# Ambient Air Quality Research Project (1996–2001)

# Dioxins, Organics, Polycyclic Aromatic Hydrocarbons and Heavy Metals

NSW EPA

ENVIRONMENT PROTECTION AUTHORITY

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## SUMMARY

Air pollution has many sources, including industry, motor vehicles, the home (e.g. from solid fuel heaters), and sporadic natural events, such as bushfires. The impact of air pollution can be viewed from a global, regional or local perspective.

Recently, international concern has turned to a number of air pollutants which, though found in relatively small concentrations, have the potential to adversely affect human health and the environment through long-term exposure. These substances have been given a variety of names including 'hazardous air pollutants' and 'air toxics', the term adopted in this report.

Scientific understanding of the identity and risk posed by these pollutants is evolving. As a result of this still limited knowledge, the elements and compounds viewed with the greatest concern varies between countries and states.

To assess the local situation, the NSW Government provided $1.4 million for the Environment Protection Authority (EPA) to study the presence of air toxics at sites representative of general urban air quality in the Sydney–Newcastle–Wollongong area. Sampling for a specific type of air toxic—polycyclic aromatic hydrocarbons (PAHs)—also occurred at a number of larger regional centres: Armidale, Cooma, Lithgow, Nowra, Orange and Tumut. Throughout the study, sampling was more intensive at those times of year when pollutant concentrations were expected to be highest.

The primary aim of the program was to obtain data on the concentrations of a wide range of air toxics. Altogether, the study ran for 5½ years from early 1996 to August 2001. It examined dioxins, 41 organic compounds, 11 PAHs and 12 heavy metals. In total, the concentrations of over 80 substances were measured, with more than 1400 samples collected at a total of 25 sites.

Armed with this large amount of data and in the absence of any Australian standards, the EPA compared the results with the overseas standards available. Where none existed the EPA measured results against either proposed or future standards or reported levels from other jurisdictions.

**In summary, the study found that most air toxics levels in NSW are low and well below current international standards and benchmarks.** However three of the pollutants—benzene, 1,3-butadiene and PAHs at some sites—will need ongoing vigilance to ensure their currently acceptable levels do not escalate in the future.

Ambient **dioxin** concentrations measured in Sydney, Wollongong and central-western NSW were very low when compared with current standards in both Europe and the US, and measured concentrations in other countries.

The NSW management program for dioxins has involved strict control and reduction by:

- banning backyard burning
- closure of some sources, especially hospital incinerators
- licensing and regulation of industrial sources
- reducing emissions from solid fuel heaters
- a phase-out of leaded petrol for cars.

The low concentrations of dioxins found in this study indicate that these control strategies have been effective, and are likely to continue to be so.

The annual average concentrations of **organic air toxics** measured in this study in the Sydney–Newcastle–Wollongong area were also very low. Many of the commonly recognised air toxics were not detected in any samples. Twenty-two of the 41 organic compounds

sampled were either not detected in any of the samples (12 compounds) or rarely encountered (10 compounds detected in fewer than 1% of the 1000 samples). The measured levels of organic air toxics were below all current international goals or standards. However, benzene and 1,3-butadiene were present at concentrations which approached, but did not exceed, the goals for these substances.

The major sources of benzene and 1,3-butadiene are motor vehicles and their fuel. Several recently introduced programs aim to reduce emissions from motor vehicles, including:

- stricter national emission standards for new vehicles
- introduction of national fuel quality standards, including a maximum limit on benzene in petrol of 1% from 2006
- lower volatility petrol in summer in the Sydney region
- the Cleaner Vehicles Plan promoting vehicles which run more cleanly in NSW
- voluntary emissions testing for cars
- programs to encourage alternative forms of transport to reduce vehicle use.

These programs and initiatives will all reduce benzene emissions. However, the Government will continue to evaluate the effectiveness of these strategies and strengthen them as necessary to avoid increasing levels of benzene and 1,3-butadiene.

Substances that damage the stratospheric ozone layer (such as Freons®) and those substances banned or being phased out under the Montreal Protocol showed little difference from global background levels. This suggests that existing strategies, which prohibit the use and release of ozone-depleting substances through regulation, are having the intended effect.

