



**Australian Government**

**Department of Sustainability, Environment, Water, Population and Communities**



## **National Pollutant Inventory**

### **Emission estimation technique manual for**

### **Explosives detonation and firing ranges Version 3.0**

**January 2012**

**ISBN:** 978-0-642-55384-3

© Commonwealth of Australia 2012

This guidance material 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 guidance material may be updated at any time.

Reproduction for other purposes requires the written permission of the Department of Sustainability, Environment, Water, Population and Communities,  
GPO Box 787, Canberra, ACT 2601,  
e-mail: [npi@environment.gov.au](mailto:npi@environment.gov.au)  
web: [www.npi.gov.au](http://www.npi.gov.au)  
phone: 1800 657 945.

### **Disclaimer**

The guidance material 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 guidance material are factually correct, the Australian Government does not accept responsibility for the accuracy or completeness of the contents and shall not be liable for any loss or damage that may be occasioned directly or indirectly through the use of, or reliance on, the contents of this guidance material.

# Emission Estimation Techniques For Explosives detonation and firing ranges Table of Contents

<b>1</b>	<b>INTRODUCTION.....</b>	<b>1</b>
1.1	THE PROCESS FOR NPI REPORTING.....	2
1.2	INFORMATION REQUIRED TO PRODUCE AN ANNUAL NPI REPORT.....	2
1.3	ADDITIONAL REPORTING MATERIALS.....	3
<b>2</b>	<b>PROCESS DESCRIPTION.....</b>	<b>4</b>
2.1	MINING OPERATIONS .....	4
2.2	FIRING RANGES .....	4
<b>3</b>	<b>EMISSION SOURCES.....</b>	<b>6</b>
3.1	EMISSIONS TO AIR FOR EXPLOSIVE DETONATION .....	6
3.1.1	<i>Point source emissions to air</i> .....	6
3.1.2	<i>Fugitive source emissions to air</i> .....	6
3.2	EMISSIONS TO AIR FOR FIRING RANGES .....	6
3.3	WATER EMISSIONS .....	6
3.4	LAND EMISSIONS.....	6
<b>4</b>	<b>THRESHOLD CALCULATIONS .....</b>	<b>8</b>
<b>5</b>	<b>EMISSION ESTIMATION TECHNIQUES .....</b>	<b>9</b>
5.1	EMISSION FACTORS.....	9
5.2	EMISSIONS FOR EXPLOSIVES DETONATION .....	9
5.2.1	<i>Emission factors for explosives</i> .....	9
5.2.2	<i>Adjustments for additives and rock type</i> .....	10
5.3	EMISSIONS FACTORS FOR AMMUNITION .....	11
<b>6</b>	<b>TRANSFERS OF NPI SUBSTANCES IN WASTE.....</b>	<b>14</b>
<b>7</b>	<b>NEXT STEPS FOR REPORTING.....</b>	<b>15</b>
<b>8</b>	<b>REFERENCES.....</b>	<b>16</b>
	<b>APPENDIX A: DEFINITIONS AND ABBREVIATIONS.....</b>	<b>17</b>
	<b>APPENDIX B: EMISSION FACTORS .....</b>	<b>18</b>
	<b>APPENDIX C: MODIFICATIONS TO THE INDUSTRY MANUAL MANUFACTURING EMISSION ESTIMATION TECHNIQUE (EET) MANUAL.....</b>	<b>20</b>
	(VERSION XX MONTH YEAR) .....	<b>ERROR! BOOKMARK NOT DEFINED.</b>

## List of Figures, Tables, Equations and Examples

Figure 1: Process for NPI Reporting.....	2
Table 1: Types and examples of common explosives.....	4
Table 2: Category 1, 1a, 2a and 2b substances that could be emitted as a result of explosive detonation and discharge of ammunition.....	7
Table 3: Example of determining fuel storage and usage for different fuel types.....	8
Table 4: Use of individual explosives to trip Category 1 and 1a substance thresholds.....	18
Table 5: Use of individual ammunition to trip Category 1 and Category 2 substance thresholds .....	18
Table 6: Percentages of Category 1 and 1a substances in explosive products .....	19
Table 7: Emission factors for Category 1 and 2a substances .....	20
Table 8: Emission factor adjustments for different additives and rock type .....	21
Table 9: Emission factors for Category 1 and 2a NPI substances emitted or discharge of ammunition.....	21
Equation 1: General equation for emissions factors.....	9
Example 1: Determining storage and usage of different fuel types .....	8
Example 2: Reporting on NPI emissions from explosives at a mining operation.....	10

---

Example 3: Reporting NPI emissions at firing range..... 12

---

# 1 Introduction

The purpose of all emission estimation technique (EET) guidance materials is to assist Australian manufacturing, industrial and service facilities to report emissions and transfers of listed substances to the National Pollutant Inventory (NPI). This guidance material describes the procedures and recommended approaches for estimating emissions and transfers from facilities engaged in explosive detonation and firing range activities. These facilities are likely to include the mining and quarrying industries, demolition industries and firing ranges.

<b>EET MANUAL</b>		Explosives detonation and firing ranges
<b>ANZSIC CODE</b>	<b>2006</b>	Facilities which have activities associated with one or more of the subset of ANZSIC codes listed below are required to report on the emissions and Transfers from the use of explosives and explosive detonations if the cumulative emissions or energy usage is triggered for all activities.

Please note that the ANZSIC code is part of NPI reporting requirements. *The NPI Guide* contains an explanation of the ANZSIC code.

