of vegetation include various metals, 1-3 butadiene, carbon monoxide (CO), oxides of nitrogen (NO_x), particulate matter (PM_{10}), and total volatile organic compounds (VOC) (see Table 1 of the *NPI EET Manual for Aggregated Emissions from Prescribed Burning and Bushfires)*. Emission factors for the estimation of these emissions are provided in Table 2.5-5 of Section 2.5 Open Burning of AP42. A range of EETs, including emission factors (Table 4), is also provided in the *NPI EET Manual for Aggregated Emissions from Prescribed Burning and Bushfires*. Facilities should assess each of the EETs presented to determine those most appropriate.

5.4 HMC Separation

Emissions of NPI substances to air from heavy mineral concentrate (HMC) separation processes include components of TSP and combustion products. Emissions of combustion products may be estimated as described in 5.3.1.

5.4.1 Dust Emissions

Emissions of TSP including metals and PM_{10} from HMC processes and product handling may be calculated using emission factors, mass balance, or engineering calculations as described in the *NPI EET Manual for Mining.*

5.4.2 Dryers

Emissions of NPI substances to air from industrial dryers used in mineral sands processing include gaseous emissions from the ore/product, such as hydrogen sulfide (H_2S), sulfur dioxide (SO_2) and combustion products (see 5.3.1 for a listing of combustion products). Direct monitoring, emission factors and engineering calculations may be used for emissions estimation.

Monitoring

Emissions to air from ore and product dryers used in mineral sands processing operations are likely to be released directly from one or more emission stacks. Such emissions may be monitored under existing environmental or O&HS monitoring programs, which may provide data applicable to NPI reporting requirements. For NPI purposes, monitoring data should be collected over an extended period of time, and be representative of normal operating conditions. Any anomalous events should also be accounted for when calculating total emissions estimates for a reporting period. For a description of the application of stack monitoring for NPI emission estimation purposes please refer to 4.2.1.

Monitoring may be a more cost-effective approach to estimating emission of NPI substances, particularly if a monitoring program exists for other environmental of process performance measurements. If monitoring is not in place alternative NPI emission estimation techniques may be more cost effective.

Emission Factors and Engineering Calculations

Emissions of combustion products from ore and product dryers may be estimated using emission factors provided in the *NPI EET Manual for Boilers*. Although these emission factors refer specifically to boilers they also apply to dryers, kilns, and furnaces. The *NPI EET Manual for Combustion in Boilers* provides emission factors for a range of boiler types and fuels which may be applicable at different facilities.

Alternatively a fuel analysis approach as described in 4.4.1 may be applied to fuel combustion in dryers for the purpose of estimating the associated combustion emissions.

In both cases these EETs relate to the emissions resulting from the combustion of fuel, and do not include emissions released from the ore or product being treated. Emissions of NPI substances to air from these sources should be accounted for separately, using other EETs such as mass balance or engineering calculations.

5.4.3 Acid Washing and Leaching

Few emissions to air are likely to result during acid wash treatment (principally of zircon however other materials may receive similar processing). By-products of the washing process and any residual reagents present in waste streams may be estimated using a combination of monitoring data and mass balance, or where applicable, engineering calculations.

Some sulfuric acid may be emitted in acid mist evolved during zircon treatment. Acid mist contained and treated within the plant’s water management system does not have to be estimated as an emission. Sulfuric acid within acid mist emitted to air land or water does have to be estimated and reported as an NPI substance. The characteristics of each facility should determine the reporting requirements of these emissions, especially in relation to the emission from other sources within the facility.

Where emissions are to be estimated, direct measurement of acid emissions may be undertaken (either regularly or historically) at some facilities and may provide useful information regarding the scale of emissions. However, there are difficulties associated with converting ambient concentrations to an actual mass emitted and complex modelling is generally required to relate such data to a quantity emitted.

At some facilities acid mist may be reclaimed. Mist may “fall out”, condense on nearby plant machinery and buildings, or be brought to ground in rainfall at or near the source from which it evolved. . If the appropriate NPI thresholds are exceeded, all emissions of NPI substances to air, land and water are to be reported to the NPI. This is the case even if substances later “fall out” or condense on plant machinery and buildings.

Mass balance may be useful providing that all pathways of the added acid can be determined and estimated accurately.

5.5 Synthetic Rutile Processing

Emissions to air generated during synthetic rutile processing are associated with three main sources:

- the combustion of coal, and reduction of ilmenite ore;
- the use of reagents, primarily ammonium chloride and sulfuric acid, in the purification process; and
- fuel combustion, and substances released by the ore or product during drying.

The majority of these emissions are often released from point sources or stacks, and it is likely that stack emissions are monitored under existing environmental or OH&S monitoring programs. This monitoring data may be applied for NPI reporting purposes and is likely to represent the most accurate available. As most emissions pass through one point it may not be necessary to consider the emissions from each individual process step separately.

Emissions not likely to be monitored are fugitive emissions originating from equipment leaks or unsealed vessels. During normal operation equipment leaks are considered a minor component of total emissions and generally need not be considered. Emissions from open vessels during synthetic rutile processing include ammonia from aeration, and ammonia, sulfur dioxide and hydrogen sulfide from by-product liquors and solids.

Other fugitive emissions may result from product handling (see 5.5.9), and maintenance activities (See 5.7). Emissions may also occur as a result of events such as the spontaneous combustion of coal (5.5.8), or accidental spills (5.9).

5.5.1 Dust from Storage and Handling of Ore and Coal

Emissions of dust generated during the handling of coal, ore, and products may be estimated as described in the *NPI EET manual for Mining*.

5.5.2 Reduction Kiln

Emissions to air from reduction kilns are primarily particulate matter and combustion products. The addition of sulfur during the process, either associated with the feed stock or added to assist the reduction process, results in additional emissions of oxides of sulfur. Sulfur may be substituted with other substances such as hydro boracite, hence reducing emissions of sulfur compounds. However, any emissions resulting from the degradation of these materials must also be considered.

Emissions resulting from the reduction process in kilns are generally released to the atmosphere via dispersion stacks. Other fugitive emissions from kiln seal leaks and input/output shafts are likely to be insignificant, and may be able to be ignored.

Common products of coal combustion include oxides of nitrogen, sulfur dioxide, hydrogen sulfide, carbon monoxide, particulate matter, organic compounds (including total volatile organic compounds, benzene, toluene, ethylbenzene, xylene, polycyclic aromatic hydrocarbons, and polychlorinated dioxins and furans), and metals (arsenic, antimony, beryllium, boron, cadmium, chromium III & VI, cobalt, copper, lead, nickel, selenium, zinc). The actual composition of combustion emissions will vary with the type and characteristics of the coal used and ore being processed.

Emissions control techniques (primarily for reducing sulfur dioxide and particulate emissions) include wet scrubbers and electrostatic precipitators. Control efficiencies of any devices present should be assessed, where necessary, by each facility.

Direct Measurement

Direct measurement of stack emissions is one of the most accurate methods of estimating emissions of NPI substances from reduction kilns. Emission monitoring programs for emissions of sulfur dioxide and/or airborne particulates are often implemented in compliance with environmental licensing conditions, or undertaken on a voluntary basis. The application of monitoring data for NPI emissions reporting purposes is generally a simple process, although available data may not cover the full list of NPI reportable substances.

A discussion of the application of direct measurement can be found in 4.2.

