National Environment Protection
(Ambient Air Quality) Measure

Review of the Practicability of a 10 Minute Sulfur Dioxide Standard

Issues Paper

March 2004

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1 INTRODUCTION

1.1 THE AMBIENT AIR QUALITY NEPM

The role of the National Environment Protection Council (NEPC), as a statutory entity within the Environment Protection and Heritage Council (EPHC), is to harmonise environmental protection approaches across Australia.

The NEPC is a body established by each State and Territory government and the Commonwealth Government. It consists of one Minister from the government of each State, Territory and the Commonwealth and is a body with law making powers.

The objective of the NEPC is to give all Australians the benefit of equivalent protection wherever they live and to ensure that business decisions are not distorted and markets are not fragmented by variations in environment protection arrangements between member governments.

The NEPC makes National Environment Protection Measures (NEPMs) and assesses how well the aims of the NEPMs are being met by each member government when they are put into place. NEPMs are broad framework-setting statutory instruments defined in NEPC legislation. They outline agreed national objectives for protecting particular aspects of the environment.

In 1998, Australia adopted an Ambient Air Quality NEPM that set national ambient air quality standards to apply in all States and Territories and over land controlled by the Commonwealth. These standards cover six criteria pollutants – particles (as PM_{10}), ozone, sulfur dioxide, nitrogen dioxide, carbon monoxide and lead. In May 2003, the Ambient Air Quality NEPM was varied to include advisory reporting standards for $PM_{2.5}$.

The national environment protection goal of the NEPM is to achieve the standards (as assessed by the monitoring protocol) by 2008 and the desired outcome is ambient air quality that allows for the adequate protection of human health and well being.

The NEPM sets out monitoring and reporting requirements for the criteria pollutants. The NEPC Acts confine the role of the NEPM to ambient air quality, and the NEPM itself requires that performance monitoring stations must be located so that a representative measure of the air quality likely to be experienced by the general population in a region or sub-region of 25,000 people or more can be obtained.

1.2 REVIEW OF THE PRACTICABILITY OF DEVELOPING A 10 MINUTE SULFUR DIOXIDE STANDARD

At the time of making the NEPM, exposure periods relevant to the protection of susceptible sub-populations were considered in evaluating each set of standards viz, short-term (of the order of 10-15 minutes), medium-term (24 hours) and long-term (annual). The health consultant recommended a set of standards covering the three exposure periods. The former National Health and Medical Research Council (NHMRC) goals for sulfur dioxide provided guidance for human health protection at two levels of exposure, short-term (10 minutes and one hour) and long-term (annual). The Technical Review Panel for the Health Review Consultancy recommended the inclusion of standards for three exposure periods.

Given the significant costs required to control sulfur dioxide emissions from some point sources, the more stringent objectives recommended by the Health Review Consultancy were not seen to be achievable in all locations in the 10 year timeframe. It was decided that the NHMRC goals be adopted except for the 10 minute goal. A 10 minute standard was not set because of the inconsistencies that would be evident in the monitoring and reporting protocols for sulfur dioxide compared to the other pollutants. This would require a monitoring network around each significant point source to be designed and approved by NEPC and was considered to be outside the scope of the NEPM at that time.

The Ambient Air Quality NEPM establishes the following standards for sulfur dioxide and sets maximum allowable exceedences to be achieved throughout Australia by 2008:

- 0.2ppm averaged over a one hour period;
- 0.08ppm averaged over a 24 hour period; and
- 0.02ppm averaged over a one year period.

When NEPC made the Ambient Air Quality NEPM, it also agreed to a program of future actions, including a staged review of some NEPM standards. The future action program included a review of the practicability of developing a 10 minute sulfur dioxide standard to commence by 2003.

A review that only considers the possibility of varying the Ambient Air Quality NEPM may not be flexible enough to address community concerns about the adverse health effects of short-term exposure. The review, therefore, will not only seek comment on the practicability of a new 10 minute standard under the NEPM but also seek views on other options outside the NEPM framework such as the development of a nationally consistent protective health value that could be used by jurisdictions for the control of short-term emissions.

The review involves:

- the development of this issues paper by the review team, which includes information on health effects and an analysis of existing monitoring data;
- placement of the issues paper on the EPHC website for public comment;
- targeted consultation with key stakeholders to be conducted by those jurisdictions with an interest in this issue; and
- a report back to NEPC in October 2004.

The purpose of this paper is to encourage discussion on the issues and to enable stakeholders to provide input into the review. The feedback provided will help ensure that all views are taken into account in deciding the best way to protect the community from the impacts of short-term emissions of sulfur dioxide.

Information on how to make a written submission on the Issues Paper is contained in chapter 7.

A full review of the Ambient Air Quality NEPM is scheduled to commence in 2005. While the current review focuses only on the practicability of a 10 minute sulfur dioxide standard, the full review will look at broader aspects of the NEPM.

2 WHAT DO WE KNOW ABOUT SULFUR DIOXIDE IN AUSTRALIA?

2.1 SOURCES OF SULFUR DIOXIDE

Sulfur dioxide is a colorless, irritating and reactive gas with a strong odour. In Australia emissions of sulfur dioxide come primarily from major industrial operations that burn fuels containing sulfur such as coal, oil, petroleum and gas. According to the National Pollutant Inventory <www.npi.gov.au> the primary sources of sulfur dioxide emissions in Australia are:

- electricity supply – 40.93%;
- basic non-ferrous metal manufacturing – 31.76%;
- metal ore mining – 18.35%;
- basic chemical manufacturing – 2.05%;
- petroleum refining – 1.41%; and
- all others – 5.51%.

Apart from major industry operations, sources of sulfur dioxide emissions include:

- small-scale industrial activity, eg textile bleaching and food preserving facilities, wineries, and fumigation activities;
- natural sources, eg geothermal activity (such as hot springs and volcanic activity), and the natural decay of vegetation;
- mobile sources, eg vehicle exhaust; and
- consumer products, eg some solvents, dechlorination agents, bleaches and fumigation products.

2.2 NATURE AND EXTENT OF SULFUR DIOXIDE DATABASES IN AUSTRALIA

2.2.1 Databases for ambient levels of sulfur dioxide

Air quality monitoring of sulfur dioxide is carried out by State Government agencies and is a key source of information about sulfur dioxide levels in the ambient air. Some jurisdictions have been collecting sulfur dioxide data for over 25 years. Since the introduction of the Ambient Air Quality NEPM in 1998 a consistent approach has been adopted by jurisdictions to monitoring of air pollutants.

Jurisdictions prepare monitoring plans under the NEPM which are approved by NEPC and which set out how the jurisdiction proposes to monitor air quality in order to meet the NEPM standards. Some jurisdictions also conduct sulfur dioxide monitoring which is additional to the requirements of the NEPM.

As outlined in section 1.2, the Ambient Air Quality NEPM contains standards for one hour, 24 hour and annual average levels of sulfur dioxide in Australia. The NEPM standards are intended to measure general population exposure, not exposure close to a major point source such as a smelter. The NEPM states:

> Performance monitoring station(s) must be located in a manner such that they contribute to obtaining a representative measure of the air quality likely to be experienced by the general population in the region or sub-region (Ambient Air Quality NEPM clause 13(2)).

Under clause 14 of the NEPM, performance monitoring is only required in regions with a population of 25,000 people or more.

New South Wales, Victoria, South Australia, Western Australia and Queensland all conduct sulfur dioxide monitoring in accordance with the NEPM. Information on the number and location of government sulfur dioxide monitoring sites is presented in the technical background document accompanying this paper which is available separately on the EPHC website.

The Northern Territory, Australian Capital Territory and Tasmanian governments do not conduct any sulfur dioxide monitoring as there are few major sources of sulfur dioxide in these areas and ambient levels of sulfur dioxide have been assessed to be well below the NEPM standards.

Under the NEPM, jurisdictions are required to annually evaluate their performance in meeting the standards and associated goal and publicly report on compliance. The results are published in the NEPC Annual Report. Some jurisdictions also report monitoring results on the websites of their environment agencies. Other sources of trend information about air quality include the State of Environment reports published at the national and state level.

Emissions inventories are another source of information about the amount of sulfur dioxide emitted across Australia, and the proportions of emissions from various sources. The National Pollutant Inventory collects nationwide emissions information from major industry sources and government[1]. State and local governments also occasionally compile emissions inventories as part of air quality management planning processes. These are based on actual measurements of sulfur dioxide emissions and estimation techniques.

2.2.2 Industry data

In New South Wales, Victoria, South Australia, Western Australia, Tasmania and Queensland some industrial premises, that are major sources of sulfur dioxide emissions, are required to monitor and report on sulfur dioxide levels in the vicinity of their premises as part of their operating conditions. Examples are Pasminco in Tasmania and South Australia, Mount Isa Mines in Queensland, Alcoa in Port Henry in Victoria, the Latrobe Valley Power Stations and Kalgoorlie Consolidated Gold Mines in Western Australia. These industry monitoring data are generally subject to audit by state regulatory agencies.

2.2.3 10 minute sulfur dioxide average levels

Although those jurisdictions that monitor sulfur dioxide under the NEPM typically measure sulfur dioxide at 10 minute intervals or less, they do not routinely conduct analysis of 10 minute average levels for sulfur dioxide (a discussion of the technical and instrumental aspects of short-term monitoring is included at section 5.4). Some industrial premises that emit sulfur dioxide are required to monitor and report on 10 minute averages as part of their licence conditions. As part of this review, jurisdictions have conducted an analysis of 10 minute data from 2000, 2001 and 2002[2]. The results are discussed in section 2.4.4.

2.3 WHAT SHORT-TERM SULFUR DIOXIDE GUIDELINES EXIST IN AUSTRALIA?

Within Australia the National Health and Medical Research Council (NHMRC) developed a set of goals for some of the major air pollutants based on their effect on human health, including a

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[1] The National Pollutant Inventory (NPI) is an Internet database designed to provide the community, industry and government with information on the types and amounts of certain substances being emitted to the environment. Australian industrial facilities using more than a specified amount of the substances listed on the NPI reporting list are required to estimate and report emissions of these substances annually. Emissions from facilities using less than the specified amount of the substances listed on the NPI are estimated by government. Government also estimates emissions arising from everyday household activities, such as driving to work and mowing the lawn.