In winter some parts of Sydney and a number of larger centres in the Great Dividing Range suffer from visibly high levels of smoke associated with solid fuel heating and still weather. The study set out to determine the types and indicative concentrations of **polycyclic aromatic hydrocarbons** (PAHs) in ambient air associated with the expected winter seasonal peaks in these problem areas.

Concentrations of PAHs at urban sites in outer Sydney, Newcastle, Wollongong and Nowra are easily lower than proposed international goals for these substances. Concentrations in the Sydney CBD and at Earlwood were in the vicinity of the goals and levels in some regional centres—Armidale, Cooma, Lithgow, Orange and Tumut—were elevated in winter. The pattern of emissions in these regional centres corresponds to the high usage of solid fuel heaters burning wood. The local practice in Lithgow of burning coal as well as wood is believed to contribute to the even higher levels of PAHs there. Existing strategies to reduce PAH emissions from solid fuel heaters are therefore confirmed as priorities by the study.

One program, for example, the NSW Government's targeted wood and coal smoke reduction program, is already in place to reduce PAH emissions from solid fuel heaters. The program involves an allocation of $1 million to selected local councils to step up education and enforcement programs and subsidise the cost of switching to non-solid fuel heating sources in the most affected areas: Armidale, the Blue Mountains, Cooma, Lithgow, Orange and Tumut. The effectiveness of this program will be monitored to decide if it should be extended to other areas.

A survey of **heavy metals** at urban sites found that the concentrations of the 12 metals measured were low when compared with levels at comparable sites overseas. They were all below applicable standards or goals, where these exist. Concentrations near some industrial sites will continue to be monitored as part of the licensing of those facilities. The sources of these emissions will be further reviewed to identify possible sites where focused local reduction programs might be effective.

# 1. INTRODUCTION

## 1.1 Background

Air pollution has many sources, including industry, motor vehicles, the home (e.g. from solid fuel heaters), and sporadic natural events, such as bushfires. The impact of air pollution can be considered from a global, regional or local perspective.

Historically, industrial point sources of pollution have been the focus for regulation by agencies such as the Environment Protection Authority (EPA). More recently, however, the cumulative impact of millions of small sources such as motor vehicles has been recognised as a dominant contributor to regional and global air quality.

To date, regional air management has concentrated on controlling six priority pollutants identified as having the potential to adversely affect human health and the environment at the levels sometimes found in urban areas. These six, included in the National Environment Protection Measure (NEPM) on Ambient Air Quality and known as 'criteria pollutants', are:

- ground-level ozone (photochemical smog)
- nitrogen dioxide
- particles (up to 10 micrometres in diameter)
- sulfur dioxide
- lead
- carbon monoxide.

The NEPM sets national goals for regional concentrations of these pollutants. NSW monitoring data on them is included in the annual report of the National Environment Protection Council and daily readings for these pollutants are also reported on the EPA's website.

More recently, international concern has turned to a number of other air pollutants which, though found in relatively small concentrations, may also have a detrimental effect on human health and the environment through exposure over many years. This latter group of substances has been given a variety of names. The United States Environmental Protection Agency (US EPA) calls them 'hazardous air pollutants'. Elsewhere they are known as 'air toxics' and this is the term adopted here. Air toxics do not include the criteria pollutants referred to above.

Air toxics cover a broad range of pollutants, and scientific understanding of their identity and the risk they pose is only evolving. Because of this limited knowledge, the elements and compounds viewed with greatest concern varies between countries and states.

As a result of this growing international focus on the hazards of air toxics, the NSW Government provided $1.4 million for the EPA to study a comprehensive range of these pollutants in urban areas and some regional centres across the State. Altogether, the study ran for 5½ years from early 1996 till August 2001.

An earlier pilot study in Sydney in 1995 and 1996 tested for the presence of 40 air toxic organic compounds covered by the US EPA standard test method (TO-14). The pilot successfully trialled the methodology and recommended that measuring continue to develop a more representative data set on air toxics.