Mass balance

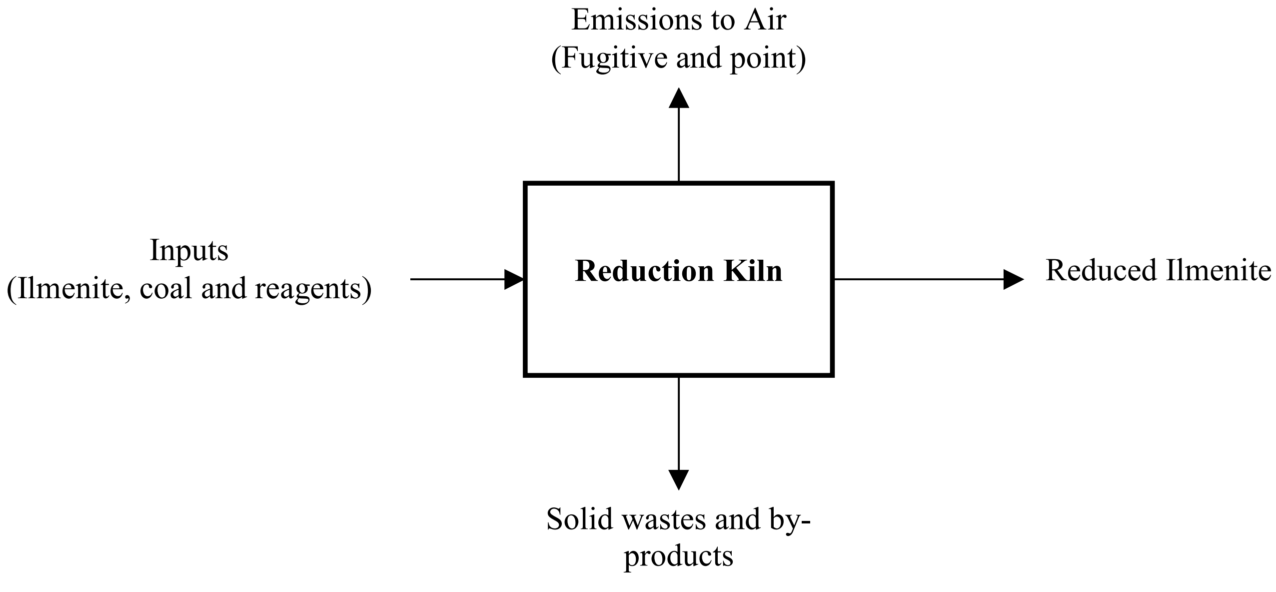
Emission of NPI substances (in particular sulfur dioxide, boron and other metals) to air from synthetic rutile reduction kilns may be estimated using a mass balance technique. Some direct measurement (such as sulfur and metals content of input and output materials) may be desirable to improve the reliability of the data in relation to variable input components.

It is important that the fate of all substances in the process is considered, and the underlying assumptions used in emissions estimation are stated. For example, it may be assumed that all sulfur lost during the reduction process is converted to sulfur dioxide, and that all metals added in ore and feed stock which are not recovered in the product or by-products, are emitted to air via the stack. This may or may not be considered appropriate, depending on the level of combustion achieved in a facility's kiln, and the efficiency of emissions recovery systems.

The benefit of the mass balance approach is that it allows for all emissions, fugitive and point source, to be accounted for. The drawback lies in the level of knowledge of the process required, and the inherent errors associated with necessary assumptions.

Figure 5 shows the typical "box" type approach used in mass balance calculations.

Figure 5 Simple mass balance for emission estimation from reduction kilns



Emission Factors

Emissions to air of combustion products associated with the combustion of various types of coal are provided in Section 3.4.1.1 of the *NPI EET Manual for Combustion in Boilers*. While these emission factors are provided for boilers and furnaces it is acceptable to use these for estimating kiln emissions where other data is unavailable. It should be noted that these emission factors only account for the combustion of coal and generally do not allow for the combustion or production of other substances associated with ore and reagents added.

5.5.3 Rotary Coolers

Emissions of NPI substances to air from rotary coolers include particulate matter released during the cooling process and water quality control additives in wastewaters. In both cases emissions will be largely dependent on additives or impurities present in the cooler water and the volume of water passed over the cooler during any given time period. Common chemical additives include biocides and anti-corrosion agents. Each facility should assess the chemicals used in this process for composite NPI substances to determine the significance of these emissions.

Available EETs for estimating particulate emissions are provided in Section 5.2.8 of the *NPI EET Manual for Fossil Fuel Electric Power Generation*. Although this section refers specifically to cooling towers as opposed to rotary coolers, these EETs may be applied in the absence of other information.

Emissions associated with the breakdown of water quality and corrosion control chemical additives may be estimated using a mass balance technique, and applying available information concerning the chemical properties of additives used. This information is generally available from MSDS sheets and/or chemical suppliers. Where information is unavailable it should be assumed that 100% of the NPI substance added is subsequently emitted.

5.5.4 Separation

Emissions from the separation process are generally limited to dust generated during ore transfer. Dust emissions may be estimated using emission estimation techniques outlined in the *NPI EET Manual for Mining*.

5.5.5 Aeration

Emissions of NPI substances to air from aeration processes are associated primarily with the evolution of ammonia from ammonium chloride used in the process. A large proportion of ammonium chloride used in the process will be passed into solid byproducts and not emitted to air from the aeration process itself. Due to the generally poor availability of emissions data, and complex nature of chemical processes involved, the most appropriate approach to estimating emissions to air from the process is considered to be mass balance.

Low levels of emissions of sulfur compounds, principally sulfur dioxide, are known to occur during the aeration process. If such emissions are to be estimated it is likely that a combination of monitoring data providing concentration of pollutant before, within and after the aeration process and a mass balance of the overall process flow will prove to be the most applicable to these emissions. It is unlikely that any other emissions of NPI substances are produced during the aeration process. However, information is limited and further investigation or monitoring may indicate otherwise.

Mass Balance

Ammonium may be lost from the aeration process via two pathways - retained in the waste solids, or emitted as ammonia gas. Emissions to air as ammonia gas can be estimated if the mass added and the mass retained in by-product streams can be quantified. This process is detailed below. Typically a mass balance would be completed on the overall process and/or the one of the individual process units. Often a mass balance is completed on the Waste Management unit. The decision about which mass balances to examine will alter the data required to complete the estimation which is outlined below.

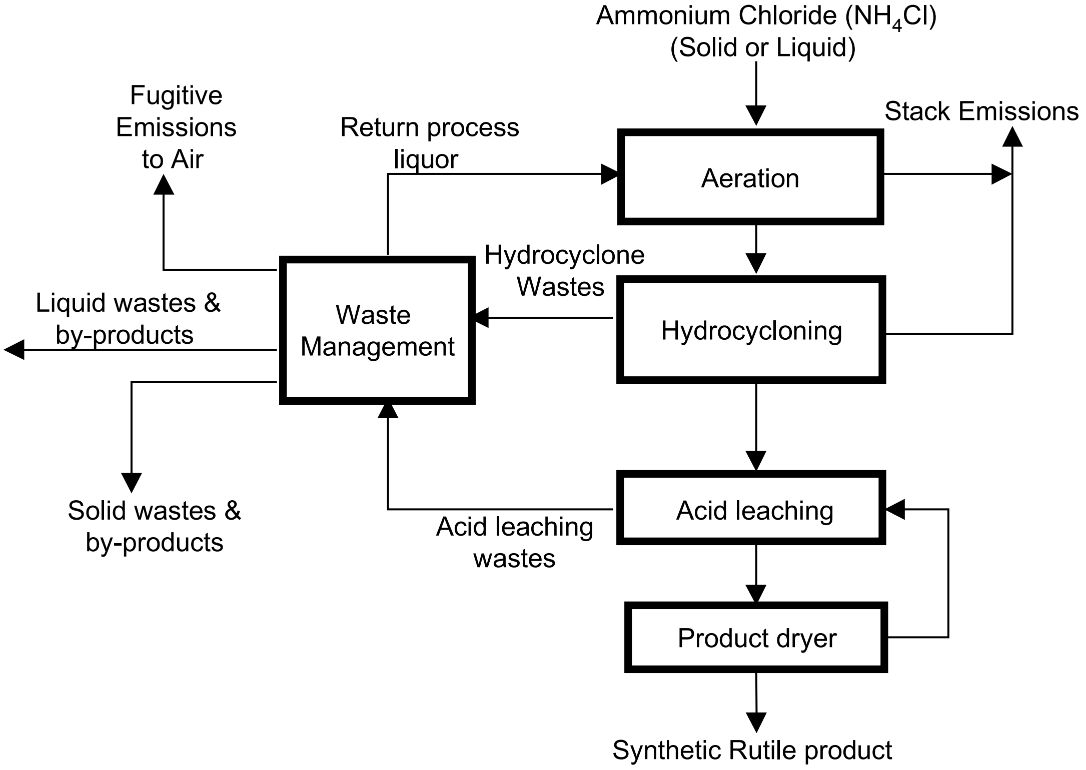
Assumptions:

- all ammonium chloride lost from the system is either emitted to air as ammonia gas, retained in the solid by-products or emitted in separation liquids;
- ammonium chloride retained in solid by-products is not released or degraded into other NPI substances; and
- evaporation, other TSFs and impoundments do not seep (if seepage is known to occur associated emissions must be accounted for and reported as emissions to land).