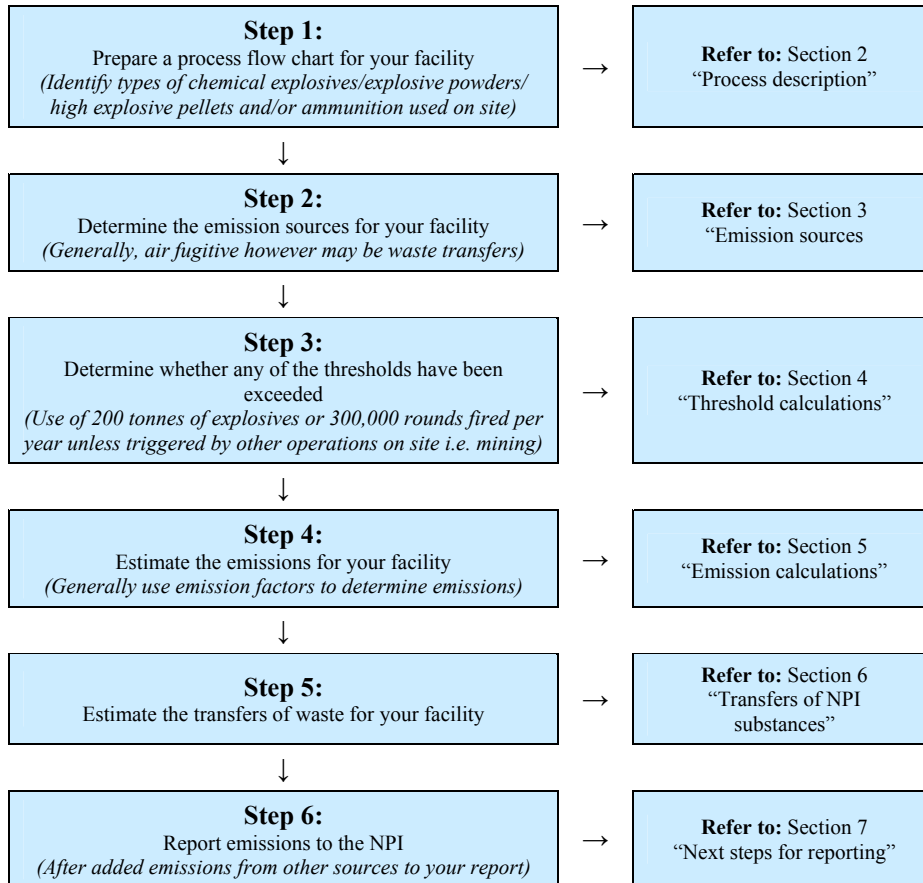
NPI substances are those that when emitted at certain levels have potential to be harmful. Australian, state and territory governments have agreed, in response to international requirements, that industries will report these emissions on an annual basis. NPI substances are set out in the *NPI Guide* and are listed in categories which have a threshold; i.e. once annual 'use' of substances is above the threshold their emissions and transfers must be reported.

This guidance material has been developed through a process of national consultation involving state and territory environmental agencies and key industry stakeholders.

Particular thanks are due to: Simtars, the Queensland Government; Queensland Police Services; Australian Sporting Shooters Association; Sporting Shooters Association Queensland Branch; Australian Defence Industries; Orica Australia; Roche Mining; Maxam Australia; Dyno Nobel Asia Pacific; Australian Explosives Industry and Safety Group; Queensland Department of Mines and Energy.

## 1.1 The process for NPI reporting

The process for NPI reporting can be seen in the following flow chart:



**Figure 1: Process for NPI Reporting**

## 1.2 Information required to produce an annual NPI report

The following data relating to explosives detonation may need to be collated for the reporting period:

- Mining activities should collate information on the type and volume of explosives detonated,
- Explosives and ammunition (explosive ordnance) manufacturing activities should collate information on the type and volume of explosives and propellants detonated for production testing, research or at technical centres and
- Firing range activities should collate data on the number/quantity discharged of shot and bullets (projectiles), and the number or mass of cartridges, primer and propellant. For each type of explosive ordnance it is recommended that information on the quantity of NPI substances in the bullets or projectiles or cartridges becoming an ‘emission to land’ or recovered for recycling (a voluntary transfer) should be gathered. Information on the amount and type of recovered explosive ordnance and the quantity and type of explosives use to manage unexploded explosive ordnance may also need to be gathered.

In order to complete the report it is necessary to consider other activities taking place at the facility, for example, fuel burning in on-site vehicles. Required data may include:

- type and amount of fuel burnt
- pollution control devices employed
- volume and throughput of fuels or organic liquids stored on site
- ‘usage’ of Category 1 and 1b substances.

---

### 1.3 Additional reporting materials

This guidance material is written to reflect the common explosives detonation and firing ranges. In many cases it will be necessary to refer to other EET guidance materials to ensure a complete report of the emissions for the facility can be made. Other applicable EET guidance materials may include, but are not limited to:

- *Combustion in boilers;*
- *Combustion in engines;*
- *Fuel and organic liquid storage;*
- *Fugitive emissions; and*
- Other industry-specific emission estimation technique guidance materials, such as the *Mining* and *Defence facilities* EET guidance materials.

Please note that draft guidance materials have been developed by the US Army Environmental Center for the 5<sup>th</sup> edition of AP 42, which cover additional emission factors for munitions. It is available at

<http://www.epa.gov/ttn/chief/ap42/ch15/index.html>

## 2 Process description

The following section presents a brief description of explosives detonation and firing ranges and identifies the likely sources of emissions. This represents a typical facility in the industry, but as a first step it is advised that you develop a process flow diagram specific to your site.

Chemical explosives, including ammunition, emit substances that may be harmful and therefore of interest to the National Pollutant Inventory. The extraction (mining and quarry) and demolition (construction) industries use explosives. Explosives are also used in firearm activities at military and civilian firing ranges.

‘Use’ and ‘usage’ is defined as the handling, manufacture, import, processing, coincidental production or other uses of NPI substances. Normally explosives are delivered and stored on site, then detonated as required. ‘Use’ in the case of the explosives and firing range industries would normally include handling and combustion, and may include storage.

### 2.1 Mining operations

Explosives can be in the form of packaged pre-mixed forms (often as aqueous gels based on ammonium nitrate/fuel oil mixes) or sometimes as raw ingredients (e.g. ammonium nitrate and fuel oil), which are mixed on site. Brand name pre-mixes include Energan, Powergel, and Amex etc. Enhancers, explosive powders and high explosive bullets are also used as boosters for blasting. The amounts of NPI substances emitted depend on the type of explosive and the volume used.

The activities associated with the detonation of explosives at a mine such as drilling the holes to place the explosives and release of rock based particulate matter (dust as PM<sub>10</sub>) after an explosion are addressed in the Emission Estimation Technique Manual for Mining.