[2] South Australia's data is from 2002/2003.

10 minute sulfur dioxide goal of 0.25ppm. These goals were developed in the 1980s and reviewed in 1995. The NHMRC noted that 'at these recommended levels, there still may be some people (for example asthmatics and those suffering chronic lung disease) who will experience respiratory symptoms and may need further medical advice or medication'.

In March 2002 the NHMRC rescinded its 10 minute sulfur dioxide goal, along with a number of other air quality goals, as part of a regular review of publications for currency and relevance. The goal is still used by a number of jurisdictions in managing air quality.

No other national guideline has been developed in Australia. However, the World Health Organisation (WHO) has a 10 minute guideline of 0.175ppm which some jurisdictions use in managing major industrial premises. As they are currently used by some jurisdictions, the WHO guideline and former NHMRC 10 minute goal are used as a point of comparison in this paper. The health effects associated with exposure to different levels of sulfur dioxide is discussed in chapter 3.

2.4 AMBIENT SULFUR DIOXIDE LEVELS

2.4.1 Current levels and trends in Australia

The 2001 Australian State of the Environment Report indicates that in urban and regional Australia ambient sulfur dioxide concentrations are generally low. This analysis was based on an evaluation of one hour and 24 hour monitoring data. This is also reflected in annual reporting to NEPC which indicates that jurisdictions are meeting the Ambient Air Quality NEPM sulfur dioxide standards and goals for one hour, 24 hour and annual average levels of 0.2ppm, 0.08ppm, and 0.02ppm respectively [3].

In 2002 South Australia reported an exceedence of the one hour standard. This was recorded at the site established to monitor the impact of the Port Stanvac oil refinery in Adelaide and was due to a severe plant malfunction. This site has now closed.

2.4.2 Current levels and trends in urban Australia

Sulfur dioxide levels vary between regions due to varied geographical distribution of major sources and different topographical and meteorological conditions. Sulfur dioxide levels in Australian cities are low compared to the USA and Europe because of the limited number of major sulfur dioxide emitting industries and low sulfur fuels. For example, maximum hourly ambient concentrations of sulfur dioxide in the Sydney region are less than 25% of the NEPM standards and peak concentrations in the Brisbane region are less than 40% of the NEPM standards.

2.4.3 Current levels and trends in regional and rural Australia

According to the 2001 Australian State of the Environment Report there has been a 30% overall reduction in sulfur dioxide emissions since 1996 in regional and rural Australia (see Figure 1).

Due to improvements in mineral extraction and processing activities at Kalgoorlie in Western Australia, sulfur dioxide levels have been reduced dramatically over the last 12 years and compliance with the NEPM goal is expected within the 10 year period specified in the NEPM. In New South Wales, copper smelting operations at Port Kembla Copper and Pasminco, Boolaroo, which resulted in significant emissions, have recently ceased and sulfur dioxide levels are

[3] It should be noted that South Australia's monitoring program requires further development before it can formally demonstrate compliance with the sulfur dioxide NEPM goals.

expected to reduce. The Australian State of the Environment Report 2001 notes that in recent years one hour sulfur dioxide levels have been below NEPM standard levels at Gladstone, the Lower Hunter and Latrobe Valley (power generation areas using coal).

However, there are still a few regional locations in Australia where high levels of sulfur dioxide levels can be recorded, including Mount Isa in Queensland and Port Pirie in South Australia. Port Pirie is the site of the world's largest integrated lead and zinc smelter and Mount Isa is centred around a major smelting operation. At the industry monitoring sites in the Latrobe Valley sulfur dioxide levels can exceed international guidelines. However, these non-NEPM sites are located in locations that are sparsely populated. Levels monitored at NEPM sites in the Latrobe Valley are low and not of concern.

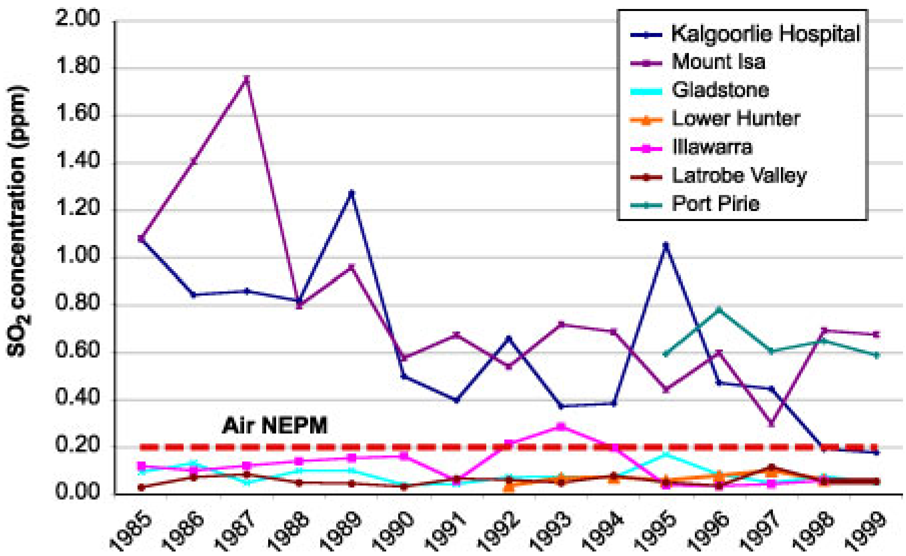

Figure 1: Highest one-hour averages of sulfur dioxide since 1985 in regional centres of Australia.

Lower Hunter from 1992; Port Pirie from July 1995

Source: 2001 Australian State of the Environment Report
[Note: The Air NEPM was not introduced until 1998 and does not apply at all of these locations]

2.4.4 10 minute levels

In order to investigate whether 10 minute average concentrations reach levels that might be considered of concern from a health perspective, jurisdictions which conduct sulfur dioxide monitoring have conducted an analysis of 10 minute sulfur dioxide data for the purpose of this review.

Jurisdictions have analysed data from all sulfur dioxide NEPM sites for 2000, 2001 and 2002 (where available). A summary is presented in Table 1. Data from some non-NEPM government sites are summarized in Table 2. Some industry data have also been considered and results are found in the technical document which accompanies this paper, along with more detailed results from government monitoring sites which provides, for each site, the maximum 10 minute sulfur dioxide levels, the 2nd highest 10 minute levels, and the 99.9th percentile levels recorded in the years 2000-02, where available. The technical document also includes a description of the location of the sites and their proximity to a point source, where relevant.

The data indicate that the short-term sulfur dioxide levels at NEPM sites without significant impacts from major point sources are typically well below the former NHMRC 10 minute average goal of 0.25ppm and the WHO guideline of 0.175ppm. In some locations, for example Paisley in Victoria, the elevated levels that occur on occasion are due to the cumulative effects of industry in the area impacting on residential areas. Although elevated, these levels are still below international guidelines. Elevated readings were recorded at Kensington in Adelaide in January 2003 that are uncharacteristic of results at other times.

High short-term levels have been recorded at Warrawong in New South Wales and Christies Beach in Adelaide. Warrawong is in the vicinity of the Port Kembla copper smelter and Christies Beach monitors the impact of the Port Stanvac oil refinery. As noted previously, both Port Kembla Copper and Port Stanvac oil refinery have now closed.

Data analysed from non-NEPM government sites confirm that short-term peaks above the WHO guidelines and former NHMRC goal can occur at sites in the near vicinity of significant point sources such as Mount Isa, Port Pirie and Gladstone. Industry monitoring sites such as those in Kalgoorlie and the Latrobe Valley, and those operated by Pasminco in Hobart and Port Kembla Copper in Wollongong are located in order to assess the impact of emissions from these point sources on local air quality. They sometimes record high short-term levels of sulfur dioxide. These levels are generally very localised in nature and do not impact on large populations. As discussed in Chapter 5, these sources are subject to emission controls through individual State/Territory legislation.

Table 1: Sulfur dioxide (10 minute averages) for 2000, 2001 and 2002 as monitored at NEPM Performance Monitoring Stations

State / Region	Location	2000		2001		2002 (2003 for SA)	
		Highest (ppm)	99.9 percentile (ppm)	Highest (ppm)	99.9 percentile (ppm)	Highest (ppm)	99.9 percentile (ppm)
New South Wales							
Sydney	Blacktown	0.019	0.013	0.023	0.014	0.024	0.013
	Bringelly	0.015	0.008	0.021	0.009	0.016	0.009
	Richmond	0.041	0.009	0.038	0.010	0.038	0.010
	Wooloware	0.046	0.019	0.048	0.026	0.051	0.028
Newcastle	Wallsend	0.062	0.035	0.085	0.037	0.108	0.038
Illawarra	Warrawong	0.225	0.098	0.321	0.119	0.146	0.044
	Albion Park	0.060	0.035	0.042	0.032	0.039	0.030
	Wollongong	0.066	0.026	0.050	0.029	0.066	0.033
Victoria							
Melbourne	Alphington	0.014	0.008	0.014	0.009	0.015	0.009
	Paisley	0.103	0.057	0.109	0.066	0.153	0.059
	RMIT	0.022	0.016	0.025	0.016	0.033	0.020
Geelong	Geelong Sth	0.059	0.019	0.069	0.032	0.065	0.032
Latrobe Valley	Moe	0.053	0.029	0.038	0.025	0.058	0.025
	Traralgon	0.093	0.032	0.086	0.032	0.081	0.027
Queensland							
Brisbane	Springwood			0.048	0.013	0.036	0.012
Western Australia							
Perth	South Lake	0.058	0.027	0.056	0.028	0.07	0.033
South Australia							
Adelaide	Elizabeth					0.043	0.010
	Kensington					0.151	0.025
	Northfield					0.014	0.007
	Christies Beach			0.280	0.078	0.350	0.028