Outline of required data:

- total mass of ammonium chloride added in top-up during the reporting period;
- concentration (ppm) of ammonium in any return water (e.g. Return process liquor) used in the process during the reporting period;
- volume of decant liquor added to process during the reporting period;
- concentration of ammonium chloride in solid by-products; and
- total volume of by-products generated during the reporting period.

Figure 6 Pathways of ammonia



Calculation process:

As indicated in Figure 6, the mass of ammonia emitted can be estimated from the balance of the mass of ammonium chloride added and the mass of ammonium chloride retained in solid by-products. The actual mass emitted to air may be determined by calculating the total mass lost in waste/separation liquids (volume released multiplied by concentration of ammonium/ammonia in the solution) and subtracting this from the total mass lost.

It should be remembered that for NPI reporting ammonia emissions includes both ammonia, and the ammonium ion in solution. Consideration also has to be made of accumulation of any material within the process or process units, and if only a single mass balance is completed how to partition the release of substances between the different destinations.

5.5.6 Leaching

Current available information indicates sulfur compounds comprise the only NPI emission associated with the leaching process. Emissions include sulfur dioxide and hydrogen sulfide. Emissions are generally captured and released via an emission stack. Direct measurement of emissions from stacks is often the most reliable method of EET and is likely to be incorporated in existing environmental or OH&S monitoring programs.

5.5.7 Drying

A discussion of the available EETs for drying during HMC separation is provided in 5.4.2.

5.5.8 Spontaneous Combustion of Coal

Limited information is available concerning EETs for emissions resulting from the spontaneous combustion of coal. Due the scale of emissions that are considered to occur from this source, and the significance of these emissions in comparison to other sources (reduction kilns), these emissions are likely to be insignificant and may be able to be ignored. However, where significant combustion occurs, it is recommended that these emissions be estimated using a mass balance approach. Data regarding the composition of coal is provided in Appendix A. It should be assumed that complete conversion of sulfur to sulfur dioxide occurs.

5.5.9 Gases Released from Solid Products

Sulfur dioxide (SO_2) retained in the synthetic rutile product from processing may be released during storage and transportation. These emissions are likely to be small and often cannot be allocated to any particular facility (as they occur throughout the life of the product). However, it is recommended that facilities exercise judgement when seeking to quantify these emissions.

Estimations may be made by sampling the SO_2 content of the product at each stage following production. Emissions can then be allocated assuming that the difference in the SO_2 content is due to gaseous release to air.

5.6 Waste and Process By-Product Treatment and Disposal

For NPI purposes major emissions released from waste materials generated by the minerals sands mining and processing industry include ammonia, sulfur dioxide and hydrogen sulfide, as well as dust generated from mining waste materials, TSFs and other pond surfaces.

Depending on the EET used, it is likely that any emissions associated with these waste streams will be accounted for in overall process mass balances. In the case of ammonia emissions, the mass balance suggested in section 5.5.5 would provide an estimate of emissions that may occur from disposal of solid wastes and by-products as well as gaseous process emissions.

Emissions of sulfurous compounds (in particular sulfur dioxide and hydrogen sulfide) are likely to be low in comparison to other sources such as reduction kilns and dryers. Other emissions will need to be reviewed by each facility independently to assess their significance.

5.7 Product transportation and handling

Emissions to air may result during the activities associated with the delivery of final products. It should be noted that these should only be considered for those activities occurring at specific facilities. Emissions resulting from activities occurring between reporting facilities, such as dust and combustion emissions released during the transportation of product from the processing plant to a port for export, need not be reported. However, emissions occurring on within facilities must be accounted for (if triggered substances are present).

The main emission types occurring during these activities are:

- dust liberated during product transfer and suspended by vehicle and equipment movement;
- combustion emissions from on-site equipment (e.g. vehicles, tugs and other vessels operating within the port);
- spills
- maintenance activities

5.7.1 Dust from Product Transfer

Emissions resulting from this activity may be estimated using the EETs provided in the *NPI EET Manual for Mining.*

5.7.2 Combustion Emissions

EETs available for the estimation of combustion related emission are outlined in Section 5.3.1 and specific EETs for maritime equipment can be found in *the NPI EET Manual for Maritime Operations*.

5.7.3 Spills

The methodology for the estimation of emissions from spills is outlined in Section 5.9 below.

5.8 Maintenance Activities

5.8.1 Solvent degreasing

Emissions to air may result from the volatilisation and evaporation of volatile NPI substances contained in materials commonly used in washing, degreasing and equipment maintenance. EETs available for estimating these emissions are provided in Section 5.1, Table 2 of the *NPI EET Manual for Railway Yard Operations*.

5.8.2 Welding

EETs available for estimating emissions from welding provided in Section 3.17 of the *NPI EET Manual for Fugitive Emissions*. This provides a comprehensive list of substances emitted from different types of welding operations (e.g. metal arc, cored arc, submerged arc), emissions factors, and control efficiencies for a range of control equipment.

5.8.3 Surface coating/painting

EETs available for estimating emissions from surface coating and painting are provided in the *NPI EET Manual for Surface Coating.* A number of different techniques are available each requiring different input data.

5.9 Spills and Incidents

Spills of materials containing NPI substances will generally only result in an emission to air if the constituent substances are volatile in nature. Such emissions may be calculated using a combination of mass balance and engineering calculations. Monitoring data will be useful in establishing the composition of materials spilt and recovered.

The *NPI EET Manual for Organic Chemical Processing Industries* (Section 9.2) provides EETs for evaporative losses from spills of organic liquids. The techniques provided in this manual would also apply to other NPI substances, and include emissions to land.

5.9.1 Mass Balance and Engineering Calculations

In the event of a spill it is unlikely that an accurate quantity of released materials will be known. In this event the amount should be estimated, and materials composition data may be used to estimate the total quantity of constituent NPI substances emitted.

NPI substances emitted in a spill event may be:

- Released to air via volatilisation and/or evaporation;
- Released to water;
- Released to land; or
- Recovered.

Total emissions to air, land and water associated with a spill event must be accounted for.
Emissions to water may generally be estimated using a similar mass balance technique to that provided in Section 9.2 of the *NPI EET Manual for Organic Chemical Processing Industries,* using the known quantity spilled and recovered, and the estimated proportion of the total emissions to air and land.

5.10 Storage Tanks

Fugitive emissions from the bulk storage of fuels and chemical materials may be associated with:

- fuels, principally diesel and natural gas;
- oils, solvents and thinners; and
- reagents such as flocculants, acids and ammonium chloride.

Emissions from storage tanks include evaporative losses during filling and transfer, as well as standing losses, leaks, and spills. For the purpose NPI reporting, storage tanks may be classified as:

- fixed roof;
- floating roof; or
- variable vapour space tanks.

Emissions from small organic liquid tanks (i.e. less than 30 tonnes capacity) may be estimated using the EET for air displacement provided in Section 5.2 of the *NPI EET Manual for Organic Chemical Processing Industries*. Where tanks have a capacity of greater than 30 tonnes the TANKS 4.0 software should be used. This package requires detailed information including the physical characteristics of tanks, tank contents, throughput and standing levels, and monthly meteorological data (including wind speed, temperature and solar insolation). There is further details on using TANKS 4.0 for Australian facilities, including appropriate meteorological data, on the NPI internet site: http://www.npi.gov.au

Further information regarding the calculations used in this software is provided on the following web site: www.epa.gov/ttn/chief/tanks.html.