The pilot also recommended extending the studies to include 1,3-butadiene, polycyclic aromatic hydrocarbons (PAHs) and a range of heavy metals as a companion to the TO-14 studies. These have been included in the new EPA study, together with dioxins, to give a more complete picture across the spectrum of air toxics.

The EPA conducted the latest study to find out whether, at a regional level, the more significant air toxics are present in NSW and, if so, at what concentrations. A comparison of concentrations here with current goals and levels overseas should indicate if further action is needed to control or reduce air toxics.

## 1.2 Measurement sites

The study focused on sampling in the Sydney–Newcastle–Wollongong region, as this is where the concentrations of these pollutants are likely to be highest. The project also included measurement of specific compounds in a number of major regional centres where there was evidence that elevated levels of these compounds might be occurring.

Study design for each group of pollutants varied according to the information already available and likely patterns of emissions:

- **Dioxins**: Measurements were made at three sites: a rural background site (Siding Spring in central-western NSW); a site representative of conditions in an urban area in western Sydney (Westmead); and an urban site near a known industrial source of dioxins (Warrawong in Wollongong). Sampling ran from November 1998 to April 2000, except for three months in early 1999.
- **Organics**: Measurements were made at 10 sites in the Sydney–Newcastle–Wollongong during the period from early 1996 till August 2001: three sites from the pilot study and seven new ones to provide a more representative data set.
- **Polycyclic aromatic hydrocarbons (PAHs)**: Samples were collected at 22 sites, covering Sydney–Newcastle–Wollongong, as well as sites in the regional centres of Armidale, Cooma, Lithgow, Nowra, Orange and Tumut. The sites in the regional centres were selected because of the likely impacts of smoke from domestic solid fuel heaters in winter. Sampling occurred at various times between August 1997 and February 2001.
- **Heavy metals**: Eight sites were sampled in the Sydney–Newcastle–Wollongong region from mid-August to early September 2000 to establish concentrations of heavy metals at times when they were likely to be highest.

## 1.3 Seasonal variations in pollution

Winter conditions tend to reduce mixing in the atmosphere because of stronger and more frequent temperature inversions. As a result, pollutants can be trapped in a shallow layer at ground level and concentrated. This is often compounded by still conditions, further limiting dispersion of the pollutants. The seasonal pattern of concentrations for benzene shown in Figure 1 is typical of many of the pollutants in this study.

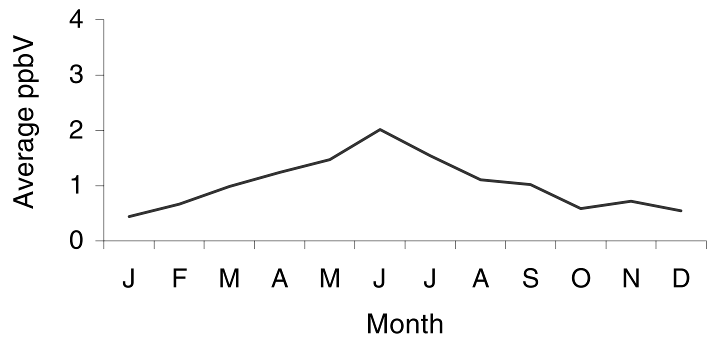


**Figure 1: Annual ambient benzene concentrations (average parts per billion by volume) at Rozelle, Sydney**

Other factors may also contribute to higher concentrations in winter for these pollutants. For many compounds produced by motor vehicles, cold starts in winter lead to longer periods of incomplete combustion and longer warm-up times for catalytic converters, which generates more pollution. Pollutants such as PAHs are also more prevalent in winter because of the use of solid fuel heaters at that time of the year.

## 1.4 International benchmarks

While there is considerable information about the toxicity and risk posed by the more common air toxics, especially at the elevated concentrations found historically in some workplaces, much less is known about the potential risks of ongoing exposure to the low levels that may occur in the general environment. No goals, standards or benchmarks have yet been set for air toxics in Australia, although a National Environment Protection Measure is currently under development to address this need. In the meantime, some other countries, particularly in Europe and North America, have proposed goals which are used to interpret the results of this study.