**Table 1: Types and examples of common explosives**

Type	Examples
Powders	Black powder
	Smokeless powder
	Dynamite, straight
	Dynamite, ammonia
	Dynamite, gelatin
	Ammonium nitrate
Slurry	ANFO <sup>1</sup>
	ANFO heavy (mix with emulsion)
Wet powder binary	Kinepak
Aqueous gels	Heavy ANFO
	Emulsion (water gel slurry)
	AMEX packaged
High explosive pellets	Royal Dutch Explosive (RDX)
	TNT
	PETN (plastic explosive)
	Tetryl (used in blasting caps)

- Note: 1 Ammonium nitrate/fuel oil mix.
- Source: Simtars 2007.

### 2.2 Firing ranges

Firing ranges are available for recreational shooters and other operations. Users usually bring their own ammunition to a firing range site but some firing ranges store and handle ammunition for client use.

Primer and propellant detonation, and barrel friction cause emissions that occur during the discharge of bullets. The typical range of ammunition types includes:

- shotgun (12, 16, 20 – 28 gauges);
- frangible bullet;
- pistol ammunition (.17, .22-.28, 7, .3 - .45 mm); and
- rifle ammunition (.17-.204, .22, .22 (jacketed), .22 - .358 (double base propellant and jacketed), .375 - .5 mm).

---

Spent cartridges, recovered projects and other fragments from the firing of explosive ordnance may be disposed of as waste or recycled. The disposal of waste either on-site or off-site may trigger reporting requirements as a 'transfer'.

---

## **3 Emission Sources**

### **3.1 Emissions to air for explosive detonation**

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

#### **3.1.1 Point source emissions to air**

Point source emissions are directed into a vent or stack and emitted through a single point source into the atmosphere. Emissions from explosions detonated at an open-cut mine would normally not be point source emissions, unless gases (and dust) from an underground explosion is removed using 'vent shafts'.

#### **3.1.2 Fugitive source emissions to air**

These are emissions not released through a vent or stack. Examples of fugitive emissions include emissions from vehicles, dust from stockpiles and gaseous emissions from the detonation of explosive materials. Most emissions from the detonation of explosives will be fugitive emissions.

### **3.2 Emissions to air for firing ranges**

Most emissions from the detonation of ammunition will be fugitive emissions.

### **3.3 Water emissions**

Explosive and ammunition detonation facilities are not, in general, expected to emit substances to water. However, wastes left over from detonations and the discharge of weapons have potential to leach or dissolve and impact on water bodies.

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

- surface waters (lakes, rivers, dams, estuaries);
- coastal or marine waters; and
- stormwater runoff.

Emissions of toxic substances to waterways may pose environmental hazards. Most facilities emitting NPI-listed substances are required by their state or territory environment agency to closely monitor and measure these emissions. Existing sampling data can be used to calculate annual emissions to the NPI.

If no monitoring data exists and an emission is likely to occur, emissions could be estimated by mass balance or using emission factors. In the case of spillages or unintentional discharges to waterways, it is a legal requirement to immediately contact the relevant state or territory environment agency for guidance. Any such emissions are also reportable to the NPI if substance thresholds are exceeded.

### **3.4 Land emissions**

Emissions of NPI substances to land can include solid materials including wastes, slurries, sediments, spills and leaks. Emissions from detonation systems, blasting caps and high explosives used in a 'blasting train' to initiate secondary explosives such as ANFO are not considered an emission to land.

Some facilities may use treated wastewater for irrigation e.g. landscaping at mine sites or firing ranges. This wastewater need only be considered for NPI reporting if it contains an NPI-listed substance. For NPI purposes this is categorised as an emission to land.

**Table 2: Category 1, 1a, 2a and 2b substances that may be emitted as a result of explosive detonation and discharge of ammunition**

Explosives	Ammunition Primer & projectile	Ammunition Propellant
<ul style="list-style-type: none"> <li>• Antimony and compounds</li> <li>• Arsenic and compounds</li> <li>• Benzene <sup>2</sup></li> <li>• Butadiene <sup>2</sup></li> <li>• Cadmium</li> <li>• Carbon monoxide</li> <li>• Chromium (VI) compounds</li> <li>• Copper and compounds</li> <li>• Cumene <sup>2</sup></li> <li>• Cyclohexane <sup>2</sup></li> <li>• Ethylbenzene <sup>2</sup></li> <li>• Lead compounds</li> <li>• N – Hexane <sup>2</sup></li> <li>• Nitric acid <sup>2</sup></li> <li>• Oxides of nitrogen (Cat 2a)</li> <li>• PM<sub>10</sub> (Cat 2a)</li> <li>• PM<sub>2.5</sub> (Cat 2a) <sup>1</sup></li> <li>• Styrene <sup>2</sup></li> <li>• Toluene <sup>2</sup></li> <li>• Total VOCs <sup>2</sup></li> <li>• Xylene <sup>2</sup></li> <li>• Zinc and compounds</li> </ul>	<ul style="list-style-type: none"> <li>• Antimony and compounds</li> <li>• Arsenic and compounds</li> <li>• Copper and compounds</li> <li>• Lead and compounds</li> <li>• Zinc and compounds</li> </ul>	<ul style="list-style-type: none"> <li>• Acrylonitrile <sup>2</sup></li> <li>• Antimony and compounds</li> <li>• Copper and compounds</li> <li>• Cyanide (inorganic) compounds</li> <li>• Cyclohexane <sup>2</sup></li> <li>• Hydrochloric acid</li> <li>• Lead and compounds</li> <li>• Manganese and compounds</li> <li>• Mercury and compounds</li> <li>• n - Hexane <sup>2</sup></li> <li>• Toluene <sup>2</sup></li> <li>• Zinc and compounds</li> </ul>

- Notes: <sup>1</sup> pm<sub>2.5</sub> is from combustion products and does not include soil particulates.
- <sup>2</sup> In general, it is expected that volatile compounds and nitric acid are unlikely to be emitted as they are likely to have been destroyed during the detonation process.
- Source: Simtars 2007 based on USEPA, Orica Australia and various documented experiments and tests.

## 4 Threshold calculations

The *NPI Guide* outlines detailed information on thresholds and identifying emission sources. The method involves identifying any NPI substances that may be used by your facility, or are components of materials used by your facility, and then calculating whether the quantity used exceeds the NPI threshold.