Emissions of NPI substances released from acids storage facilities may be estimated use EETs provided in Section 6.5.1 of the *EET Manual for Alumina Refining*.

5.11 Fossil Fuel Electric Power Generation

Emissions of NPI substances to air from fossil fuel electric power generation may be estimated using EETs detailed in the *NPI EET Manual for Fossil Fuel Electric Power Generation*. The manual does not cover emissions from stationary internal combustion engines used for power generation. In this case EETs provided in *NPI EET Manual for Combustion Engines* should be used.

5.12 Stationary Internal Combustion Engines

EETs for the estimation of emissions to air from stationary internal combustion engines are provided in Section 5.3.1.

6.0 EETs for Emissions to Water

6.1 Background

For the purposes of NPI reporting, emissions of substances to water can be categorised as discharges to:

- surface waters (e.g. lakes, rivers, dams, estuaries and dry water bodies);
- coastal or marine waters; or
- stormwater.

Groundwater is not included in the NPI definition of a “water body”, and any emissions of NPI substances to groundwater should be considered as emissions to land.

Emissions to water from mineral sands mining and processing activities may be associated with:

- surface runoff and erosion from processing and mining areas;
- the release of process discharge waters and liquid waste streams;
- discharge of sewage and domestic waste waters; and
- spills to surface waters.

Point or pipe sources involve a release from a single fixed point or pipe. Fugitive sources and leaks include spills, pipe failure, and any emissions resulting from erosion, surface runoff, or overflow from liquid impoundment that is released to surface waters.

The most accurate method of estimating emissions to surface waters is likely to be direct measurement. Mass balance, supplemented with some monitoring data, may also prove effective. Ultimately facilities should choose the combination of approved EETs most suited to their operations, procedures, and the characteristics of the emissions involved.

6.2 Runoff and Erosion

Surface runoff may contain NPI listed substances either suspended, or in solution. Any runoff containing sediment due to erosion process is likely to contain trace metals in similar concentrations to that of the source soil, ore, or waste material. The efficiency of a facility’s existing stormwater management system will determine the volume and composition of waters being emitted at the facility.

Actual emissions will be dependant on weather conditions and the characteristics of the facility area as a catchment. At some facilities runoff may be completely contained within site boundaries, collected and treated, disposed of, or reused. In such cases, NPI substances involved are transferred, as opposed to being emitted by the facility, and should not be considered for NPI reporting purposes.

Depending on the quantities of NPI substances a facility is likely to emit to water and the type of information available, either a direct measurement/engineering calculation or mass balance approach may be used for emission estimation.

Direct Measurement

Site-specific information concerning runoff flow rates and composition may be used to estimate emissions of NPI substances to surface waters. Water quality and flow rate monitoring data may indicate the mass of any constituent NPI substances emitted, although it is unlikely that all NPI substance will be covered. Where assay data is unavailable the concentration of NPI substances in suspended particulate matter contained in runoff can be assumed to be equivalent to the source material.

Flow and erosion rates can often be estimated based on models, or engineering calculations such as those presented in Australian Rainfall and Runoff (1997).

Mass Balance

Emissions of NPI substances contained in water may be estimated using a mass balance approach. This technique is only suitable for sealed surfaces such as a plant floor, as it requires the quantification of total materials into and out of the process, with the difference being accounted for in release to water:

Release to Water = Total Quantity Input – Total Quantity Output (including wastes and emissions to air)

This is a very simplified equation and may be modified to account for any additional information or data available in relation to specific facility operations. Control measures such as sediment traps must also be accounted for when using this approach.

6.3 Discharge of Waters

Where facilities release treated process waters, sewage, decant liquor or liquid waste streams to surface waters, all constituent NPI substances are considered to be emissions. NPI substances in emissions to water may include metals, nutrients and/or substances contained in reagents or reagent residue. Each facility should assess the wastewater streams to determine which, if any NPI substances are present. The characteristics of the source process should give a reasonable indication of the likely composition.

Where waters are not altered from their natural/original state (i.e. concentrated, containing additives, been treated, or containing run-off from stock-piles or TSFs) their discharge is not considered an emission for the purposes of estimating emissions of NPI substances.

Discharged waters are often monitored either for regulatory purposes, or as a matter of “good practice” resource management and as an indication of operational efficiency. Where existing data is available, direct measurement is an effective means of quantifying emissions of NPI substances. Alternatively a mass balance approach may be applied.

Direct Measurement

Emissions of NPI substance contained in discharged waters are best estimated using direct measurement (i.e. monitoring discharge streams release rate and composition). Monitoring must be conducted over an extended period and should be representative of emissions generated under normal operating conditions. Any anomalous events such as a spill or leak into the wastewater stream must also be accounted for.

Mass balance

In some cases it may be assumed that trace levels of chemical reagent will remain in the by-product or discharge stream, and the quantities of any composite NPI substances may be estimated using a simple mass balance approach. The total quantity of an NPI substance added to a process must be accounted for in recovery and reuse (e.g. decant liquor), emissions to air (e.g. evaporation and volatilisation), and emissions to land (e.g. impoundment seepage). The difference may then be assumed to be emitted to water. Available monitoring data may be useful in this process.

6.4 Spills to Surface Water

Emissions to surface waters from spills should be estimated using techniques as outlined in Section 5.9.

7.0 EETs for Emissions to Land

7.1 Background

Emissions of NPI substances to land may result from the treatment, storage, and handling of solid and liquid by-products, slurries, sediments, processing reagents, and chemicals used at the facility. Emissions may also result from the use of chemicals (such as pesticides, herbicides and fertilisers) in environmental management practices, where the application may contain listed NPI substances.

Sources of emissions to land can be broadly classified as:

- emissions to land from surface impoundments of liquids, solids and slurries, such as tailings storage facilities and decant ponds;
- emissions to land from storage facilities for solid, liquid and slurry by-products and wastes (including emissions during transfer of materials to tailings storage facilities);
- unintentional leaks and spills; and
- surface applications.

For the purpose of NPI reporting the deposition of process by-products to surface impoundments, such as various TSFs, and mine voids are not considered emissions. However, emissions from these facilities to the environment, such as seepage to surrounding groundwater, are considered emissions and need to be considered in NPI reporting.

On-site landfill refers to those emissions originating from a landfill or other impoundment within the facility boundaries, including dredging ponds, solar evaporation impoundments, various TSFs and mine voids. Emissions to land from irrigation sources include the use of treated or contaminated waters for irrigation purposes. Land emission sources referred to as ‘other’ include all emissions not covered under landfill or irrigation definitions, including spills and leaks, and deposition of materials containing NPI substances to areas not classified as landfills.

Similarly, some application of materials to land may be classed within the concept of ‘beneficial use’ and contained NPI substances therefore not reportable as emissions. This is often the case with by-product solids that are used as soil ameliorants. Where an emission is believed to fall within this category, advice should be sought from your local NPI unit before reporting (or not reporting) emissions.

7.2 Impoundment Seepage

When considering seepage as an NPI reportable emission, three variables need to be quantified:
(i) the seepage rate
(ii) the rate of seepage recovery
(iii) NPI substance concentration in seepage.

Determining Seepage Rate

7.2.1 Mass Balance

In the case of closed system containment facilities, an input/output mass balance approach may be applied. The loss of solution as seepage can be assumed to be the difference between the amount added and the amount recovered, with consideration being given to evaporation losses, rainfall additions, and groundwater flow through rates. This approach will also apply to other containment facilities such as TSFs and various waste or by-product storage impoundments.