International standards and guidelines for air toxics vary considerably from country to country, because of the limited knowledge about them and differing approaches to their assessment and management. For some air toxics, there are no standards or goals at all, making the task of assessing our own air toxics even more challenging.

Comparison with the standards or goals that do exist is also complex because results may be influenced by differences in measurement techniques (types of equipment used, sampling periods) as well as other factors.

This report seeks to interpret the findings of the recent study by comparing them with relevant overseas benchmarks and similar studies to assess whether further control strategies are necessary and what relative priority they should receive.

## 1.5 Health impacts

Some compounds, such as benzene, are known to cause cancer. Others are suspected to be carcinogenic or are likely to have other impacts. Further detail can be found in publications from the World Health Organization, US EPA and other environment agencies and research institutes. The following websites may assist in further research:

- www.epa.gov/ttn/atw/urban/urbanpg.html
- www.epa.gov/iris/sunst/index.html

- www.defra.gov.uk/environment/airquality/aqs/index.htm#fr

It is important to note that this study is not a public health study, which would typically involve an analysis of air quality data with toxicological and epidemiological data. However the data collected may provide a useful basis for a public health study.

## 1.6 Structure of the report

This report summarises the findings of each component of the EPA air toxics study: dioxins; organics; PAHs; and heavy metals.

Chapters follow the same general structure for each of the air toxics groups:

- introduction, including sources of the pollutants
- the measurement program
- results/average concentrations
- comparisons with international benchmarks (standards, future goals and studies) and other Australian data, where available
- conclusions about current levels of the pollutants (relative to those benchmarks)
- a summary of current and proposed management strategies.

# 2. DIOXINS

## 2.1 Introduction

'Dioxins' is a term used to describe a group of 210 compounds or 'congeners' which contain either a dibenzo-para-dioxin or dibenzofuran nucleus substituted with chlorine.

Dioxins are highly toxic substances generally found at such extremely low concentrations that they challenge the limits of scientific measurement. They have been a source of international concern because they are a known by-product of some combustion processes and they do not readily break down, but persist in the environment.

A number of dioxin congeners have been shown to cause adverse health effects in humans, including cancer. Several international organisations have classified the most toxic congener—2,3,7,8-tetrachlorodibenzo-para-dioxin (2,3,7,8-TCDD)—as a human carcinogen.

Over the past 10–20 years, programs have been in place in NSW and elsewhere to eliminate known sources of dioxins from the manufacture of chemicals, including pesticides, emissions from waste incinerators and industry, and more diffuse sources such as backyard burning. These programs have resulted in significant reductions in their emissions.

## 2.2 Project design for dioxin measurements

The EPA study measured concentrations of the 17 most toxic congeners (with chlorine atoms in the 2,3,7 and 8 positions) at three sites, chosen to reflect a range of distinct environments. These were:

- a rural background site—Siding Spring Observatory in central-western NSW
- a site in western Sydney representative of urban conditions—Westmead, approximating the geographical centre of the Sydney Metropolitan Area
- an urban site near an industrial source of dioxins—Warrawong, about 3 kilometres south-east of the steelworks at Port Kembla in Wollongong.

Sampling began in November 1998 and continued till April 2000, excluding three months in early 1999.

Collection and analysis followed the US EPA Method TO-9A. Air was drawn into a canister through a filter paper and both the contents of the canister and the filters were then analysed by gas chromatography/mass spectrometry. Air was sampled continuously for 12 days at Westmead and Warrawong. Because the readings at Siding Spring were so low and the test methodology requires a sample to be taken which can provide a detectable concentration, samples at that site were taken continuously over 24 days.

## 2.3 Results

Table 1 summarises the results for dioxin samples collected at each site over 18 months. They indicate that, on a regional basis, ambient dioxin levels are very low.

The results are reported as femtograms per cubic metre ($fg/m^3$): one femtogram is $1 \times 10^{-15}$ grams or 0.000000000000001 g. To put this extremely small measure in perspective, 1 fg is to a gram as 1 milligram is to one million tonnes.