Table 2 Sulfur dioxide (10 minute averages) for 2000, 2001 and 2002 as monitored at non-NEPM State Government Monitoring Stations

State / Region	Location	2000		2001		2002 (2003 for SA)	
		Highest (ppm)	**99.9 percentile** (ppm)	**Highest** (ppm)	**99.9 percentile** (ppm)	**Highest** (ppm)	**99.9 percentile** (ppm)
Queensland							
Brisbane	CBD			0.048	0.010	0.024	0.011
Gladstone	Barney Point					0.124	0.046
	Clinton					0.100	0.045
	Targinie			0.132	0.045	0.217	0.041
Mt Isa	Menzies			1.034	0.639	1.997	0.854
Western Australia							
Perth	Hope Valley	0.121	0.045	0.095	0.033	0.132	0.043
	Wattleup	0.096	0.034	0.117	0.035	0.112	0.037
	Rockingham	0.051	0.026	0.055	0.024	0.044	0.022
South Australia							
Spencer	Port Pirie					1.253	0.454

3 WHAT ARE THE HEALTH EFFECTS OF SULFUR DIOXIDE?

Adverse health effects have been associated with exposure to sulfur dioxide over a range of averaging periods. The Ambient Air Quality NEPM currently contains one hour, 24 hour and annual average standards for sulfur dioxide to protect against health effects for exposures to sulfur dioxide for these averaging periods. The current review is focussed on the practicability of setting a short-term (10 minute) standard for sulfur dioxide and this section therefore focuses on the evidence for health effects associated with shorter exposure periods of 5-15 minutes.

3.1 HEALTH EFFECTS OF SULFUR DIOXIDE

Sulfur dioxide is a highly soluble irritant gas that is quickly absorbed in the moist environment of the upper or lower airways. Most inhaled sulfur dioxide is absorbed in the nose (Speizer and Frank, 1966), especially under resting conditions. During exercise it is likely that a larger proportion of inhaled sulfur dioxide reaches the lower respiratory tract. Sulfur dioxide appears to reduce the diameter of airways and airflow by acting on cells that cause inflammation, constriction and create mucus. Inhalation of sulfur dioxide leads to the production of reactive species (such as hydrogen ions, bisulfite and sulfite ions) in the airways that leads to irritant responses. These species are thought to react directly with the smooth muscle or via sensory vagal nerves in the airways leading to reflex bronchoconstriction (Bascom et al, 1996; Barnes, 1986).

Evidence for health effects of air pollutants in humans can be derived from both epidemiological studies and controlled exposure studies. Both classes of studies can provide valuable information on the overall weight of evidence of an effect of an air pollutant on human health. The advantages of controlled exposure studies are that they enable an assessment of individual health responses to a range of known single-pollutant exposures for fixed periods of time and hence reduce the potential for other unmeasured factors to impact on an individual's health. However, they are limited by the fact that the most sensitive individuals are generally excluded and the fact that only minor, reversible health effects can be investigated. These studies are also limited to small groups of individuals that may not be representative of the general population, particularly not children or the elderly, and exposures are generally limited to a short duration.

To complement information derived from controlled exposure studies, population based epidemiological studies give an estimate of the impact of exposures to these pollutants in the 'real world', ie people breathe a mixture of pollutants not just a single pollutant, for the range of susceptible groups found in populations. They are also useful in deriving information about the impacts of longer exposures. However such studies are limited by their ability to control for the range of other factors that may also impact on health and the difficulty in accurately estimating exposures to the pollutant of interest.

Recent epidemiological studies have revealed increases in daily mortality from respiratory and cardiovascular causes associated with current ambient sulfur dioxide levels found in various parts of the world (Le Tetre et al, 2002; Hong et al, 2002; Ballester et al, 2002; Samoli et al, 2001; Gouveia and Fletcher, 2000). In addition, associations between daily hospital admissions for asthma, chronic obstructive pulmonary disease (COPD) and respiratory disease have also been observed (Koken et al, 2003; Sunyer et al, 2003a; Sunyer et al, 2003b; Martins et al, 2002; Wong et al, 2002). Panel studies of adults with asthma or chronic obstructive pulmonary disease (COPD) have reported associations between 24-hour average sulfur dioxide exposure and respiratory symptoms of wheeze (Higgins et al, 1995). These effects persist when other pollutants, such as particles, are controlled for. These studies have been conducted using daily measures of sulfur dioxide (such as daily one hour maximum or daily average) as the health data used in these studies is only available on a daily basis.

The reported associations from overseas studies relate to a range of 24 hour average and daily one hour maximum exposure levels including very low levels, suggesting that there may be no threshold for the health effects associated with exposures to sulfur dioxide in sensitive subgroups of the population.

As the levels of sulfur dioxide in Australian cities are generally low, only a limited number of studies have been conducted to investigate the health effects associated with exposure to sulfur dioxide. The studies have focussed on areas that are influenced by industry. Cross-sectional studies conducted in New South Wales in the Hunter and Illawarra regions (Henry et al, 1991; Lewis et al, 1998) found no association between annual average levels of sulfur dioxide and prevalence of asthma in children (Henry et al, 1991) and chest colds and respiratory symptoms such as cough and wheeze (Lewis et al, 1998).

Most information on the effects of short-term exposure to sulfur dioxide has arisen from controlled human exposure studies. These studies have involved the exposure of volunteers to sulfur dioxide for periods ranging from a few minutes up to one hour. The results of controlled exposure studies have been extensively reviewed (Bascom et al, 1996; US EPA, 1982, 1986).

These reviews indicate that effects occur within the first few minutes after inhalation and that effects are not changed by further exposure. Observed effects include symptoms such as sneezing or shortness of breath, reductions in mean forced expiratory volume over one second (FEV_1) and increases in specific airway resistance (sRAW) which is another sensitive measure of the ease of airflow. These effects are greater when the person is exercising.

3.2 SUSCEPTIBILITY

Controlled human exposure studies have revealed that health effects from short-term exposures to sulfur dioxide are most pronounced in people with asthma and other respiratory conditions such as COPD, and particularly in exercising asthmatics. Exercising is important for two reasons – it increases the amount of air inspired and it increases the amount of mouth breathing that allows for deeper penetration of the air into the respiratory tract and dries the airways. This affects the absorption of the sulfur dioxide gas (Scheslinger, 1999).

Epidemiological studies that have examined longer exposure times (one hour maximum, 24 hour and annual average) indicate that other susceptible populations, in addition to people with asthma, may include those with chronic obstructive pulmonary disease and existing cardiovascular disease, children and the elderly. Compared to healthy adults, children are generally more sensitive to air pollutants as their exposure is generally higher. The reasons for this are that children inhale more air per minute and have a larger contact lung surface area relative to their size compared to adults. Other factors that increase the potential for exposure in children are that children generally spend more time outdoors and more time exercising.

Asthmatics appear to be the most susceptible group to the effects of sulfur dioxide (Streeton, 1997). The elderly are also a susceptible population as they have reduced respiratory reserve as a result of the ageing process. This is also often exacerbated by pre-existing cardio-respiratory disease.

3.3 THRESHOLDS FOR THE EFFECTS OF SHORT-TERM EXPOSURE TO SULFUR DIOXIDE ON HUMAN HEALTH

Most information about the acute effects of sulfur dioxide has arisen from controlled studies involving the exposure of volunteers to sulfur dioxide for periods ranging from a few minutes up to one hour (Linn et al, 1983, 1987; Sheppard et al, 1981; Tunnicliffe et al, 2001). Such studies indicate that short-term exposures to sulfur dioxide of:

- >1ppm are associated with bronchoconstriction in non-asthmatic individuals (Streeton, 1997);
- >= 0.2-0.3ppm are associated with bronchoconstriction of exercising asthmatic individuals (Linn et al, 1987);
- <0.2ppm are possibly associated with changes in airways resistance in exercising asthmatic individuals (Sheppard et al, 1981).

In addition to respiratory effects, a study that examined one hour exposure to 0.2ppm sulfur dioxide in a panel of non-asthmatics and mild asthmatics reported a significant association with cardiac power but not with heart rate variability (Tunnicliffe et al, 2001). The relationship between sulfur dioxide exposure and cardiac power was different in the two groups and the authors suggest that one hour sulfur dioxide exposures of 0.2ppm may influence the autonomic nervous system. Despite the use of cardiovascular endpoints in air pollution and health studies, the clinical significance of measures of heart-rate variability has not been clearly determined (Cardiac Society of Australia and New Zealand, 2001).

The key study of exercising individuals by Linn et al (1987) provides information on dose-response relationships for 10 minute exposures to sulfur dioxide in normal subjects, atopic subjects, mild asthmatics and moderate/severe asthmatics. The characteristics of these individuals are provided in detail in Linn et al (1987). Individuals were exposed to 0, 0.2, 0.4 and 0.6ppm sulfur dioxide for 10-15 minutes while exercising and a range of responses including changes in FEV_1, specific airways resistance and symptoms were recorded.

Figures 2 and 3 derived from data provided by Linn et al (1987) show the average changes in FEV_1 and total symptom scores after exposure for approximately 15 minutes for three groups of exercising subjects - those with no asthma, those with mild asthma and those with severe asthma. The symptom score represents a sum of a range of symptoms measured on a scale of 0 to 40 where 0 = not present and 40 = incapacitating. The symptoms used in the score included cough, sputum, substernal irritation, wheeze, chest tightness, dyspnea, throat irritation, nasal discharge/congestion, fatigue, headache, eye irritation, other) (Linn et al, 1983).