7.2.2 Modelling and Engineering Calculations

Knowledge of the design criteria of the containment facility, combined with local hydrogeological profiles and groundwater monitoring data from the surrounding area can be applied to develop a seepage loss model. This may be based on Darcy's Law as shown in Equation 12:

Equation 12 Seepage Loss Model according to Darcy's Law

$$\text{Volume seepage } (m^3/\text{day}) = k * A_s * S * (dh/dl)$$

Where;

k = permeability of impoundment floor in metres per day

A_s = surface area of impoundment/pond floor in square metres

S = specific yield of material in pond (%) (amount of water potentially released by by-product material, e.g. if saturation moisture content of solids = 10% the specific yield may be half the saturation content thus = 5%)

dh = hydraulic head above floor of impoundment/pond in metres

dl = thickness of material in impoundment/pond in metres

Note: This equation is reliable when applied to unlined storage facilities. Many storage impoundments at mineral sands mining and processing operations will be lined with an impermeable lining. Where no known leaks from such storage facilities occur, emissions may be assumed to be zero. Where leaks are known to occur, the above equation should be applied only to the area known to be leaking. It is recognised that errors inherent in this approach may be large.

7.2.3 Emission factors

The *NPI EET Manuals for Gold Ore Processing*, and *Nickel* and*, Lead and Zinc Concentrating, Smelting and Refining* indicate that in the absence of facility-specific data, a seepage rate of 10% should be assumed. This is not applicable to dredging ponds but may be applicable solar evaporation impoundments. Where ponds are lined, in the absence of other data emissions may be assumed to be zero. Use of emission factor EETs also relies on monitoring data for substance concentrations.

Factors such as seepage recovery via toe drains, seepage trenches, and bores may be accounted for where the volume of recovered solution and the concentration of NPI substances in the solution are known. Similarly, retention of substances within the pond/solids matrix can also be allowed for where sufficient information is available.

Concentrations of Pollutants in Seepage Water

7.2.4 Direct Measurement

Obtaining reliable data from monitoring seepage and/or monitoring/recovery bores is often difficult because samples are likely to be compromised by either groundwater dilution, or soil retention.

Alternatively it may be assumed that seepage has the same composition as the added solution. This may overestimate emissions by not accounting for retention of substances in the solid matrix of the containment facility.

Assuming seepage has the same composition as return/decant liquor is generally the most reliable method and is recommended.

It is assumed that in the absence of reliable data, the retention of NPI substances within the containment facility is zero (i.e. concentration of seepage water output should be assumed to be equivalent to the concentration of input waters). As input water can contain NPI substances (principally metals) as suspended solids, which are filtered out and retained within the contained solids within the TSF or other impoundment facility, only the soluble component of the input water should be considered.

7.3 Spills

Emissions to land from spills should be estimated using the EETs outlined in Section 5.9.

7.4 Surface Applications

All surface applications of NPI substances must be considered as emissions to land unless they fall within the concept of beneficial use (for information regarding the classification of beneficial use refer to your local NPI unit). Applications may include NPI substances contained in fertilisers or materials applied to control dust. MSDS and data supplied by chemical manufacturers may be used to determine the composite proportions of any listed NPI substances, which may then be applied to total volumes of chemicals used to give a reportable emission estimate. Where chemicals contain volatile substances, emissions to air from evaporation and volatilisation must also be accounted for (see Section 5.8).

8.0 Glossary of Technical Terms and Abbreviations

Reference should be made to various NPI Publications, particularly the *NPI Guide* and *NPI National Environment Protection Measure* for definition of terms used within the NPI system.

Table 3 Glossary of technical terms and abbreviations used in this manual

Term	Definition
BTEX	benzene, toluene, ethylbenzene and xylenes
Direct Measurement	an emission estimation technique relying on the use of monitoring data to quantify emissions to the environment
Emission	Refers to the release 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 other purpose built impoundments, but does not include removal of a substance from site for recycling, destruction, treatment or further processing
Emission Boundary	The boundary at which a release is considered an emission is defined by several parameters depending on the emission type. For emissions to air the boundary is considered to be the point of creation (such as the surface of a liquid for volatilisation, or the wheel of a vehicle for dust). Emission to land and water are considered from the point at which the substance is no longer controlled, contained or recovered (such as a spill to ground from a storage vessel, or discharge of treated effluent to surface waters)
Emission Factor	a generic emission estimation technique for calculating emissions of a particular substance resulting from a particular activity. These take the form of providing a factor for the mass of a substance emitted per unit of activity (e.g. kilograms emitted per tonne processed). They are based on extensive research and monitoring data from the particular activity within the specific industry, activity or process.
Engineering Calculations	use of physical and chemical properties to estimate the mass of a substance emitted from a particular process.
Equivalent Aerodynamic Diameter	the diameter of a spherical particle of density 1,000 kg/m^3 which exhibits the same aerodynamic behaviour as the particle in question (Standards Australia, 1994)
Fossil Fuel Electric Power Generation	the generation of electricity through the combustion of fossil fuels not including combustion engines type generation.
Fugitive Emissions	emission not originating from a point source. Includes emission from mobile sources, open vessels and activities with multiple release points
HMC	Heavy Mineral Concentrate

Table 3 cont'

Term	Definition
Mass Balance Technique	emission estimation technique based on the law of mass conservation. In its simplest form it assumes the amount emitted from a process will be equivalent to the balance of the amount added and the amount removed or recovered
NEPM	National Environment Protection Measure. The NPI NEPM outlines the fundamental parameters of the NPI
NPI	National Pollutant Inventory
PM	PM – Particulate Matter (same as TSP – Total Suspended Particulates)
PM_{10}	"Particles which have an equivalent aerodynamic diameter of 10 micrometers or less (i.e. ≤10 microns, ≤10µm)" This definition comes from the Ambient Air Quality NEPM 1998.
Point Source Emission	an emission from a stationary point, stack or line source
TSF	Tailings Storage Facilities
TSP	Total Suspended Particulates (same as PM – Particulate Matter)
Volatile Organic Compounds (VOC	any chemical compound based on carbon chains or rings (and also containing hydrogen) with a vapour pressure greater than 2 mm of Mercury at 25°C excluding methane. Note: These compounds may contain oxygen, nitrogen and other elements, but specifically excluded are carbon monoxide, carbon dioxide, carbonic acid, metallic carbides and carbonate salts *(see VOC 2000 in Section 9.0 –references*)

9.0 References

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

Australian Institute of Engineers 1997, Australian Rainfall and Runoff.

Mulligan, D. (ed.), 1996, *Environmental Management in the Australian Minerals and Energy Industries Principles and Practices*, UNSW Press and Australian Minerals & Energy Environment Foundation, Sydney.

National Pollutant Inventory Homepage
http://www.npi.gov.au

USEPA. 1995. *Emission Factor Documentation for AP-42, Section 2.5 Open Burning*. 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

VOC 2000, Volatile organic compounds definition and background information
http://www.npi.gov.au

The following EET Manuals, referenced in this manual, are available (at time of writing) at the NPI Homepage, and from your local NPI unit:

NPI EET Manual for Aggregate Emissions from Prescribed Burning and Bushfires
NPI EET Manual for Alumina Refining
NPI EET Manual for Combustion Engines
NPI EET Manual for Combustion in Boilers
NPI EET Manual for Fossil Fuel Electric Power Generation
NPI EET Manual for Fuel and Organic Liquid Storage
NPI EET Manual for Fugitive Emissions
NPI EET Manual for Mining
NPI EET Manual for Maritime Operations
NPI EET Manual for Railway Yard Operations

Appendix A - Generic Assay Data

Table 4 Generic Ore Assay (grams/tonne)