**Table 1: Dioxin concentrations at each site**

| Site | No. (and length) of samples | Total concentrations (fg/m³) | | |
|---|---|---|---|---|
| | | Minimum | Average | Maximum |
| Siding Spring | 15 (24-day) | 3 | 17 | 43 |
| Warrawong | 33 (12-day) | 40 | 160 | 320 |
| Westmead | 34 (12-day) | 83 | 480 | 1500 |

At both Warrawong and Westmead, higher concentrations were observed in winter than in summer. This is probably due to a number of factors, including poor dispersion because of the effects of inversion layers and possibly increased inputs from domestic heating.

Dioxins usually occur as a complex mixture of congeners. To enable the relative toxicity of such a mixture of compounds to be expressed as a single number, the concept of toxic equivalents (TEQ) has been developed. In this report, toxic equivalents are based on the international toxic equivalents scheme (I-TEQ).

The toxicity of each congener is given a toxic equivalent factor (TEF) rating. The most toxic congener—2,3,7,8-tetrachlorodibenzo-para-dioxin (TCDD)—is rated as 1. Other congeners are rated between 0 and 1, depending on their relative toxicity.

The total toxicity of a sample is calculated in two steps. Firstly, the concentration of each congener in the sample is multiplied by its TEF. Next, the total toxicity is calculated by adding together the contributing toxicity of each congener. This standardises the measurement so it can be used to compare results with other sites and international levels and goals.

Table 2 shows the results obtained from the three monitored areas, expressed as I-TEQs.

**Table 2: Dioxins—toxic equivalents at each site**

| Site | International toxic equivalents – total (fg/m³) | | |
|---|---|---|---|
| | Minimum | Average | Maximum |
| Siding Spring | 0.2 | 0.64 | 2.4 |
| Warrawong | 3 | 10 | 20 |
| Westmead | 2.3 | 14 | 53 |

## 2.4 Comparison with international benchmarks

There are no Australian goals or standards for ambient concentrations of dioxins against which to assess the NSW results. Similarly, there are not many overseas benchmarks known to the EPA. Those goals that are available tend to use a range of different averaging periods and compounds.

Japan has an annual average goal for I-TEQ of 600 fg/m$^3$ (including coplanar polychlorinated biphenyls) (Ministry of the Environment, Government of Japan 1999, www.env.go.jp/en/lar/regulation/aq.html). Ambient air concentrations of dioxins at all measured sites in NSW were well below this goal. The highest mean annual concentration measured in this study (I-TEQ of 14 fg/m$^3$ at Westmead) is only 2.5% of this yardstick.

Ontario, Canada has an ambient (maximum) criterion for dioxins of 5000 I-TEQ fg/m$^3$ over 24 hours (Ontario Ministry of the Environment 1999, *Summary of Point of Impingement Standards*, *Point of Impingement Guidelines* and *Ambient Air Quality Criteria*, www.ene.gov.on.ca/envision/gp/2424e.pdf). Samples in NSW were collected over 12 or 24 days and, while indicative, are not directly comparable with this goal. However, all measured concentrations in NSW were well below these levels. The maximum result measured (an I-TEQ level of 53 $fg/m^3$ at Westmead over a 12-day sampling period) was just 1% of the Canadian goal.

## 2.5 Conclusions

The dioxin samples collected at the three sites over 18 months indicate that, on a regional basis, ambient dioxin levels are low and are in all cases a small fraction of current overseas standards for these substances.

Background levels at Siding Spring are among the lowest of any of the available results reviewed by the EPA and are comparable with those reported in New Zealand and Connecticut, USA. European readings at comparable locations were generally an order of magnitude higher.

The urban-industrial levels measured at Warrawong were lower than at comparable sites in all other places, including New Zealand, Belgium, Germany, Spain and the Netherlands.

The levels of dioxins measured at urban Westmead were similar to those measured in the Netherlands, Sweden and New Zealand, but considerably lower than those in Japan (winter), Belfast in the UK and Cracow in Poland. The Westmead results were well within current international goals.

## 2.6 Management strategies

Strict management and reduction strategies have kept dioxin levels at the three NSW sites low enough by international standards not to pose a credible health risk. Nonetheless, it is important to continue the current strategies and programs to minimise dioxin emissions into the future.