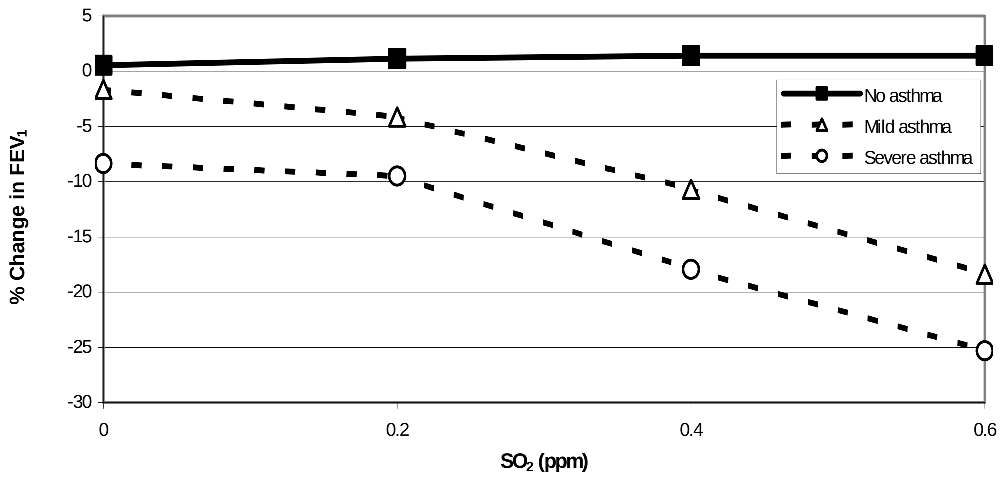

Figure 2: Mean percentage change in FEV_1 associated with sulfur dioxide exposures for approximately 15 minutes

Source: Health Impacts of Ozone and Sulfur Dioxide, Woolcock Institute of Medical Research, 2003 (using data provided in Linn et al, 1987)

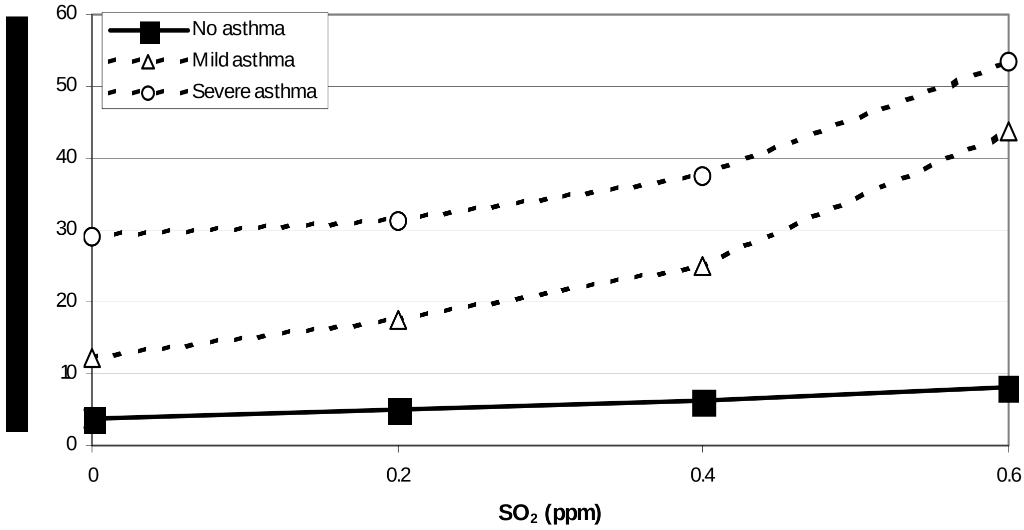

Figure 3: Mean absolute change in symptom scores with sulfur dioxide exposures for approximately 15 minutes

Source: Health Impacts of Ozone and Sulfur Dioxide, Woolcock Institute of Medical Research, 2003 (using data provided in Linn et al, 1987)

As indicated by Figures 2 and 3, only very small changes are observed in mean percentage reduction FEV_1 and absolute change in symptom scores in the asthmatic individuals exposed to concentrations of sulfur dioxide from 0 to 0.2ppm. The clinical significance of such a small mean change in FEV_1 (a 2.5% decline in the mean for the group with mild asthma and a 1.15% decline in the mean for the group with severe asthma) is not well understood.

A larger mean FEV_1 decline of approximately 6-8% was observed between 0.2 and 0.4ppm for the mild and moderate/severe asthma groups. An assessment of the statistical significance of the differences in response between doses cannot be assessed as the data required to determine this was not supplied by the authors. However, figures provided by Linn et al (1987) displaying average and extreme responses do indicate a wide variability in responses, with an increase in variability with increasing dose. Though only a small adverse change was observed between 0 and 0.2ppm, the results of this study suggest a Lowest Observed Adverse Effect Level (LOAEL) of 0.2ppm, associated with a 15 minute average exposure to sulfur dioxide for exercising asthmatics.

The study by Linn et al (1987) also indicates that:

- there is little difference in the dose-response relationships between types of asthmatics (eg mild versus moderate/severe as defined by Linn et al, 1987). However, as the exercising moderate/severe asthma group also responded to clean air, the absolute risk of an adverse outcome is higher for people with more severe asthma as they are already responsive to exercise (as demonstrated by Figure 2);
- there are a wide range of bronchoconstrictive responses in individuals with mild asthma;
- there is rapid reversal of bronchoconstriction following the end of sulfur dioxide exposure; and
- there is a comparative lack of response in non-asthmatics at the range of doses used.

An earlier controlled human exposure study by Sheppard et al (1981) examined changes in specific airway resistance in seven exercising subjects with mild asthma. Although results of the study suggest that exposure to 0.1ppm in two exercising individuals with mild asthma was associated with a reduction in specific airways resistance, the clinical significance of the change cannot be determined on the basis of information provided by the study authors.

One epidemiological study that has investigated the association between short-term sulfur dioxide exposures and adverse health outcomes is a study conducted in Mt Isa in Queensland where maximum five minute average sulfur dioxide levels frequently exceed 0.3ppm. This study examined the relationships between maximum five minute average sulfur dioxide levels and hospital attendances and admissions for asthma, wheeze or shortness of breath (Donoghue and Thomas, 1999). No positive association was found between five minute sulfur dioxide levels measured in the Mt Isa community and hospital attendances and emergency department visits for asthma and other respiratory problems. A key limitation of this study is the relatively small population that reduces the statistical power of the analysis. Also, this study design does not provide data on other expected responses to sulfur dioxide exposure including self-medication in keeping with asthma management plans, visits to general practitioners and pharmacist consultations.

3.4 SUMMARY

In summary, the studies reviewed indicate that short-term exposures of 5-15 minutes to sulfur dioxide are associated with a dose-response effect on lung function of exercising individuals with asthma. The controlled exposure study by Linn et al (1987) in exercising individuals with asthma is indicative of a LOAEL of 0.2ppm for a 15 minute exposure period for this small sample of susceptible individuals. Responses to brief short-term exposures to sulfur dioxide are immediate and do not appear to worsen after longer exposure periods.

4 WORLD-WIDE SITUATION

4.1 WHAT DO WE KNOW ABOUT SULFUR DIOXIDE LEVELS OVERSEAS?

Concentrations of sulfur dioxide in the atmosphere have historically been of particular concern in North America and Europe, due to the high levels of industrialisation and high sulfur content of the fuels in those countries. Sulfur dioxide levels in Australia have been relatively low due to lower levels of industrialisation and lower sulfur content of our fuel.

4.2 WHAT SULFUR DIOXIDE STANDARDS EXIST OVERSEAS?

A number of overseas jurisdictions have considered the introduction of a short-term sulfur dioxide standard. Current sulfur dioxide standards from Australia, New Zealand, Europe and North America are provided in Table 3.

The World Health Organisation (WHO) Air Quality Guidelines for Europe 2000 recommend a 10 minute guideline value of 0.175ppm. The WHO Air Quality Guideline value for 10 minute sulfur dioxide levels defines the concentration of sulfur dioxide below which no significant risk is posed to the health of individuals exposed for 10 minutes or less. In setting the guideline value, the impact of short-term sulfur dioxide exposure on the most sensitive population groups was taken into consideration, in particular, exercising asthmatics.

It is recommended by the WHO that countries use the WHO Air Quality Guideline values to set national or regional air quality standards, also taking into account existing environmental, social, economic and cultural conditions.

The United Kingdom has a 15 minute standard of 0.1ppm (with 35 exceedences per year allowed). The UK's air quality objective for 15 minute average levels of sulfur dioxide has been set at a level which is protective of human health and is also considered achievable by 31 December 2005. The objective is intended to apply at outdoor locations where members of the public are regularly present and might reasonably be expected to be exposed to elevated concentrations of sulfur dioxide over the 15 minute averaging time of the objective.

Under the 2000 Air Quality Strategy for England, Scotland, Wales and Northern Ireland, local authorities are obliged to review and assess sites where monitoring for sulfur dioxide would be appropriate. Where 15 minute sulfur dioxide levels are expected to exceed the objective, the Air Quality Strategy indicates that local authorities will need to designate an Air Quality Management Area.

The national ambient air quality standards (NAAQS) in the USA apply to regional air quality including peak sites where significant numbers of people are exposed. The United States Environmental Protection Agency (US EPA) decided against the introduction of a five minute standard in 1996 on the grounds that short term exposure to sulfur dioxide did not pose a broad public health problem. Its decision was challenged in the courts and to address the concerns raised the US EPA is considering the introduction of a state-administered Intervention Level Program to address short-term (5 minute) peaks of sulfur dioxide through localized, targeted control programs. The intervention level program would provide guidance to states in determining whether 5-minute peak concentrations of sulfur dioxide pose a health risk in the local population.

A key element of the proposed program is the establishment of a 'concern level' of 0.6ppm and an 'endangerment level' of 2ppm. The program would provide flexibility for each state to determine the nature and degree of intervention warranted in response to 5-minute peaks of concern. A decision whether to proceed with the program or an alternative approach is due in 2004.