Element	Symbol	Basalt	Granite	Coal	Soil	Earth's Crust	Marine Clays	Marine Carbonates	Shale	Limestone	Sandstone	Sediment
Antimony	Sb	0.69	0.2	3.5	1	0.2	1	0.05	1.5	0.3	0.05	1.2
Arsenic	As	1.5	1.5	6.5	6	1.5	13	1	13	1	1	7.7
Beryllium	Be	0.3	5	1	0.3	2.6	2.6	--	3	<1	<1	2
Boron	B	8	12	70	20	10	230	55	130	20	30	100
Cadmium	Cd	0.13	0.09	0.2	0.35	0.11	0.21	0.23	0.22	0.028	0.05	0.17
Chromium	Cr	200	4	20	70	100	90	11	90	11	35	72
Cobalt	Co	35	1	5.4	8	20	74	7	19	0.1	0.3	14
Copper	Cu	90	13	15	30	50	25	30	39	5.5	30	33
Fluorine	F	510	1400	-	200	950	730	550	800	220	180	640
Lead	Pb	3	24	30	35	14	80	17	23	5.7	10	19
Manganese	Mn	1500	400	41	1000	950	6700	1000	850	620	460	770
Mercury	Hg	0.12	0.08	0.23	0.06	0.05	0.08	0.46	0.18	0.16	0.29	0.19
Nickel	Ni	150	0.5	15	50	80	225	30	68	7	9	52
Selenium	Se	0.05	0.05	2.9	7	0.05	0.17	0.17	0.5	0.03	<0.01	0.42
Zinc	Zn	150	240	31	90	190	150	20	160	20	220	150

Note:

1. Extracted and adapted from Bowen, H.J.M. 1979. *Environmental Chemistry of the Elements*, Academic Press and generally checked against Berkman, D.A. 1989 *Field Geologists Manual*, The Australasian Institute of Mining and Metallurgy.
2. The figures listed above are average or median concentrations of the particular element within the rock or material specified.
3. The NPI requires the reporting of emissions of the elements listed in this Table and their compounds. As noted in the body of this manual, it is recognised that trace metal analyses are not routinely undertaken for mining operations. In these situations, it is likely that the trace metal concentrations would be average to below average. Thus, where data on particular elements is not available, the average concentrations listed above for the particular material type should be used. In most cases, it would be expected that a low reliability would be attached to the emission estimate.
4. Further to Note 2, trace metal concentrations will be significantly greater than average where the reportable metal occurs at the site. For example, at a lead or zinc mine, the concentrations of lead, zinc and probably cadmium in waste rocks, TSFs and soils will be significantly greater than the average concentrations listed in the above Table. It is expected that where it is necessary to use an assumed trace metal concentration to estimate emissions from a site, the facility will nominate a credible figure, which can be justified to the administering authority (EPA). The reliability attached to the estimate will generally depend on the data sets available from which the estimate has been calculated.

(Source: *EET Manual for Mining*)

Table 5 below presents the total tonnage of ore handled in a reporting period that will trigger reporting at different concentrations of the composite Category 1 NPI substances.

Table 5 NPI Triggers as Related to Metal Concentration in Ore

Metal conc. in ore (ppm)	Annual tonnage (millions of tonnes)
0.1	100
0.2	50
0.3	33.3
0.4	25
0.5	20
0.6	16.7
0.7	14.3
0.8	12.5
0.9	11.1
1	10
10	1
100	0.1

Note that the trigger levels shown are for Category 1 Threshold of 10 tonnes.

Table 6 Indicative Coal Properties for Various Types of Coal.

(from NPI EET manual for fossil fuel electric power generation)

Coal constituent	Black Coal				Brown Coal	
	NSW[a]	Queensland[a]	Western Australia		Victoria	South Australia[b]
	(Range)	(Range)			Range	Range
% Carbon	57.1 – 64.5 (af)	53.2 – 80.5 (af)	70.9 (db)[e]		67.5 – 69.2 (db)	50.4 (db)
% Hydrocarbon	3.54 – 4.1 (af)	2.6 – 6.5 (af)	3.9 (db)[e]		4.8 – 4.9 (db)	2.9 (db)
% Nitrogen	1.15 – 1.5 (af)	0.8 – 1.5 (af)	1.2 (db)[e]		0.57 – 0.60 (db)	1.1 (db)
% Sulfur	0.34 – 0.55 (af)	0.15 – 0.75 (af)	0.7 (db)[e]		0.29 – 0.38 (db)	0.7 (db)
% Moisture	1.9 – 7.7 (af)	5.0 – 19.0 (af)	25.0 (ar)[e]		61.3 – 66.5 (ar)	28.0 (ar)
% Ash	17.4 – 25.8 (af)	11.7 – 15.3 (af)	6.7 (ar)[e]		1.3 – 3.0 (db)	27.8 (db)
Other elements (mg/kg) all db			**Low[b]**	**High[b]**		
Antimony	<0.05 – 1.7	0.2 – 1.41	<1	2	<0.02 – 0.02	0.3 – 2.6
Arsenic	<1 – 5	0.69 – 3.5	<1	2	0.05 – 0.2	0.7 – 0.6
Beryllium	0.8 – 7	0.6 – 2.8	<1	3	<0.05 – 0.26	<1 – 1.5
Boron	<5 – 36	10.0 – 38.0	2	5	3 – 24	40 – 300
Cadmium	<0.2 – 0.4	0.04 – 0.10	0.1	1.4	0.01 – 0.03	0.1 – 0.11
Chlorine	35 – 270	0.02 – 540	<50	230	0.06 – 0.08	500 – 17,000
Chromium	7 – 23	9.8 – 28.0	1	10	0.3 – 3.9	5 – 80
Chromium[d]	ND	ND	ND	ND	ND	ND
Cobalt	1.7 – 98	4.0 – 7.3	2	18	0.2 – 0.9	<2 – 25
Copper	4 – 14	14.0 – 37.0	1	13	0.3 – 2.4	3 – 60
Fluorine	75 – 168	51.0 – 160	16	55	8 – 22	191 – 367
Lead	6.7 – 16	5.0 – 8.7	<1	10	0.3 – 1.9	<2 – 50
Magnesium	ND	670 – 11,900	ND	ND	0.05 – 0.35	0.29 – 0.45
Manganese	5 – 360	7.1 – 438	<1	43	0.7 – 40	<2 – 500
Mercury	0.02 – 0.11	0.01 – 0.1	ND	ND	0.06 – 0.34	0.12 – 0.27
Nickel	5 – 50	5.1 – 16.0	2	22	1.2 – 3.8	4 – 60
Selenium	<1 – 2	0.12 – 0.53	ND	ND	0.3 – 0.6	<0.5 – 1
Zinc	6 – 370	10.5 – 31.0	1	72	1.3 – 20	15 – 200
Higher heating value (MJ/kg)	22.9 – 26.27	19.3 – 27.4	27.6 (db)[e]		8.76 – 10.2	

Notes: ND	no data available
db	dry basis
ar	as received
af	as fired basis
a	personal communication with NSW and Queensland electricity companies
b	Reference: Swaine D *Trace Elements in Coal* (Butterworth, 1990)
c	includes compounds
d	chromium (III and VI)
e	personal communication with Griffin Coal

Appendix B - Sources of Existing Data for NPI Reporting

Emission estimation techniques proposed in this manual require the best available data to maximise the reliability of emission estimates. Existing data may be available in a number of forms, from internal facility sources, external industry sources and other areas.

Existing data may be used to:
- estimate emissions directly;
- provide guidance on the most appropriate emissions estimation techniques for particular emissions sources;
- indicate the value of direct monitoring; and
- provide guidance on the best approach to take.

The collection of data required for emission estimation can often be a time consuming and laborious process. This is especially the case where required data is not already collected or available in a form compatible to the requirements of NPI reporting. It is therefore crucial to identify areas where data is available and unavailable.

Data sharing between individual facilities and within the industry may aid in the reporting process, and allow a greater level of accuracy and subsequent value of emission estimates. Information sharing may also provide financial benefits by reducing resource requirements for the NPI reporting process.

Existing data sources that may be useful during NPI reporting can be classified into three main areas:

- research projects of interest to, and often sponsored by industry, such as undergraduate, Honours, Masters and PhD projects, or in-house studies commissioned for specific purposes such as Occupational Health and Safety or environmental issues;
- data collected in accordance with regulatory requirements including licensing, reporting, and approvals;
- monitoring of process parameters; and
- supply inventories.

B1 Research

Research projects and other specific site investigations carried out by mining companies, and on mine sites often have very specific topics or limited scopes of investigation. The information provided by such projects may not be widely available elsewhere. Facilities may have also carried out discreet monitoring studies to determine the health, or environmental impacts of particular activities or substances. While these studies may indicate minimal environmental or health risks, they may provide valuable information for NPI reporting purposes.