The NPI thresholds in the explosives and firing range industries include Categories 1, 1a, 2a and 2b substances. In the case of Category 1 and 1a substances they must be reported if they exceed the threshold. In the case of Category 2 substances, if any substance exceeds the threshold then all Category 2a and 2b substances must be reported.

### Example 1: Determining storage and usage of different fuel types

A facility uses a mix of diesel, petrol (ULP) and explosives on site, the amount of each fuel that needs to be considered for category 2a, 2b and 1a thresholds are shown in Table 3.

**Table 3: Example of determining fuel storage and usage for different fuel types**

Fuel type	Consumption	How is fuel used?	Category 2a/2b "Fuel burnt"	Category 1a "Total VOC"
Diesel	800 tonnes per annum.	As a coal flotation additive.	Exclude as it is not burnt in the process.	Include as fuel contains Total VOC.
	6,200 tonnes per annum	As a fuel for on site engines.	Include as it is burnt in the process	Include as fuel contains Total VOC
Petrol (ULP)	100 tonnes per annum	As a fuel for on site engines.	Include as it is burnt in the process	Include as fuel contains Total VOC
Solid explosives	3,800 tonnes per annum	For overburden removal	Include as for the purpose of NPI, detonation is considered a combustion process for explosives.	Exclude as it is a solid fuel which doesn't contain Total VOC.
Total "Usage"			10,100 tonnes per annum	7,100 tonnes per annum
NPI Threshold tripped?			Yes	Yes

In Table 3, it is shown that for this facility, both category 2a, 2b and 1a have been tripped based on how the different fuels have been used. This example doesn't include a determination of category 1 thresholds which will also need to be considered.

---

## 5 Emission estimation techniques

If you have established under Section 4 whether the quantity of explosives and/or ammunition the facility uses exceeds NPI thresholds, you will need to estimate emissions of NPI substances.

More information regarding emission estimation techniques can be located in *The NPI Guide*.

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

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

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

### Spills and accidental releases

You should note that the EETs presented in this guidance material 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 (e.g. spills) will also need to be estimated.

Emissions to land, air and water from spills must be estimated and added to process emissions when calculating total emissions for reporting purposes. The emission resulting from a spill is the net emission, i.e. the quantity of the NPI reportable substance spilled, less the quantity recovered or consumed immediately (within 24 hours) during clean up operations.

## 5.1 Emission factors

### Equation 1: General equation for emissions factors

$$E_{(s)} = A \times EF_{(s)} \times CE$$

Where:

$E_{(s)}$  = is the annual emission level for an NPI substance (s) - e.g. carbon monoxide.

A = is the activity rate over a year (e.g. operating hours, number of operations, tonnage used etc.).

$EF_{(s)}$  = is the emission factor for the substance (s) as set out in this manual at Sections 5.1 and 5.2 and Tables 5, 6, 7 and 8.

CE = control efficiency reflects any devices or processes that control the level of emissions. (E.g. a scrubber in a stack). It is not expected that control efficiency will be applicable to explosives detonation and firing range operations

## 5.2 Emissions for explosives detonation

### 5.2.1 Emission factors for explosives

Emission factors for likely NPI threshold substances that are known to be components of explosives are calculated in terms of kilograms of substance per tonne of explosive, and are set out in Table 5 in

Appendix C, which lists emission factors for a range of Category 1 and 2a substances in relation to explosives.

### 5.2.2 Adjustments for additives and rock type

Some of the substances, specifically carbon monoxide and oxides of nitrogen, are emitted at different levels depending on the characteristics of the explosion. The characteristics of an explosion are dependent on the explosive product, priming methods, hole characteristics (soil moisture, rock type, hole size) and level of additives/enhancers. Table 8 in Appendix C outlines an adjustment factor that varies depending on the level of additives and hardness of rock.

Table 8 should be used in conjunction with the emission factors in Table 7. For example, in a situation where additional fuel oil is used in the ANFO mix; the emission factor in Table 7 should be increased by the applicable factor in Table 8.

#### Example 2: Reporting on NPI emissions from explosives at a mining operation

The facility in this example is a mining operation that detonates explosives to clear rock face in an open quarry. It uses branded ANFO (aqueous gel) for small bore (<152mm) work necessary for rock face clearing. The facility purchases brand name ANFO in bulk and in the reporting year used 450 tonnes. The rock is classified as hard, so additional fuel oil is added to the explosive to increase the explosive force.

##### Step 1. Determine NPI substances used at the facility

As set out in Table 2 ANFO contains a number of Category 1, 1a, 2a and 2b substances. In addition, all explosives are considered to be fuels and emit a number of NPI substances upon combustion.

##### Step 2. Determine whether NPI thresholds are exceeded

Table 3 indicates that ANFO includes the Category 1a substance (total volatile organic compounds), and that where usage of ANFO exceeds 1,389 tonnes in a year, reporting for this substance is required. In this example, usage is less than the threshold, therefore reporting of emissions of this substance is not required. In addition, ANFO is classed as a fuel for NPI purposes. Section 4.2 indicates that when used in quantities of 400 tonnes or more it has exceeded the Category 2a threshold, therefore, emission of all Category 2a substances must be estimated and reported.

##### Step 3. Determine the level of emissions

In this example, the use of emission factors is suggested for estimating emissions of tripped substances.

##### Category 1

Table 6 shows Category 1 substances in ANFO. It indicates that ANFO comprises (among other things) trace levels of nitric acid, no emission of nitric acid is expected from the detonation process.

##### Category 2a

As the mass of explosive used triggers the Category 2a threshold, all Category 2a NPI substances must be reported. Table 5 provides emission factors in terms of kilograms per tonne for a range of substances, including carbon monoxide and PM<sub>2.5</sub>.

Using the general equation 1,  $E(s) = A \times EF(s) \times CE$ .

Example: Carbon monoxide

E(s): (Emissions of Carbon monoxide) at the facility in a year

A: (Activity rate) is 450 tonnes used on site in a year.

EF: The emission factor for carbon monoxide related to combustion of branded ANFO in small holes is 8 kg per tonne. In addition, the ANFO is enhanced by additional fuel oil, which according to Table 8, requires the EF to be tripled.