The European Union limit values also apply to regional air quality where large numbers of people are exposed. The European Union has chosen not to adopt a 10 minute standard on the basis that the levels of sulfur dioxide based on a short time averaging period are highly variable in space and time which makes the assessment of exceedences very difficult. However, member states were required to report the number of 10 minute concentrations that exceed 500µg/m^3 at selected measuring stations until the end of 2003. In addition to limit values, the European Union has an alert threshold of 500µg/m^3 that is measured over three consecutive hours at locations representative of air quality over at least 100km^2. When the threshold is exceeded, details of the occurrence are made public with any precautions that should be taken by the sensitive population.

Table 3: Ambient air quality standards/guidelines for sulfur dioxide

Country	Averaging time	Maximum permissible concentration
Australia (NEPM standards and goals for 2008)	1 hour	0.20ppm with one exceedence
	24 hours	0.08ppm with one exceedence
	annual	0.02ppm
New Zealand	1 hour	0.122ppm (350 µg/m^3)
	24 hour	0.042ppm (120 µg/m^3)
US (1997)	3 hours	0.500ppm (1300 µg/m^3)
	24 hours	0.140ppm (365µg/m^3)
	1 year	0.030ppm (80µg/m^3)
California	1 hour	0.25ppm
	24 hours	0.04ppm
Canada (1989) (National Ambient Air Quality Objectives NOT Canada Wide Standards)	1 hour	0.334ppm (maximum acceptable level)
	24 hours	0.115ppm (maximum acceptable level)
	annual	0.023ppm (maximum acceptable level)
WHO Guidelines (2000)	10 minutes	0.175ppm (500µg/m^3)
	24 hours	0.04ppm (125µg/m^3)
	1 year	~0.018ppm (50µg/m^3)
UK (2000)	15 minutes	0.100ppm (266µg/m^3) with 35 exceedences per year
	1 hour	0.132ppm (350µg/m^3) with 24 exceedences per year
	24 hours	0.047ppm (125µg/m^3) with 3 exceedences per year
EU (1999)	1 hour	0.131ppm (350µg/m$^{3)}$
	24 hours	0.047ppm (125µg/m$^{3)}$
	1 year	0.008ppm (20µg/m$^{3)}$

Note that the conversion factor between ppm (volume/volume) and µg/m^3 is inversely proportional to the absolute temperature. Different countries assume different reference temperatures – Australia (NEPM) and WHO 0°C, Europe 20°C, USA 25°C. At 0°C, the conversion factor is 1ppm = 2,860µg/m^3 Most sampling techniques are based on volume concentrations (ppm) whereas dispersion modelling is often based on a mass flux from a source and so uses µg/m^3. For this table the New Zealand concentrations have been converted using 0°C and EU using 20°C.

5 ISSUES FOR SETTING A SHORT TERM SULFUR DIOXIDE STANDARD

5.1 INTRODUCTION

Regulatory agencies worldwide have set ambient air quality standards for sulfur dioxide in acknowledgement of the adverse health effects associated with exposure to sulfur dioxide. As discussed in Chapter 3, there is evidence from both controlled exposure studies and epidemiological studies that exposure to sulfur dioxide is associated with a range of adverse health effects and that there are groups in the population that are particularly susceptible to the effects of sulfur dioxide including asthmatics. Although the epidemiological studies indicate that there may be no threshold for the effects of sulfur dioxide on susceptible groups, there is some evidence from controlled exposure studies that a threshold may exist for the populations that were included in those studies.

Although there is wide acceptance that sulfur dioxide is linked with adverse health effects, in setting air quality standards/guidelines a range of averaging times is used. The controlled exposure studies indicate that asthmatics react to short (minutes) exposures to sulfur dioxide but that their response does not worsen with prolonged exposure. A number of questions arise therefore as to what is the appropriate averaging time(s) to ensure protection of the health of susceptible groups while taking into consideration the practicability of monitoring sulfur dioxide over short time periods.

In terms of ambient air concentrations of sulfur dioxide, 5-10 minute levels are usually only of concern at specific locations, usually located close to sources. High concentrations are not widely experienced. This has led a number of international agencies to not set 5-10 minute standards, but to address localised problems in a different manner. The USEPA, for example, did not set a five minute NAAQS standard for sulfur dioxide, but is considering introducing an intervention level program as part of the implementation of the NAAQS standards that applies in areas where short-term sulfur dioxide peaks are experienced. This program would set an intervention level that, if exceeded, requires stricter emission controls on point sources of sulfur dioxide. The EU have set a 10 minute alert level that, if exceeded, requires public health warnings to be issued.

In assessing whether a 10 minute standard for sulfur dioxide should be included in the Ambient Air Quality NEPM, the following issues require consideration:

- are the sulfur dioxide levels at existing NEPM Performance Monitoring Stations of concern with respect to adverse health effects?;
- how widespread are the areas that may experience high short-term peaks of SO_2?;
- are high short-term peaks of sulfur dioxide only experienced near point sources (therefore not an issue to be addressed through the Ambient Air Quality NEPM); and
- can 10-minute sulfur dioxide levels be accurately monitored in ambient air away from point sources?

The issue then becomes one of whether a health risk may occur in relation to the general population exposed to regional air pollution levels, or primarily in relation to communities located close to major point sources of sulfur dioxide who are most likely to be exposed to high short-term peaks.

5.1.1 Applicability of overseas health data

Most of the information on the health effects of sulfur dioxide from epidemiological studies has come from studies conducted in North America and Europe where the levels of sulfur dioxide are much higher than those experienced in Australia. This raises the question of transferability of data from one country to another. Transferability concerns are not an issue with controlled exposure studies, however these studies can be limited by an inability to include the most vulnerable groups within the population and only minor health effects (which are reversible) can be investigated, providing one level only of evidence for adverse health effects. Most of the evidence for the health effects of short–term exposures (5-10 minutes) to sulfur dioxide in humans is derived from controlled human exposure studies.

There are potentially significant differences in ambient air composition and patterns of exposure to sulfur dioxide between Australian urban regions and those overseas commonly used for epidemiological studies. The NEPC Risk Assessment Taskforce Report and Risk Assessment Working Group Report (available on the EPHC website <www.ephc.gov.au>) discuss the issues around the transferability of overseas health data to Australia. The main concerns arise from the fact that in the USA and Europe, where most of the air pollution epidemiology has been conducted, the levels of sulfur dioxide in ambient air are considerably higher than in Australia. This is due largely to the low sulfur content in Australian fuels. These differences limit the confident transfer of overseas data to Australia. However, very few epidemiological studies in Australia have examined the health effects of short-term exposures to sulfur dioxide.

5.1.2 Exposure of the Australian population to levels of concern

The intent of the NEPM is to set air quality standards that are protective of the health of the general population, and to evaluate compliance by measurements of ambient concentrations at sites that are generally representative of the exposure of the population. Compliance with the NEPM is not assessed at peak sites. It is therefore important to consider whether the general population, away from peak sites, is subject to exposure to short-term peaks of sulfur dioxide that are of concern to human health, and whether such exposures are best addressed by a national 10 minute sulfur dioxide standard. Another issue for consideration is, in sites where there is a risk of exposure to high 10 minute peaks of sulfur dioxide, whether the magnitude of that exposure is likely to pose a health risk not addressed by the one hour standard.

A further question is whether the NEPM is the most appropriate instrument for providing protection from high 10 minute peaks given the localised nature of these exposures. Matters for consideration include the number of regions in which short-term exposure to sulfur dioxide occurs, and the size and characteristics of any populations within the region.

As shown in chapter 2, 10 minute sulfur dioxide levels measured at NEPM performance monitoring stations are generally low and below international guidelines. Major point sources that contributed to elevated levels in the vicinity of NEPM sites at Warrawong in Wollongong and Christies Beach in Adelaide have recently closed. In some areas, for example Paisley in Melbourne, the 10 minute peaks are occasionally higher than those observed in other parts of the airshed and this is due to the cumulative influence of industry in the local area. The low sulfur content of Australian fuels is a major factor contributing to the low levels of sulfur dioxide experienced by the majority of the population.

The large industrial sources of sulfur dioxide identified in Australia are predominantly located outside the heavily populated urban centres and hence do not figure in the exposure of large urban populations. Even in those regional cities associated with point sources, the impact of high short-term peaks is generally localised to small areas of these cities. For example, the short-term peaks at Port Pirie are associated with the variability in dispersion from the 205m smelter chimney, particularly under the fumigation conditions that arise from the land–sea interface. The resultant effect is relatively localised in one suburban area of the city, not extending to the whole city of 14,000 people. The exposure in those locations is characterised by low concentrations for the most of the time punctuated by occasional high peaks.

From the discussion above and examination of the data in chapter 2, it is clear that high short-term peaks of sulfur dioxide are not widely experienced by the Australian population, with high levels only experienced close to sources.

5.2 APPLICATION OF THE AMBIENT AIR QUALITY NEPM

5.2.1 Purpose of the NEPM

Chapter 1 explained that the objective of the NEPC is to give all Australians the benefit of equivalent protection wherever they live and to ensure that business decisions are not distorted and markets are not fragmented by variations in environment protection arrangements between member governments. Even so, the NEPC Acts confine the role of the NEPM to ambient air quality. The Ambient Air Quality NEPM itself requires that performance monitoring stations must be located so that a representative measure of the air quality likely to be experienced by the general population in a region or sub-region of 25,000 people or more can be obtained.

A 10 minute standard was recommended by the original health study review in 1997 but not included in the NEPM as it was not considered practicable at that time. In 1998, when NEPC decided not to set a 10 minute standard for sulfur dioxide, the Impact Statement reported that a 10 minute standard would:

- create inconsistency in the monitoring and reporting protocols for sulfur dioxide compared to other pollutants; and
- require a monitoring network around each significant point source to be designed and approved by NEPC.

This latter point was considered to be outside the scope of the Ambient Air Quality NEPM. The standards in the NEPM are the first step in developing a more consistent national approach to air quality management so that Australians can enjoy equivalent protection from the adverse health impacts of air pollution, but they are not the only means to achieve that. In order to achieve the objective of consistent national ambient air quality, jurisdictions implement strategies appropriate to their particular mix and range of sources to ensure the cumulative impact, as indicated by ambient air measurements, achieve the NEPM standards and goals. Control of the individual sources or classes of air pollution source, and other management strategies, were not considered the responsibility of NEPC but the responsibility of the individual jurisdictions.