Examples of such research may include the investigation of the fates and pathways of reagents and other pollutants used, generated or otherwise during processing and process by-product streams.

Many mining facilities will have access to information such as geotechnical and groundwater data from studies carried out in the past (generally during exploration and planning/commissioning stages of the operation). This data may define groundwater flows, the location of palaeochannels and other geological formations, and provide useful data for deciding the location and depths of monitoring bores for data collection.

B2 Process Monitoring

A variety of processing parameters is monitored regularly to ensure optimal recovery to resource use ratios. This data may be used in emissions estimation techniques (e.g. mass balance). It may also be useful in verification of the accuracy other EETs and provide essential raw data.

Monitored areas may include:

- ore inputs and concentrate/product outputs (mass), and compositions for various key indicators;
- mass of reagents added to process streams and entrainment within by-product streams;
- water input and overall balances (including reuse); and
- resource consumption during process, including fuel and electricity consumption.

Monitoring of key chemicals may also be undertaken for environmental and/or health and safety reasons, and may include:

- reagents;
- stack emissions;
- by-product liquid discharges; and
- groundwater seepage.

Key substances monitored may include:
- sulfur dioxide;
- hydrogen sulfide;
- oxides of nitrogen;
- ammonia; and
- metals

B3 Licensing and Reporting

Synthetic Rutile plants and mineral sands mining and processing sites may be required under environmental licences or works approval conditions to carry out monitoring that may be useful for NPI reporting. This data is likely to include:

- sulfur dioxide emissions;
- particulate matter emissions;
- carbon monoxide emissions;
- metals and nutrients in releases to surface and groundwater;
- spills and incidents; and
- dangerous goods listing.

This is likely to form the main source of emissions information for emissions to air from synthetic rutile processing.

Characteristics of the underlying stratification and surrounding environments may have been assessed to ascertain the potential for reagent reclamation, pollutant recovery and/or neutralisation. Where there is a potential for pond and containment impoundments to seep a network of monitoring bores will usually be installed, and regular monitoring programs implemented. Parameters may be monitored in a number of forms but generally include:

- pH;

- standing water level;
- conductivity and TDS; and
- metals.

This data may be used for:

- direct emissions estimations;
- indirect emissions estimation – as in the case of most dust monitoring where the speciation of dust may be required; and
- relative emissions estimation – where the ratio of a monitored parameter can be related to the emission of an NPI substance.

B4 Approvals Data

Facilities may produce environmental assessment reports, or other approval documents prior to commissioning operations, that generally include facility characterisation and operational efficiency data. This may extend to the identification of the main anticipated emissions sources, and provide estimations of the scales of these emissions. This information provides a reference source for general information about the facility, and allows for the assessment and generation of more accurate emissions estimation techniques.

B5 Regulatory Data

Regulatory and other government departments may hold data relating to individual facilities, industries, states and territories from national and international sources. This data may be accessed to develop facility or industry emissions estimation strategies.

B6 Supplier Data

Suppliers should be able to provide detailed information regarding the compositions of chemicals used within facility processes. Suppliers should also be able to provide guidance on the behaviour and products of these chemicals during processing.

B7 Inventory

Most facilities have either supply or hazardous chemical databases listing the majority, if not all chemicals used and stored on site. This inventory may be used in a number of ways:

- to identify NPI substances present on site;
- the quantities of substances consumed under normal operation;
- areas where different chemicals are used;

An example of an inventory for a mineral sands mining and processing facility is presented in Table 7.

Table 7 Hypothetical inventory of a mineral sands mining and processing facility.

INPUT	Units	Jan	Feb	Mar	…..	Total
Mining						
Ore mined	tonnes					
Overburden/Interburden mined	tonnes					
Ore treated	tonnes					
HMC produced	tonnes					
By-product solids/liquids produced	tonnes					
Flocculant used	litres					
Diesel consumed	litres					
Electricity used	MWhrs					
Other byproducts produced	tonnes					
Bore water consumed	kilolitres					
Potable water consumed	kilolitres					
Decant recovered/used	kilolitres					
Dry/wet processing						
HMC processed	tonnes					
Ilmenite produced	tonnes					
Zircon produced	tonnes					
Tailings produced	tonnes					
Natural gas consumed	litres					
diesel consumed	litres					
Electricity	MWhrs					
Potable water consumed	kilolitres					
Bore water consumed	kilolitres					
Decant water consumed	kilolitres					
Synthetic Rutile Processing						
Ilmenite Processed	tonnes					
Synthetic rutile produced	tonnes					
By-products produced	tonnes					
Diesel	litres					
Natural gas	litres					
Coal	tonnes					
Electricity	MWhrs					
Sulfur (added)	kilograms					
Sulfur dioxide (emitted)	tonnes					
Ammonium chloride	tonnes					
Sulfuric acid	tonnes					
Flocculant	litres					
Biocide	litres					
Potable water	kilolitres					
Bore water	kilolitres					
Decant water	kilolitres					

Appendix C - Emissions Controls

C1 Air Emissions

Air emission control technologies, such as electrostatic precipitators, fabric filters, baghouses, and wet scrubbers are commonly installed to reduce the concentration of substances in venting air streams. Where such emission abatement equipment has been installed, and where emission factors for uncontrolled sources have been used in emission estimation, the collection efficiency of the abatement equipment needs to be considered.

The simplest way to account for emissions reductions due to control measures is to apply an emission control factor either to the total emission estimate:

$$E_{kpy,i} = E_{uncontrolled} * (1 - CE_i/100)$$

Where:

$E_{kpy,i}$ = controlled emission of NPI listed substance in kilograms
$E_{uncontrolled}$ = uncontrolled emission of NPI listed substance in kilograms
CE_i = emission control efficiency for substance i (%)

Where multiple emission control devices are present the resulting emission control is cumulative and should be counted as such. For example, where a particular stack has an electrostatic precipitator, wet sulfur scrubber and an afterburner all present, and the emission reduction for each to sulfur dioxide emissions are 20%, 98% and 10% respectively actual controlled emissions would be equivalent to (1 – 20%) * (1 – 98%) * (1 – 10%) = 1.44% of uncontrolled emissions, or an emission control factor of 98.56%.

Where emission control efficiencies are not accurately known these can be estimated from design criteria. Comparisons monitoring data between times when the control device is in operation and not may also be used to provide an indication of the emission reduction achieved.

In the case of emission of PM_{10} (particulate matter with an equivalent aerodynamic diameter of 10 micrometres or less i.e. $\leq 10\mu m$) a control efficiency of 90% should be assumed when the control efficiency of a particular collection device is not known. This default value should only be used if there is no other available control efficiency data.

C2 Emissions to Water

Emission reduction measures in place for process by-product liquids mainly constitute the treatment of waters prior to release. Water treatment processes include flocculation and precipitation of solids, filtering, and neutralisation of acids using limes and/or soda ash.

Sediment traps may be considered as controls for emissions to water or land depending on surface water flow and destination. Sediment traps reduce the quantity of suspended solids and composite NPI substances in surface water flow.

Other control measures for releases to water include the recovery of contaminated waters.

Generally these control measures are applied to achieve specific quality criteria for released liquids. As such the released water will be closely monitored to ensure such criteria are met. Where released waters are not monitored the concentration of pollutants in the discharge water can be assumed to be at levels of at least the maximum allowable release concentration.

C3 Emissions to Land

Control measures available for reducing emissions to land take the form of recovery and prevention. Any significant quantity of material spilled or leaked to the surface is generally recovered and disposed of. Any underground leakage, including seepage, may be recovered via groundwater extraction systems. Other measures may include neutralisation (e.g. acid) and biodegradation (e.g. hydrocarbons).

Where NPI substances are recovered following their release in a leak the recovered mass is not considered to be emitted and should be subtracted from the total reportable emission.