CE: The control efficiency factor does not apply in this case as the combustion involves fugitive emissions.

$$\begin{aligned} E &= A \times EF \\ &= 450 \times (8 \times 3) \\ &= 10,800 \text{ kg of carbon monoxide} \end{aligned}$$

Example: PM<sub>2.5</sub>

E(s): (Emissions of PM<sub>2.5</sub>) at the facility in a year

A: (Activity rate) is 450 tonnes used on site in a year.

EF: (Emission Factor) for PM<sub>2.5</sub> emitted from blasting is 5.1 kg per tonne.

CE: (Control efficiency factor) does not apply in this case as the combustion involves fugitive emissions.

$$\begin{aligned} E &= A \times EF \\ &= 450 \times 5.1 \\ &= 2,295 \text{ kg of PM}_{2.5} \end{aligned}$$

This calculation should be repeated for other substances listed in Table 7 (note that emission factors are provided for carbon monoxide and oxides of nitrogen for ANFO (<152mm). Facilities should attempt to estimate emissions of other Category 2a substances using an alternative technique where possible).

Similar calculations would then be undertaken for the use of fuel for various other on-site purposes using the NPI emission estimation technique manual for combustion engines.

#### Step 4. What needs to be reported?

That 450 tonnes of ANFO is stored, handled and combusted on site and this exceeds the Category 1 threshold.

It is estimated that 28.3 tonnes of the Category 1 and Category 2a NPI substance, carbon monoxide (among others), is emitted each year (plus those emitted from fuel used on site).

It is estimated that 2.3 tonnes of the Category 2a NPI substance, PM<sub>2.5</sub> (among others), is emitted each year at the facility.

### 5.3 Emissions factors for ammunition

NPI substances can be found in all components of ammunition. Most ammunition rounds are comprised of a projectile or bullet, a shell or cartridge, primer and propellant.

The projectile or bullet is usually made of lead or lead and copper. The shells are generally made of copper, zinc and boron. The shells are all solid materials that are incorporated in the structure of the ammunition round and make up the permanent vehicle for ammunition discharge. These components, although discarded, are not considered to be an emission for NPI purposes. However ground and water contamination and waste transfer at firing ranges may be an issue - although the available evidence suggests, for example in relation to the ammunition type with the most lead (12 gauge shotgun cartridges containing 30 grams of lead), some three hundred thousand rounds would need to be used to exceed the Category 1 threshold.

In calculating such possible contamination, rifle range owners should note, and include in their calculations, that many users, especially pistol shooters, reload (i.e. recycle) the shell casings.

The primer and propellant are present in ammunition at about equal weight – one to five grams depending on the type and gauge. Primers and propellants contain a number of NPI substances that are emitted into the atmosphere on discharge.

Most of the toxic emissions from primers and propellants are emitted at low levels (i.e. their emission factors are low). While hydrochloric acid and particulate matter  $\leq 10 \mu\text{m}$  (PM<sub>10</sub>) are likely to be the main emissions along with possibly lead and carbon monoxide, it is most likely that only the largest of Australian firing ranges would exceed NPI Category 1 thresholds.

Table 9 contains emission factors for propellants used in the discharge of ammunition.

**Example 3: Reporting NPI emissions at firing range**

Determine which thresholds have been tripped for a facility that used 400,000 rounds in 12 gauge shotguns, 600,000 rounds in .22 rifles (not jacketed) and 200,000 rounds in 7mm pistols.

**Step 1: Determine the usage of the five substances associated with ammunition usage**

The five substances: antimony, arsenic, copper, lead and zinc should be considered separately.

Substance mass per round figures can be found in Table 4.

$$\begin{aligned} \text{Antimony use from}_{(\text{shotgun})} &= \text{rounds used}_{(\text{shotgun})} \times \text{substance mass per round}_{(\text{shotgun})}(\text{g}) / \\ & \quad 1,000,000 \text{ g/tonne}] \\ &= 400,000 \times 0.9\text{g}/1,000,000 \text{ g/tonne} \\ &= 0.36 \text{ tonnes} \end{aligned}$$

$$\begin{aligned} \text{Antimony use from}_{(\text{rifle})} &= \text{rounds used}_{(\text{rifle})} \times \text{substance mass per round}_{(\text{rifle})}(\text{g}) / \\ & \quad 1,000,000\text{g/tonne}] \\ &= 600,000 \times 0.1\text{g}/1,000,000\text{g/tonne} \\ &= 0.06 \text{ tonnes} \end{aligned}$$

$$\begin{aligned} \text{Antimony use from}_{(\text{pistol})} &= \text{rounds used}_{(\text{pistol})} \times \text{substance mass per round}_{(\text{pistol})}(\text{g}) / \\ & \quad 1,000,000\text{g/tonne}] \\ &= 200,000 \times 0.2\text{g}/1,000,000\text{g/tonne} \\ &= 0.04 \text{ tonnes} \end{aligned}$$

$$\begin{aligned} \text{Total Antimony used} &= \text{Antimony use}_{(\text{shotgun})} + \text{Antimony use}_{(\text{rifle})} + \text{Antimony use}_{(\text{pistol})} \\ &= 0.36\text{t} + 0.06\text{t} + 0.04\text{t} \\ &= 0.46\text{t} \end{aligned}$$

Repeat for each additional substance

$$\begin{aligned} \text{Arsenic usage} &= (400,000 \times 0.2/1,000,000) + (600,000 \times 0.2/1,000,000) + \\ & \quad (200,000 \times 0.5/1,000,000) \\ &= 0.08 + 0.12 + 0.1 \\ &= 0.3 \text{ tonnes} \end{aligned}$$

$$\begin{aligned} \text{Copper usage} &= (400,000 \times 0.3/1,000,000) + (600,000 \times 0.7/1,000,000) + \\ & \quad (200,000 \times 0.7/1,000,000) \\ &= 0.12 + 0.42 + 0.14 \\ &= 0.68 \text{ tonnes} \end{aligned}$$

$$\begin{aligned} \text{Lead usage} &= (400,000 \times 30/1,000,000) + (600,000 \times 4/1,000,000) + \\ & \quad (200,000 \times 9/1,000,000) \\ &= 12 + 2.4 + 1.8 \\ &= 16.2 \text{ tonnes} \end{aligned}$$

$$\begin{aligned} \text{Zinc usage} &= (400,000 \times 0.1/1,000,000) + (600,000 \times 0.3/1,000,000) + \\ & \quad (200,000 \times 0.3/1,000,000) \\ &= 0.04 + 0.18 + 0.06 \\ &= 0.28 \text{ tonnes} \end{aligned}$$

**Step 2: Determine if any Category 1 thresholds have been tripped**

For each of the five substances, the usage threshold is 10 tonnes. Thus, the only substance for which a threshold has been tripped is lead (16.2t usage). Emissions will need to be calculated for this substance.