5.2.2 The nature of short term exposure

The issue of whether short-term exposure to sulfur dioxide is a problem affecting the general community in urban regions, or point source related, is central to this review of the NEPM standards. Chapter 2 summarises the monitoring data available and the contributing sources of exposure identified by the National Pollutant Inventory. The results indicate that exposures characterised by elevated short-term peaks are likely to result from individual sources, not from the cumulative effects of diffuse sources. Given that the only circumstances in which short-term exposures occur are associated with individual facilities, a short-term ambient sulfur dioxide standard appears to fall within the realm of a specific source control or management strategy.

5.3 CURRENT CONTROL STRATEGIES FOR SHORT-TERM SO_2 EXPOSURES

The fact that sulfur dioxide can adversely affect human health has been well recognised for many decades and, across the globe, a range of emission reduction and exposure mitigation strategies have been applied to emission sources.

Responsibility for control of sulfur dioxide from industrial facilities in Australia is vested in the States and Territories, as detailed in Appendix 1.

A feature common to most environment protection legislation is a requirement to consider economic and social factors in applying environmental controls. This has led to the use of codes or guidelines relating to best practice for generic application throughout the jurisdiction, and site-specific requirements where circumstances dictate.

Petroleum based fuel is the most widespread source of sulfur dioxide, used for combustion in furnaces and engines, both stationary and mobile. Industrial facilities burning oil represent a common source of potential short-term exposure to sulfur dioxide in urban regions. In the absence of practicable sulfur removal technologies from the exhausts of small scale and medium scale furnaces, jurisdictions have controlled sulfur dioxide exposure from this type of source by using the petroleum industry specifications for fuel sulfur content and mathematical dispersion models to achieve desired maximum ground level concentrations. The performance criteria (in some cases known as design criteria) and averaging times in the modelling have adequately addressed the issue of potential short-term peaks from that class of point source.

Another feature common to State legislation is the licensing systems that apply to point sources likely to emit air pollution of environmental significance. Large scale emitters of sulfur dioxide are obvious candidates for such systems. Generally listed in schedules to legislation, these facilities must hold a licence to operate, and may be subject to specific licence conditions and emission limits. Licence holders tend to require ‘works approval’ consents to change operations and to install or modify process or control equipment associated with the licenced activities. In some States, planning legislation incorporates a procedure for specialist assessment of facilities that require a licence to operate under the environment protection legislation, as a means of ensuring new developments will not cause unacceptable impacts. This procedure applies to facilities that may not trigger the more public Environmental Impact Assessment processes.

All jurisdictions apply a hierarchical approach to pollutant management, with the first priority being avoidance of generation by process change. Dispersion of the residual pollutant following treatment is the last level of management. Industrial processes that generate sulfur dioxide, such as pulp mills, petroleum refineries, power stations or smelters are subject to planning consent or licence conditions that may require installation of technology to limit the mass, concentration or both mass and concentration of sulfur dioxide emitted. These limits are combined with appropriately sized chimneys to disperse the residual gas.

It could be concluded that current strategies are appropriate and widely effective, in that all but a small number of sites near large point sources in Australia experience sulfur dioxide concentrations that comply with current internationally recognised guidelines.

Of the large smelters, Kalgoorlie and Mt Isa have shown significant improvement in overall sulfur dioxide emissions. In South Australia, the EPA has determined that atmospheric lead emission is the priority issue for the Port Pirie lead smelter. Additional sulfur dioxide control is considered necessary but of secondary importance in application of the *Environment Protection Act*. Public health authorities in the SA Department of Human Services concur, having found that in studies of asthma prevalence, that the short-term sulfur dioxide exposures in a localised sector of the city are not a determining factor in the incidence of asthma in the city population.

In the case of a population exposed to short-term levels of concern, the imposition of a short-term ambient standard for sulfur dioxide amounts to the specific application of an instrument targeting an individual source, not a class of sources or combination of sources. That being so, the current system of state-based environmental protection legislation may be the most appropriate way to address short–term sulfur dioxide exposures. Jurisdictional legislation incorporates site-specific consideration of the balance of environmental, economic and social factors to determine the performance criteria and timeframes within which individual sources should comply to protect public health.

5.4 MONITORING AND DATA MANAGEMENT ISSUES

There are a number of monitoring and data management issues which need to be considered in determining whether it would be practicable for jurisdictions to implement a 10 minute sulfur dioxide standard.

5.4.1 Instrument capability

Measurements for comparison with a standard or guideline are normally specified with the standard to ensure consistency of that comparison. In the case of sulfur dioxide measurement, the accepted standard method in Australia is ultraviolet fluorescence as per AS3580.4.1-1990.

Although the instruments read a concentration every one or two seconds, this reading is not truly representative of the concentrations in the ambient air at that time, for several reasons. The physical act of sampling involves drawing gas from the ambient environment through a sampling tube and into the instrument sampling chamber where the electronic sensor reads the characteristic being measured. For completely discrete readings, the gas sample must be purged from the chamber ready for the next reading, and instrument design may not achieve that. The response characteristic of the data processing electronics in an instrument also has a time-limited capability, so that in a suddenly changing sample the actual representation of the ambient concentration is a compromise of matching a digital response to a continuously variable concentration. The measured value becomes less accurate as averaging time decreases. These physical factors combine to result in an instrument "time constant" which is a limiting factor in attempts to obtain short-term averages.

Further, air monitoring practitioners are guided by statisticians' recommendations that a sample size of approximately 200 is needed to calculate an average. At one reading per second, a three minute average (using 180 readings) is the shortest time frame that could be considered representative of the environment by current instruments. A 10 minute average may be the shortest time frame which can be achieved realistically, given the instrument dynamics.

Monitoring of 10 minute averages can be achieved with currently available instrumentation. The accuracy of the data is greater in more recent models of instruments as the response time of the older instruments was much greater (2-4 minutes). Data loggers may need to be configured to automatically record and store the 10 minute data, but this is not a significant issue.

5.4.2 Data management

The quantity of data recorded for 10 minute averaging, the validation of such data and how it should be reported are issues for resolution in the provision of an undistorted picture of short-term exposure that is relevant to health protection.

Currently some jurisdictions calculate two minute averages within the instrument and store those data, upon which the 10 minute averages are based. Others calculate the 10 minute average using all the one second readings for that period and store only the result. This procedure results in a database for each sulfur dioxide measurement site containing 51,264 concentration values and associated wind speed and direction data points for each year. The former method produces some 256,320 concentration records per year, plus the matching number of wind speed and wind direction values. The amount of data collected may pose a significant problem with disc space for storage of 10 minute data and is likely to require an upgrading of some systems to create the space required.

The collection and storage of two or ten minute averages is likely to be possible for jurisdictions, although there may be time and cost implications for the software modifications required for formulating the averages and the database and hardware overheads for storage of these data. A more significant problem occurs in the routine performance of quality assurance and data validation on these datasets. The additional resourcing requirements for jurisdictions needed to validate the larger volumes of 10 minute data will depend on the number of monitoring sites identified, the protocols chosen and current database construction. This could potentially have practical limitations for some jurisdictions if a 10 minute standard were introduced.

A further practical consideration relates to the meteorological parameters of wind speed and direction in the formulation of 10 minute averages from two minute data. This is not a straight averaging process but requires implementation of vector averaging routines.

5.5 SUMMARY

Controlled exposure studies indicate that there are health effects associated with exposure to short-term peaks of sulfur dioxide and that people with asthma appear to be a particularly susceptible group to the effects of sulfur dioxide. Analysis of air quality data in Australia indicates that, in general, sulfur dioxide levels are low with short-term peaks only experienced in locations close to major sources of sulfur dioxide. These locations are limited in Australia. These sources are currently being managed through individual State environmental legislation and frameworks, and significant improvements in industry performance have been observed in recent years.

Given that the short-term peaks of sulfur dioxide are source related and that these locations are not covered by the Ambient Air Quality NEPM, the question is raised as to whether the inclusion of a 10 minute sulfur dioxide standard in the Ambient Air Quality NEPM is appropriate. The following chapter outlines options for addressing these issues.

6 WHAT ARE THE OPTIONS FOR SETTING A 10 MINUTE SULFUR DIOXIDE STANDARD?

6.1 THE AMBIENT AIR QUALITY NEPM

The focus of this review is on the practicability of setting a 10 minute sulfur dioxide standard for inclusion in the Ambient Air Quality NEPM. The current structure of the Ambient Air Quality NEPM is such that the standards apply at sites that are representative of general population exposure.

The information presented in the previous chapters indicates that 10 minute peaks of sulfur dioxide are of most concern in areas close to large point sources, and that at locations where compliance with the NEPM standards is assessed (ie performance monitoring stations), these short-term peaks are generally low and well within international guidelines/standards. However, it is also clear that there are health effects associated with exposure to short-term peaks of sulfur dioxide.

The question then arises as to the best mechanism/s for ensuring the protection of the health of communities that live close to major sources of sulfur dioxide and may be exposed to high short-term peaks. The following three options are proposed for discussion and comment.

Option 1: incorporate a 10 minute standard for sulfur dioxide in the Ambient Air Quality NEPM

The introduction of a 10 minute standard would involve the establishment of a level at which the new standard should be set and a variation to the NEPM. Should NEPC decide to initiate an amendment to the Ambient Air Quality NEPM to incorporate a 10 minute sulfur dioxide standard, then a statutory process, including public consultation, would follow. Once adopted, a new standard would mean that jurisdictions would be required to monitor and report on 10 minute average levels at their designated sulfur dioxide monitoring stations under the NEPM.

Advantages

- this could provide a nationally consistent approach to monitoring and reporting on short-term peaks;
- it would provide communities living in the vicinity of NEPM monitoring sites with more information about short-term peaks; and
- there is currently no Australian health benchmark for short-term sulfur dioxide exposure and a NEPM standard would fill that gap.