Appendix D - EET Background Information

D1 EETs should be considered as 'points of reference'

The EETs and generic emission factors presented in the manual should be seen as 'points of reference' for guidance purposes only. Each has associated error bands that are potentially quite large (e.g. based on generic emission factors only) uncertainties of up to 100% may be possible. Appendix E discusses the general reliability associated with the various methods.

The potential errors associated with the different EET options should be considered on a case-by-case basis as to their suitability for a particular facility. Facilities may use EETs that are not outlined in this document. They must, however, seek the consent of their relevant environmental authority to determine whether any 'in house' EETs are suitable for meeting their NPI reporting requirements.

D2 Hierarchical approach recommended in applying EETs

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

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

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

The accuracy of particular EETs is discussed in Appendix E.

D3 NPI emissions in the environmental context

It should be noted that the NPI reporting process generates emission estimates only. It does not attempt to relate emissions to potential environmental impacts, bioavailability of emissions or natural background levels. No account is given of the likely fates of emitted substances following their release to the environment, the form that they are in (other than if they are emitted to air, land or water) or the specific nature of the source that they were emitted from (other than point or fugitive etc).

D4 NPI Reporting Requirements

It is anticipated that each facility will begin recording emissions within three months of gazettal of the Industry Handbook. The substances that require consideration are detailed in Tables 1 and 2 of the *NPI Guide*. The substances considered significant to the mineral sands mining and processing industry having been reproduced in Table 4 of this manual. Initially facilities need only report substances from Table 1 of the *NPI Guide*, however as of July 1, 2001 the additional substances from Table 2 need also be considered. When reporting to the NPI for the first time consideration should be given to reporting from the full list of 90 substances as this will probably save resources in the longer term.

At the end of each reporting period every mineral sands mining and processing facility is required to report emissions of all triggered NPI substances to their State or Territory environmental regulatory agency by September 30. The reported quantities are the summation of the individual emissions from the various sectors within the facility operations, for example only one value for the sulfur dioxide emissions is reported (facility total), which represents the summation of all individual emissions throughout the year from all facility divisions.

The State Environmental Agency may conduct an assessment of whether the reported levels are a reasonable estimate of the actual emissions and will forward the values to Environment Australia where they will be published on a publicly accessible Internet database, www.npi.gov.au.

Appendix E - 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 NPI 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 mineral sands mining and processing facilities. The technique chosen is dependent on available data, and available resources, and the degree of accuracy sought by the facility in undertaking the estimate. In general, site-specific data that is representative of normal operations is more accurate than industry-averaged data such as the emission factors presented in Section 5 of this Manual.

E1 Direct Measurement

Use of stack sampling data is likely to be a relatively accurate method of estimating air emissions from mineral sands facilities. However, collection and analysis of samples from facilities can be expensive and 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 operation, and may provide only one example of the facility's emissions.

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

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 incorrect to assume that a snapshot (stack sampling) can predict long-term emission characteristics. It is the responsibility of the facility operator to properly calibrate and maintain monitoring equipment and to assess the accuracy and reliability of emission estimates.

E2 Mass Balance

Calculating emissions from a mineral sands mining and processing facility using mass balance appears to be a straightforward approach to emission estimation. However, it is likely that few facilities consistently track material usage and waste generation with the overall accuracy needed for application of this method. Also, inaccuracies associated with individual material tracking, or other activities inherent in each material handling stage, can result in large deviations for total facility emissions.

E3 Engineering Calculations

Theoretical and complex equations, or *models* can be used for estimating emissions from mineral sands processes. EET equations using models are available for the following types of emissions common to facilities.

- Dust
- Pond and TSF seepage
- substances generated during chemical processes such as ammonia

Use of emission equations to estimate emissions from these facilities is a more complex and time-consuming process than the use of emission factors. Emission equations require more detailed inputs than the use of emission factors but they do provide an emission estimate that is based on facility-specific conditions, and can be expected to provide more accurate representation of emissions.

E4 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 NPI 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. The emission factor ratings will not form part of the public NPI database.

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

The EFR system is as follows:

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

Appendix F - Variables and Symbols Used

Table 8 lists the variables and symbols used throughout this Manual.

Table 8 List of variables and symbols

Symbol	Variable	Units
ρ_a	Density of air	kg/m^3
ρ_m	Density of material	kg/L
*	Multiplication sign	
A_s	Surface area	m^2
A	Activity rate	units/hr (e.g. t/hr)
Acc	Amount of pollutant accumulating within the process	e.g. kg/yr
AS_i	Amount of pollutant i in sludge	kg/yr
$C_{a,i}$	Average concentration of pollutant i	ppm_v (volume/volume) $ppm_{v,d}$ = volume of pollutant gas/10^6 volumes of dry air OR kg/kg, OR mg/m^3, OR kg/L
CE_i	Overall control efficiency, (i.e. Emission reduction control factor)	% reduction in emissions of pollutant i
C_f	Filter catch of particulate material	g
C_i	Concentration of pollutant i	ppmv OR kg/L
C_{PM}	Concentration of PM	$grams/m^3$
C_{PM10}	Concentration of PM_{10}	$grams/m^3$
C_{VOC}	VOC (Volatile Organic Compounds) content of material	kg/L
dh	Hydraulic head above floor of impoundment/pond	m
dl	Thickness of material in impoundment	m
EF_i	Uncontrolled emission factor for pollutant i	kg of pollutant/unit of weight, volume, distance OR duration of activity emitting the pollutant
E_i	Total emissions of pollutant i per hour	kg/hr
$E_{kpt,i}$	Emissions per tonne	kilograms of pollutant i per tonne of fuel consumed
$E_{kpy,i}$	Annual emissions of pollutant i	kg/yr
EL_i	Emissions to land from spill	*Kgkg/spill event*
E_{VOC}	Total VOC emissions	kg/L
EW_i	Elemental weight of pollutant i	kg/kg-mole
k	Permeability of impoundment floor	m/day
K_i	Gas-phase mass transfer coefficient	m/sec

Table 8 cont'

Symbol	Variable	Units
K_p	Pressure correction for pressure differences during test	dimensionless
K_t	Temperature correction for temperature differences during test	dimensionless
M_i	Mass of substance i emitted	kg
$moist_R$	moisture content	vol %
MW_i	Molecular weight of pollutant i	kg/kg-mole
OpHrs	Operating hours	hr/yr
PL_i	Process losses of pollutant i	kg/yr
PM	Particulate Matter (the same as TSP)	kg (usually)
$P_{sat,i}$	Saturation vapour pressure of pollutant i	kilopascals (kPa)
P_{STP}		
P_t	Total pressure	kPa
$P_{vap,i}$	Vapour pressure of pollutant i	kPa
Q_a	Volumetric flow rate of actual (wet) stack gas	actual cubic metres per second (m^3/s)
Q_d	Volumetric flow rate of dry stack gas	dry standard cubic metres per second (m^3/s)
Q_f	Fuel used	kg/hr
Q_{in}	Material entering the process	L/hr OR kg/hr OR t/hr OR unit/yr
Q_{out}	Material leaving the process (as an emission, transfer, or in product)	L/hr OR kg/hr OR t/hr
R	Ideal gas constant (e.g. 8.314 J/K/g-mol)	various units e.g. J/K/g-mol
S	Specific yield of material	%
STP	Standard Temperature & Pressure	0^oC (273K) and 1 atmosphere (101.325 kPa)
T	Temperature	^oC of K (Celsius or Kelvin)
TSP	Total suspended particulates	kg (usually)
T_{STP}	Standard temperature	0°C or 273.15 K
U_{10}	Wind speed at 10 m	km/hr
V	Molar volume	m^3/kg-mole
V_{lc}	volume of moisture collected at STP	litres (l)
V_T	Volume of total emissions	m^3
VKT	Vehicle kilometres travelled	km
W_i	Evaporation rate of pollutant i	kg/sec
WL_i	Losses in wastewater of pollutant i	kg/yr
$Wt\%_i$	Percentage weight of pollutant i	%

Source: modified from Queensland Department of Environment and Heritage, 1998.