---

**Step 3: Determine if any Category 2 thresholds have been tripped**

Fuel combusted (shotgun)	= rounds used <sub>(shotgun)</sub> x propellant <sub>(shotgun)</sub> (g) / 1,000,000g/tonnes = 400,000 x 1.4g / 1 000 000g/tonnes = 0.56 tonnes
Fuel combusted (rifle)	= rounds used <sub>(rifle)</sub> x propellant <sub>(rifle)</sub> (g) / 1,000,000g/tonnes = 600,000 x 1.2g / 1,000,000g/tonnes = 0.72 tonnes
Fuel combusted (pistol)	= no propellant information available
Total fuel combusted	= Fuel combusted <sub>(shotgun)</sub> + Fuel combusted <sub>(rifle)</sub> + Fuel combusted <sub>(pistol)</sub> = 0.56 + 0.72 + 0 = 1.28 tonnes

Thus no Category 2 thresholds have been tripped.

---

## 6 Transfers of NPI substances in waste

The NPI requires the mandatory reporting of NPI substances that are transferred as waste to a final destination. Transfers are required to be reported if a Category 1, Category 1b or Category 3 reporting threshold is exceeded. For example, if the threshold has been exceeded for the Category 1 substance lead and compounds as a result of use of this substance on site, transfers to final destination of lead and its compounds as well as the emissions are reportable. Both emissions and transfers are reportable in kilograms.

There is no requirement to report transfers of substances that are exclusively Category 2a or 2b in the event that they have been tripped only by the fuel and energy use threshold (i.e. there is no requirement to report transfers of oxides of nitrogen, particulate matter  $\leq 10 \mu\text{m}$  (PM<sub>10</sub>), particulate matter  $\leq 2.5 \mu\text{m}$  (PM<sub>2.5</sub>), polychlorinated dioxins and furans, or polycyclic aromatic hydrocarbons). Transfers are also not reportable if they are contained in overburden, waste rock, uncontaminated soil or rock removed in construction or road building, or soil used in capping of landfills.

Transfers are, however, required if they are transported to a destination for containment or destruction which includes:

- a destination for containment including landfill, tailings storage facility, underground injection or other long term purpose-built waste storage facility
- an off-site destination for destruction
- an off-site sewerage system, and
- an off-site treatment facility which leads solely to one or more of the above.

A containment destination may be onsite, for example a tailing storage facility on a mine site, or off-site, for example waste going to landfill. The transport or movement of substances contained in waste to a sewerage system is also included.

In the specific context of explosives detonation and firing ranges, the quantities of NPI substances contained in waste moved onsite or offsite to landfill, or other final destination, must be reported as a transfer if thresholds have been exceeded.

The transfer of NPI substances to a destination for reuse, recycling, reprocessing, purification, partial purification, immobilisation, remediation or energy recovery can be reported voluntarily. This is an opportune way for facilities to promote good news stories to their local community.

Further information regarding transfers of waste, including how to estimate and report, can be found in *The NPI Guide*.

---

## 7 Next steps for reporting

This guidance material has been written to reflect the common processes employed in explosives detonation and firing range operations. To ensure a complete report of the emissions for your facility, it may be necessary to refer to other EET guidance materials. These include:

- *Combustion in boilers;*
- *Combustion in engines;*
- *Fuel and organic liquid storage; and*
- *Fugitive emissions.*
- Other industry-specific emission estimation technique guidance materials, such as the *Mining* and *Defence facilities* EET guidance materials.

When you have a complete report of substance emissions from your facility, report these emissions according to the instructions in *The NPI Guide*.

---

## 8 References

Australian Bureau of Statistics New Zealand, *Australian and New Zealand Standard Industrial Classification*, (ANZSIC), 2006 ABS Catalogue 1292.0

Environment Australia (now Department of Environment and Water Resources), *Emission Estimation Technique Manual for Explosives Detonation and Firing Ranges*, Version 1.0, March 1999.

Simtars Queensland Government, Review of Emission Factors for Explosives Detonation and Firing Ranges, September 2007 and references contained therein.

United States Environmental Protection Agency (USEPA), January 1995, *Compilation of Air Pollutant Emission Factors, Volume 1, Stationary Point and Area Sources, Fifth edition*, AP-42, Section 13.

United States Environmental Protection Agency (USEPA), February 2008, *Compilation of Air Pollutant Emission Factors, Volume 1, Stationary Point and Area Sources, Fifth edition*, AP-42, Draft Section 15.

---

## Appendix A: Definitions and abbreviations

Term	Definition/abbreviation
ANFO	Ammonium nitrate and fuel oil slurry
ANZSIC	Australia and New Zealand Standard Industrial Classification
CO	Carbon monoxide
EET	Emission estimation technique
EF	Emission factor
EFR	Emission factor (quality) rating
NO <sub>x</sub>	Oxides of nitrogen
NPI	National Pollutant Inventory
PM <sub>10</sub>	Particulate matter less than 10 micrometres
PM <sub>2.5</sub>	Particulate matter less than 2.5 micrometres
RDX	Royal Dutch Explosive, Cyclotrimethylenetrinitroamine
TNT	Trinitrotoluene
PETN	Pentaerythritol tetranitrate (plastic explosive)
USEPA	United States Environmental Protection Agency

## Appendix B: Threshold assessment tables

**Table 4: Use of individual explosives to trip Category 1 and 1a substance thresholds**

Explosive	NPI substance	Tonnage of explosive to trip Category 1 threshold
Water gel slurry	Nitric acid	200
ANFO	n-Hexane	10,000
ANFO	Benzene	5,000
ANFO	Toluene	2,500
ANFO	Ethylbenzene	5,000
ANFO	Xylene	1,250
ANFO	Cumene	10,000
ANFO	Total VOCs	1,389 (Category 1a)
Gel with 1% crosslinker	Chromium (VI) compounds	10,000
Detonator	Lead compounds	200