Disadvantages

- given that short-term peaks are a fairly localised problem occurring principally in the near vicinity of major point sources, strategies to manage emissions with a local focus may be more effective than a national standard;
- sulfur dioxide levels are generally low in Australia and additional monitoring for sulfur dioxide may not be a priority when compared to other air quality issues; and
- there would be additional costs for jurisdictions in data analysis and validation.

Option 2: retain the status quo

Under this option individual jurisdictions would continue to monitor and report on regional one hour, 24 hour and annual sulfur dioxide levels but would not be required to report on regional 10 minute levels. Jurisdictions would manage the emissions from point sources through their own legislation and management strategies.

Advantages

- jurisdictional programs have been successful in achieving significant reductions in emissions of sulfur dioxide over recent years. This avoids a single, less flexible approach and allows individual jurisdictions to work with their industries to ensure that management programs meet jurisdictional goals for environment protection, within a timeframe that is economically viable for the industries. The social, economic and environmental considerations pertinent to a particular jurisdiction can be taken into account in such decision-making; and
- monitoring on a regional basis may not target problem areas. Few overseas jurisdictions have adopted short-term standards. They have, instead, favoured other management approaches.

Disadvantages

- there may be existing inconsistencies between jurisdictions that may not provide a level playing field for industry, and may create difficulties if a company has facilities in different jurisdictions; and
- communities living in the vicinity of point sources may prefer greater consistency.

Option 3: establish a non-NEPM health protection value

A third option is to establish, through a non-NEPM process under EPHC, a health protection value that could be used by jurisdictions as an objective to be met in communities that are impacted by the short-term emissions from large point sources. It could be used in a similar way to the former NHMRC 10 minute goal.

The form that this may take (eg an air quality objective or design criteria for individual premises) would need to be determined through a separate consultative process conducted by EPHC.

Advantages

- would provide a nationally consistent basis for the assessment of potential health risks on locally impacted communities. This would provide communities with some assurance that their health is being protected at the same level across the country; and
- while this option stops short of varying the NEPM, and therefore making a binding health protection value, it may provide greater national consistency in contrast to simply maintaining the status quo.

Disadvantages

- this option would be a non-statutory approach that would not require all jurisdictions to adopt the objective. Therefore some differences may remain in how jurisdictions manage the emissions from point sources;
- such an approach would be outside the existing NEPM framework and the prescribed process for NEPM development; and
- overseas standards such as the WHO 10 minute sulfur dioxide guideline are currently available and used by some jurisdictions in managing emissions.

6.2 THE WAY FORWARD

The NEPC is seeking your views and any pertinent information as to whether it is most appropriate to:

1. incorporate a 10 minute standard for sulfur dioxide in the Ambient Air Quality NEPM; or

2. retain the status quo where individual jurisdictions develop their own management strategies for short-term emissions from large industrial sources;
   or
3. undertake a non-statutory process through the EPHC to establish a health protection value to be used by jurisdictions in communities affected by short-term peaks of sulfur dioxide. This value would be developed through a separate consultative process.

7 WHERE TO FROM HERE?

7.1 MAKING A SUBMISSION

The first step in the review has been the preparation of this issues paper. It is expected the release of the issues paper and any subsequent feedback on its contents will lead to a better-informed review.

NEPC encourages you to make your views on the practicability of developing a 10 minute sulfur dioxide standard known, and to make available any information that you consider pertinent to the review. Views on an appropriate option for the way forward are specifically sought. Your input will ultimately ensure that when NEPC makes a decision, that decision can be made on the basis of the best possible information available.

Written submissions should be sent to:
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The closing date for submissions is **Friday 7 May 2004**.

All submissions are public documents unless clearly marked "confidential" and may be made available to other interested parties, subject to Freedom of Information Act provisions.

An electronic form for lodging comments is available. The form can be emailed to you by the NEPC Service Corporation or downloaded from the EPHC website <www.ephc.gov.au>. This form can be filled out and submitted electronically. Consideration of your submission will be facilitated if it is provided, if possible, in this format.

Should you wish to provide your comments in another format, submissions may be made:
- in hardcopy;
- on a 3.5 inch floppy disk; or
- emailed to mgilbey@ephc.gov.au.

To allow ease of photocopying, hardcopy submissions should be unbound. Electronic submissions should preferably be provided as a Word for Windows file.

7.2 THE NEXT STEPS

Following analysis of the comments received on the issues paper, a report will be prepared for the NEPC.

Should the NEPC decide to initiate an amendment to the Ambient Air Quality NEPM to incorporate a 10 minute sulfur dioxide standard, then a statutory process for the variation of the NEPM would follow. If, however, one of the other options discussed in this paper were to be the preferred approach arising from the review, this matter would be considered by the EPHC outside the NEPM framework.

GLOSSARY

Asthma	Chronic disorder of the airways that causes them to narrow too easily and too much in response to a wide range of stimuli
Atopic subjects	Individuals with a genetically determined state of hypersensitivity (exaggerated response) to foreign agents (including environmental allergens)
Bronchoconstriction	Constriction of the bronchial tube
Bronchospastic	Contraction of the smooth muscle in the walls of the bronchi and bronchioles
Cholinergic mediators	A chemical (acetycholine) whose primary purpose is to transmit nervous impulse from the nervous system to effector cells such as muscles
Cross-sectional study	A study that examines the relationship between diseases (or other health related characteristics) and other variables of interest as they exist in a defined population at one particular time
Cyclo-oxygenase	One of a group of enzymes that allows oxygen to be incorporated into cells to create energy
Dose-response relationship	A relationship in which a change in amount, intensity or duration of exposure is associated with a change, either an increase or a decrease, in risk of a specified outcome
Dyspnea	Shortness of breath
Endothelial	Relating to the layer of flat cells lining especially the blood and lymphatic vessels and the heart
Epidemiology	Branch of medicine that deals with the study of the distribution and determinants of disease in populations and with investigations into the sources and causes of infectious diseases
Health effect	An adverse health outcome associated with exposure to an air pollutant
Sputum	Expectorated matter or phlegm
Substernal irritation	Irritation behind the breastbone
Symptom score	A score usually derived from the sum of scores for individual symptoms
Time series study	Form of analysis that examines factors influencing change in an observation over time
Waste hierarchy	Nationally recognised framework under which waste generation may be managed and reduced, incorporating the options of reduce, reuse, recycle, energy recovery and disposal.

ACRONYMS AND ABBREVIATIONS

COPD	Chronic obstructive pulmonary disease – a group of diseases characterised by an irreversible reduction in expiratory airflow
EPHC	Environment Protection and Heritage Council
EU	European Union
FEV_1	mean forced expiratory volume in one second - which is a measure of ease of airflow in the airways and is the amount of air that is exhaled in the first second when a person is exhaling as fast and forcefully as possible
LOAEL	Lowest observed adverse effect level – refers to the lowest concentration or amount of a substance, found by experiment or observation, that causes adverse alterations of morphology, functional capacity, growth, development or life span of target organisms
NEPC	National Environment Protection Council
NEPM	National Environment Protection Measure
NHMRC	National Health and Medical Research Council
ppm	Parts per million
SO_2	Sulfur dioxide
sRAW	Specific airways resistance – the resistance to flow of gases during ventilation due to obstruction or turbulent flow in the upper and lower airways
UK	United Kingdom
USEPA	United States Environmental Protection Agency
WHO	World Health Organisation
$\mu g/m^3$	Micrograms per cubic metre

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APPENDIX 1

APPROACHES TO MANAGEMENT OF SOURCES OF SULFUR DIOXIDE

VICTORIA

In Victoria the primary legislation that guides the approach to protection of the environment and EPA's environmental systems and practices is the *Environment Protection Act (1970)*. The Act allows for the development of a range of instruments that guide the protection of Victoria's air environment. This Act established the Environment Protection Authority (EPA) and defines its powers, duties and functions. The Act's provisions include statutory powers, instruments and measures to:

- manage environmental quality;
- establish environmental standards and criteria;
- regulate emissions, discharges and wastes; and
- prevent and clean up pollution.

Some of the most important instruments for environmental management include state environment protection policies (SEPPs), industrial waste management policies, regulations, works approvals, licences and pollution abatement notices.

SEPPs establish a statutory framework for protecting the environment. SEPPs are declared by the Governor in Council, on the recommendation of EPA. These policies:

- identify the beneficial uses of the environment (including particular segments such as the air environment, or a particular water body or catchment) that are to be protected;
- establish environmental indicators and associated environmental quality objectives to establish if the environment is being protected; and
- define programs for attainment of these objectives so that identified beneficial uses are adequately protected.

Attainment programs usually specify a range of approaches, measures and instruments for policy implementation, and usually require the compliance and cooperation of government agencies, industry and the community to manage sources of pollution, reduce environmental impacts and improve environmental quality.

SEPPs provide the management approach and technical basis for the application of regulations, works approvals, licences and other statutory measures to manage the environment. The application of these instruments and measures must always be consistent with the requirements of SEPPs.

Which SEPPs protect air quality?

The air environment in Victoria is currently protected by two SEPPs. These were created in February 1999 by dividing the State Environment Protection Policy (The Air Environment) (made in 1981 and subsequently amended several times) into two policies:

- State Environment Protection Policy (Ambient Air Quality) or SEPP (AAQ); and
- State Environment Protection Policy (Air Quality Management) or SEPP (AQM).

The SEPP (AAQ) contains the indicators, standards, goals and monitoring and reporting protocol of the Ambient Air Quality NEPM. The SEPP (AAQ) also includes an ambient air objective for visibility reducing particles.

The SEPP (AQM) sets the framework for managing emissions to the air environment and underwent a major review in 2001. Emissions are managed in such a way as to ensure that the air quality objectives of the SEPP (AAQ) are met. In addition, a philosophy of continuous improvement is also pursued. The Principles of Environmental Protection contained in the *Environment Protection Act 1970* are explicitly stated in the SEPP (AQM) and guide the management of emissions to the air environment in Victoria. The focus is on the application of the wastes hierarchy with avoidance being the primary aim rather than end-of pipe controls.