- Note (1) All references to ANFO in this table refer to ANFO alone or in blend
- Source: *Simtars 2007 based on Maxam MSDS sheets and EET Manual for petroleum refining.*

**Table 5: Use of individual ammunition to trip Category 1 and Category 2 substance thresholds**

Ammunition Type	Substance	Cat 1 threshold (million rounds)	Cat 2a threshold (million rounds)	Cat 2b threshold (million rounds)
Shotgun 12 gauge (1.4g propellant)	Antimony	11	286	1,429
	Arsenic	50		
	Copper	33		
	Lead	0.33		
	zinc	100		
Shotgun 16 gauge (1.2g propellant)	Antimony	13	333	1,667
	Arsenic	100		
	Copper	33		
	Lead	0.33		
	zinc	100		
Shotgun 20 to 28 gauge (0.8g propellant)	Antimony	14	500	2,500
	Arsenic	100		
	Copper	33		
	Lead	0.5		
	Zinc	100		
Frangible bullet	Copper	1		
	Lead	100		
	Zinc	33		
Pistol .17	Arsenic	100		
	Copper	14		
	Lead	6		
Pistol .22 to .28	Antimony	100		
	Arsenic	33		
	Copper	14		
	Lead	2		
	Zinc	33		
Pistol 7mm	Antimony	50		
	Arsenic	20		
	Copper	14		
	Lead	1		
	Zinc	33		
Pistol .30 to .45 (0.6g double base propellant)	Antimony	33	667	3,333
	Arsenic	14		
	Copper	14		
	Lead	0.7		
	Zinc	33		
Rifle .17 to .204	Arsenic	100		
	Copper	14		
	Lead	4		
	Zinc	33		
Rifle .22 (1.2g double base propellant)	Antimony	100	333	1,667
	Arsenic	50		
	Copper	14		

Ammunition Type	Substance	Cat 1 threshold (million rounds)	Cat 2a threshold (million rounds)	Cat 2b threshold (million rounds)
	Lead	3		
	Zinc	33		
Rifle .22 (2g propellant) jacketed	Antimony	25	200	1,000
	Arsenic	50		
	Copper	7		
	Lead	3		
	Zinc	20		
Rifle .22 to .358 (5g double base propellant) jacketed	Antimony	25	80	400
	Arsenic	8		
	Copper	3		
	Lead	0.4		
	Zinc	8		
Rifle .375 to .5	Antimony	100		
	Arsenic	8		
	Copper	3		
	Lead	0.4		
	Zinc	8		

- Note: (1) Given the exceptionally large numbers required to exceed the category 2a and 2b thresholds for most types of ammunition, only some threshold values have been provided.
- Source: *Simtars 2007*

**Table 6: Percentages of Category 1 and 1a substances in explosive products**

This is a table of compositions and should only be used for determining if NPI thresholds have been tripped. This table should not be used for determining emissions.

Explosive	NPI substance	Mass per cent
Water gel slurry	Nitric acid	5
ANFO (1)	Nitric acid	trace levels
ANFO	n-Hexane	0.1% x X
ANFO	Benzene	0.01% x X
ANFO	Toluene	0.03% x X
ANFO	Ethylbenzene	0.01% x X
ANFO	Xylene	0.1% x X
ANFO	Cumene	0.215% x X
ANFO	Total VOCs	1.2% x X
Gel with 1% crosslinker	Chromium (VI) compounds	5
Detonator	Lead compounds	5

- Note (1) All references to ANFO in this table refer to ANFO alone or in blend, some MSDS<sup>7</sup> refer to nitric acid up to 5% by weight.
- Source: *Simtars 2007 based on Maxam MSDS sheets and EET Manual for Petroleum Refining.*
- *X = fraction of fuel oil (Composition of oil is taken from the Fuel and organic liquid storage eet manual version 3.2)*

## Appendix C: Emission estimation tables

**Table 7: Emission factors for Category 1 and 2a substances**

Process	Fuel/explosive	Substance	Emission factor (kg /tonne)	Emission factor rating
Detonation	Black powder	Carbon monoxide	85	D
	Black powder	Hydrogen sulfide	12	D
	Smokeless powder	Carbon monoxide	38	D
	Smokeless powder	Hydrogen sulfide	10	D
	Dynamite (straight)	Carbon monoxide	141	D
	Dynamite (straight)	Hydrogen sulfide	3	D
	Dynamite (ammonia)	Carbon monoxide	32	D
	Dynamite (ammonia)	Hydrogen sulfide	16	D
	Dynamite (gelatin)	Carbon monoxide	52	D
	Dynamite (gelatin)	Hydrogen sulfide	2	D
	Dynamite (gelatin)	Sulfur dioxide	1	D
	Dynamite	Oxides of nitrogen	26	D
	ANFO (on site mix)	Carbon monoxide	34	D
	ANFO (on site mix)	Sulfur dioxide	0.06	D
	ANFO (on site mix)	Oxides of nitrogen	8	D
	ANFO (branded <152mm)	Carbon monoxide	21	U
	ANFO (branded <152mm)	Oxides of nitrogen	3.8	U
	ANFO (Branded >152mm)	Carbon monoxide	8	U
	ANFO (Branded >152mm)	Oxides of nitrogen	1.4	U
	TNT	Carbon monoxide	13	D
	TNT	Ammonia	14	D
	TNT	Cyanide (inorganic)	13	D
	TNT	Hydrogen sulfide	11	D
	TNT	Oxides of nitrogen	11	D
	TNT	PM <sub>10</sub>	93	D
	RDX	Carbon monoxide	98	D
	RDX	Ammonia	22	D
	PETN	Carbon monoxide	149	D
	PETN	Ammonia	1.3	D
	Heavy ANFO (<150mm)	Carbon monoxide	4.2	U
	Heavy ANFO (>150mm)	Carbon monoxide	1.3	U
	Emulsion (Water based gel) (<150mm)	Carbon monoxide	17	U
	Emulsion (Water based gel) (>150mm)	Carbon monoxide	2.3	U
	Emulsion (Water based gel)	Oxides of nitrogen	0.2	U
Amex	Carbon monoxide	16	U	
Amex	Oxides of nitrogen	3.5	U	
average for Heavy ANFO, Emulsion (Water based gel), Amex	Carbon monoxide	12	U	
average for Heavy ANFO	Oxides of nitrogen	2	U	
Blasting (2)	All	PM 0-2.5µm (4)	5.1	U
	All	PM 2.5-15µm (3)	46	U

- Note (1): PM material from combustion products and does not include soil particulates.
- Note (2): This particulate matter represents rock dust emitted as a result of blasting, not particulate emissions directly from explosive detonation.
- Note (3): This emission factor is based on measurements for pm<sub>2.5</sub> µm to pm<sub>15</sub> µm, as no other factor for pm<sub>10</sub> µm is currently available, this can be used instead to estimate emissions of pm<sub>10</sub> µm.
- Note (4): Emissions for pm<sub>2.5</sub> µm from rock dusted generated by blasting are included for information only as pm<sub>2.5</sub> µm emissions from non combustion sources aren't reportable.
- Source: Simtars 2007 and NPI based on data from Orica Australia, USEPA, USA Bureau of Mines (Pittsburg Research Centre), Mitchell and Suggs (1999), NPI Emission Estimation Techniques for Explosives Detonation and Firing Ranges 1999 - using USEPA data (1981)

**Table 8: Emission factor adjustments for different additives and rock type**

Explosive	Usage factor	Emission substance	EF Adjustment
ANFO	increase 10% fuel oil (1)	CO	Multiply EF by 3
ANFO	increase 1% fuel oil (1)	NOx	Multiply EF by 4
Emulsion (Water based gel)	ANFO doping (2)	CO, NOx	Multiply EF by 2
Dynamite (ammonium)	Hard rock (3)	NOx	Multiply EF by 4

- Notes:
  - (1) Relative to 6% normal
  - (2) Dry conditions
  - (3) product leakage into fissures of the hard rock.
- Source: Simtars 2007 based on data from Weiland (2004), Turcotte (2002), Santas et al (1995)

**Table 9: Emission factors for Category 1 and 2a NPI substances emitted or discharge of ammunition**

Process	Fuel/propellant	Substance	Emission factor (kg /tonne)	Emission factor (mg /round)	E F Rating
Discharge	Aluminised ammonium perchlorate (triple base)	Carbon monoxide	2.1	4.2	D
		Chlorine	5	10	D
		Chromium	0.01	0.02	D
		Hydrochloric acid	210	420	D
		Lead	0.04	0.08	D
		Oxides of nitrogen	2.41	4.8	D
		PM <sub>10</sub>	430	860	D
		Sulfur dioxide	0.06	0.12	D
	Zinc	0.06	0.12	D	
	Ammonium perchlorate (triple base)	Carbon monoxide	0.15	0.3	D
		Chromium	0.01	0.02	D
		Chlorine	11	22	D
		Chlorophenol	0.01	0.02	D
		Copper	0.1	0.2	D
		Hydrochloric acid	215	430	D
		Oxides of nitrogen	8.4	17	D
		PM <sub>10</sub>	18	36	D
	Sulfur dioxide	0.11	0.22	D	
	Double base	Benzene	0.12	0.24	D
		Carbon monoxide	1.5	3	D
		Copper and compounds	37	74	D
	Double base	Oxides of nitrogen	8.4	54	D
		PM <sub>10</sub>	18	38	D
		Sulfur dioxide	3.2	6.4	D
	Smokeless powder	Zinc	0.01	0.02	D
		Benzene	0.0012	0.0024	D
		Carbon monoxide	1.6	3.2	D
		Cyclohexane	0.00048	0.00096	D
		Sulphur dioxide	0.61	1.22	D
		PM <sub>10</sub>	1.8	3.6	D
	Double base spheroidal Olin VC844	Toluene	0.0034	0.0068	D
		Acrylonitrile	0.0236	0.039	D
		Antimony	0.052	0.086	D
Barium		0.039	0.064	D	
Benzene		0.174	0.29	D	
Carbon disulfide		0.00018	0.0003	D	
Carbon monoxide		337	556	D	
Copper		0.33	0.54	D	
Cyanide(inorganic) compounds		0.8	1.3	D	
Hexane		0.00017	0.00028	D	
Lead (from projectile)		0.54	0.89	D	
Polycyclic aromatic hydrocarbons		0.003	0.0021	D	
Toluene	0.0182	0.030	D		
Zinc (from projectile)	0.039	0.064	D		

## Appendix D: Modifications to the industry manual manufacturing emission estimation technique (EET) manual

### Modifications to emission estimation technique (EET) manual (Version 2.1 January 2012)

Page	Outline of alteration
7	Note 1 updated to reflect that $pm \leq 10 \mu m$ does include soil particulates
11	Emissions of nitric acid removed from example 1. Assumed percentage of nitric acid in ANFO reduced from 5% to trace levels.
20	Powergel renamed to Emulsion (water based gel) Energen renamed to Heavy ANFO Emission factor for sulfur dioxide for ANFO reduced from 1kg/tonne to 0.06 kg/tonne, this reflect the reduction in the diesel sulfur standard to 10ppm.
22	Correction to ANFO (Branded), Energen and Powergel emission factors for Carbon monoxide and Oxides of nitrogen.
23	Correction to Table 7 title and moved from Appendix C to Appendix B
26	Added missing category to Table 8 emission factors for ammonium perchlorate (triple base)
26	Corrected emission factor for Carbon monoxide for aluminised ammonium perchlorate (triple base) kg/tonne

### Modifications to emission estimation technique (EET) manual (Version 2.0 January 2008)

Page	Outline of alteration
throughout	Version 2.0 follows the new standard format for emission estimation technique manuals.
	Version 2.0 acknowledges that Australian firing range facilities are unlikely to meet the thresholds for any category of NPI substances.
	Version 2.0 makes use of new emission factors which are additional or modifications of those used in the March 1999 version of the manual based on further research reports.
	Version 2.0 incorporates the changes to the National Environmental Protection Measures (NEPM-NPI) by Australian environment ministers from June 2007.