Management practices for sulfur dioxide

The SEPP (AQM) classifies pollutants into Class 1, 2 and 3 indicators. Pollutants are classified according to their toxicity, odorous properties and persistence in the environment. Sulfur dioxide is classified as a Class 1 indicator. All generators of sulfur dioxide, and other Class 1 indicators, must control their emissions by the application of best practice. Best practice involves the application of eco-efficient practices with the application of end-of-pipe controls as the last option to be considered. Avoidance of emissions is the primary aim. Design criteria have been set for sulfur dioxide at 0.17ppm for a one hour average and all applicants for works approval and licences must ensure that emissions of sulfur dioxide are managed in such a way that the design criteria are not exceeded at ground level. Design criteria are modelling tools to be used in the design stage of an operation. Large point sources of sulfur dioxide in Victoria are subject to works approval and licensing. Emission limits are set to ensure that the beneficial uses of the environment, which includes human health, are protected.

The SEPP (AQM) also specifies an intervention level for sulfur dioxide. An intervention level is a local air quality objective that can be used to assess the cumulative impacts of emissions in a local area. If an intervention level is exceeded then a Neighbourhood Environment Improvement Plan may be triggered. The intervention level for sulfur dioxide is 0.21ppm for a one hour averaging period.

NEW SOUTH WALES

The development of new industrial facilities in New South Wales is managed through the development approval processes under the *Environmental Planning and Assessment Act 1979* to ensure that only developments with acceptable environmental impacts proceed. If approval is required under the *Protection of the Environment Operations (POEO) Act 1997*, the Department of Environment and Conservation (DEC) provides general terms of approval. These terms of approval typically include emission limits and ambient monitoring requirements.

Environment protection licences issued under the *POEO Act* are site-specific and set conditions for a facility's operation that take its specific environmental and health impacts into account. Activities that require an Environment Protection Licence in order to legally operate are listed in Schedule 1 of the *POEO Act*. These activities have been identified by the DEC as those activities that have the most potential to have a significant adverse effect on the environment.

The Clean Air (Plant and Equipment) Regulation 1997 sets minimum performance standards for point sources and applies to all licensed industries, including sulfur dioxide limits for sulfuric acid plant and restrictions for sulfur in liquid fuels.

When industry applies for development consent or a licence, the applicant must assess the anticipated impact on ambient air quality in accordance with DEC requirements - the Approved

Methods for Modelling[4]. This assessment is used by the DEC to determine licence conditions and/or General Terms of Approval for development consents (the economic and technical feasibility of pollution control equipment is also taken into account).

The Approved Methods for Modelling require that, where relevant, the impact of an activity on ambient sulfur dioxide levels should be assessed. The DEC requires assessment against the following sulfur dioxide standards:

- 10 minute average levels 0.25ppm;
- one hour average levels 0.20ppm;
- 24 hour average levels 0.08ppm; and
- annual average levels 0.02ppm.

The DEC expects that emissions of sulfur dioxide will be controlled or mitigated to ensure that ambient sulfur dioxide levels do not exceed these standards.

The licences of significant sulfur dioxide emitters generally include stack emission limits and monitoring requirements. Stack emission limits are set to ensure that sulfur dioxide is adequately controlled and to ensure that the ambient air quality standards are met. Licences may also:

- specify an upper limit on the sulfur content of fuel that may be used at the premises; and/or
- require ambient monitoring (as opposed to stack monitoring) in order to ensure that the community surrounding a major point source of sulfur dioxide is not being exposed to unacceptable levels.

For certain industries, licences also include annual sulfur dioxide load limits and annual load-based fees with the purpose of protecting the environment against cumulative increases in total sulfur dioxide pollution. Industries that are subject to load limits and load-based fees include electricity production, petroleum refining, and primary and secondary iron and steel production.

For existing plant, DEC may negotiate Pollution Reduction Programs with the plant operator that are then attached to the Environment Protection Licence for the site.

Licensees are required to report on compliance with their licence conditions. Any specified non-compliance is put on the public register on the DEC website. DEC carries out independent audits of licensed premises and issues warnings or notices or commences prosecutions if licence requirements are not met.

WESTERN AUSTRALIA

In Western Australia, current management is focused on the control of one hour or longer average concentrations (one hour, 24 hour and annual). Historically, the areas in Western Australia with the most significant sulfur dioxide problems have been Kalgoorlie and Kwinana.

Environmental Protection Policies (EPPs) with associated licensing arrangements have been developed for both areas.

The Kwinana EPP and associated regulations set sulfur dioxide standards for three zones (rural/residential, buffer, and industrial). The policy also establishes the procedure whereby

[4] Abbreviated title for the Approved Methods and Guidelines for the Modelling and Assessment of Air Pollutants in New South Wales.

emission limits are determined by computer modelling for each sulfur dioxide emission source such that, in the opinion of the CEO of the Department, compliance with the ambient sulfur dioxide standards will be achieved. These emission limits are applied as licence conditions.

The Kalgoorlie EPP defines protected areas that encompass all of the residential/community areas within the region and sets an ambient sulfur dioxide limit (one hour average) that must never be exceeded within a protected area. In this region, there are three industries, all located outside of the protected areas, emitting sulfur dioxide. Each of these industries has a condition of license that requires it to operate its plant so as to not cause or contribute to causing an exceedence of the sulfur dioxide limit in any protected area. The limit is somewhat higher than the NEPM, reducing from 0.40ppm in 2002 to 0.25ppm by 2005.

QUEENSLAND

The Environmental Protection Policy (EPP) for Air includes a goal for 10 minute average sulfur dioxide concentration of 700 micrograms/m^3 (0.25ppm). This is expressed as a goal to be progressively achieved over the long term. Queensland's pattern of urban settlement, and relatively low levels of sulfur in Queensland's coal and liquid fuels mean that exceedences of this goal are generally highly unlikely, and specific management measures are usually unnecessary. Nevertheless, possible threats to the goal are checked when considering licences for large industrial sources of sulfur dioxide.

The only exception to this is the Mount Isa Mines (MIM) operation at Mt Isa. The MIM smelters operate under special legislation (*Mount Isa Mines Agreement Act 1985*) that provides exemption from the 10 minute goal in the EPP and requires that a three hour average of 1300 micrograms/m^3 be met. This is managed through a closed loop control system which initiates staged shutdowns when unfavourable meteorological conditions or elevated ambient levels of sulfur dioxide are predicted or detected.

SOUTH AUSTRALIA

The principal relevant legislation in South Australia is the *Environment Protection Act 1993* (the EP Act) and its Regulations and Environment Protection Policies administered by the Environment Protection Authority. The EP Act establishes a general duty for persons undertaking any activity to take all reasonable and practicable measures to avoid causing environmental harm, which includes harm to human health.

The EP Act also establishes an authorisation system under which activities of environmental significance, as defined in Schedule 1 to the Act, require approval (either through Development Act procedures or via Works Approval provisions under the EP Act) and a licence to operate. The schedule of activities covered by these provisions includes point sources likely to emit significant quantities of sulfur dioxide.

Thus the emission of sulfur dioxide from major point sources is regulated by a combination of conditions of development consent (imposed at the direction of the Environment Protection Authority) and licence conditions. These conditions are generally directed at equipment design or operational parameters solely within the control of the licensee so that compliance can be readily checked by both the licensee and the regulator. EPA also imposes a design maximum ground level concentration for sulfur dioxide at a level that addresses the potential cumulative impact from an individual source and others. It is not possible to ascertain individual source compliance by measuring ambient sulfur dioxide levels nearby because of the potential influence of other local sources. However, the "design maximum glc" approach leads to specification of plant design and operational parameters that can clearly be set as licence conditions and thereby ultimately achieve desired ambient air quality criteria.

The Pasminco smelter in Port Pirie is subject to a licence under the *Environment Protection Act 1993*. In the sintering process, sulfide ore releases sulfur dioxide, the majority of which is converted to sulfuric acid, but there is still a significant residual emission of the gas from a 205 metre chimney. One of the licence conditions is compliance with an agreed protocol to mitigate the effects of the residual sulfur dioxide emissions by reducing plant throughput when the mass emission rate of sulfur dioxide exceeds 65 kilograms per minute as sulfur (the 'tall stack' protocol). Those criteria require progressive actions to reduce sulfur dioxide generation and thereby avoid exceedence of the NHMRC one hour sulfur dioxide goal, which was used as the design maximum.

TASMANIA

The Tasmanian Environment Protection Regulations (Air Quality) recently expired and consequently there are no current in-stack or design ground-level criteria for sulfur dioxide. A draft Environment Protection Policy (Air Quality) is presently being considered. The draft Environment Protection Policy specifies an in-stack limit of $7.2g/m^3$ for sulfuric acid manufacture and sets a general design ground-level concentration of 0.2ppm averaged over one hour.

The main industrial sources of sulfur dioxide include Comalco Aluminium in Bell Bay (3,900tpa), Goldamere Pty Ltd pelletising plant (970tpa) and Australian Paper (810tpa). Some 56 industrial sources are reported on the National Pollutant Inventory (NPI), of which the emissions from six exceed 5,000tpa of sulfur dioxide.

The Pasminco Australia Ltd plant at Lutana in Hobart reports emissions of 76tpa and is extensively monitored because of its location adjacent to residential areas. The company maintains three community monitoring stations for sulfur dioxide in addition to continuous in-stack monitoring of emissions. The Tasmanian Government will be reporting the results of this monitoring as part of its annual Ambient Air Quality NEPM reports. Data from these stations has been considered in this review.

Facilities that emit less than the NPI reporting threshold are estimated to emit about 530tpa, domestic sources total around 340tpa and all forms of transport sum to around 240tpa.

The permits for these activities are being amended to meet the requirements of the draft Environment Protection Policy, including revised provisions for air dispersion modelling and ground-level monitoring.