For the past 10 years, in line with international awareness of the environmental risks posed by dioxins, NSW has had a number of strategies to reduce dioxin emissions.

### *EPA measures*

The EPA has a comprehensive regulatory system which limits pollutant emissions from recognised industrial sources. Pollution reduction programs negotiated with licensees eliminate or ensure compliance with current goals for dioxins.

Specific examples of reduction programs and other EPA actions to curb dioxins include the following:

- The sinter plant at BHP’s Port Kembla steelworks has been a major source of dioxin emissions. However emissions have fallen continually over the past 10 years. By using cleaner production approaches, BHP halved dioxin emissions from its stacks in 1997. Since then, pollution reduction programs have cut its emissions a further 15%. BHP’s environment protection licence includes a $93-million plan to reduce dioxin and other pollutant emissions from the sinter plant by the end of 2002.
- The Waverley-Woollahra municipal waste incinerator at Zetland was shut down in 1997, ending its emissions of dioxins and furans. The EPA undertook comprehensive studies of the emissions from the incinerator over several years and negotiated a program to upgrade the facility with the operator. The timetable for upgrading was not met and the EPA revoked the licence for the facility to process waste. An objection by the operator to the revocation was dismissed in the Land and Environment Court, resulting in closure of the incinerator.

- In 1993, sewage sludge incinerators at North Head and Malabar which emitted dioxins were closed. The EPA directed the operator of these incinerators to meet more stringent emission standards because of concerns about their impact on public health. The operator chose to close the facilities rather than meet the revised standards.
- The EPA issued a draft notice to Clinical Waste Australia (CWA) indicating that the licence for its medical waste facility at Silverwater would be amended to set tougher emission limits for dioxin, equivalent to world's best practice. CWA has now committed to achieving a reduction in the amount of waste being burnt at the plant, which will cut dioxin emissions by up to 80% from the site. Approval has been granted by Auburn Council for construction of new plant to house an alternative process for handling the waste.

The EPA also evaluates new industrial developments and reviews the performance of existing facilities which could be a source of dioxins. Where appropriate, it will require reduction and monitoring programs to eliminate or control such sources in line with contemporary international practice.

### *Other industrial changes*

Recent changes in industrial processes, while mostly occurring for other reasons, have also reduced dioxin emissions in NSW.

- As a result of a concerted program of review and decommissioning, all hospital bio-medical waste incinerators in NSW have ceased operation. This has reduced total emissions across the State and removed regional point sources in many country towns.
- The closure by BHP of its sinter plant at the Newcastle steelworks reduced another significant regional source of dioxins.
- In 1998 Orica Australia closed its ethylene di-chloride plant at Botany in Sydney, which had emitted dioxins as a by-product.

### *Motor vehicle controls*

Combustion of leaded petrol in motor vehicles is a source of dioxins. After the introduction of unleaded fuel to NSW in 1986, the proportion of leaded petrol declined; it was phased out completely in January 2002. The removal from sale overseas of leaded fuel has clearly demonstrated a reduction in dioxin emissions from vehicles and this is expected to be repeated in Australia. Diesel vehicles are the remaining problem area for dioxins from road transport.

Hybrid electric vehicles and those which use some alternative fuels, such as compressed natural gas (CNG) and liquefied petroleum gas (LPG), do not emit dioxins. The Government will continue to evaluate and promote, where appropriate, low emission vehicles.

In November 2001 the Government announced the NSW Cleaner Vehicles Action Plan. The plan aims to improve air quality in NSW by reducing fuel consumption, dependence on oil, and greenhouse gas emissions through development of a market for new cleaner vehicle models.

### *Domestic sources*

Domestic behaviour can also have an impact on emissions of dioxins. A combination of regulatory and educational initiatives is being applied to reduce or eliminate domestic sources of dioxins. EPA regulatory controls include:

- banning the use of incinerators in high-rise apartment buildings from 1 September 2001

- banning backyard burning in specific local government areas, particularly in metropolitan areas which face greater problems from smoke pollution
- a review of the Clean Air (Domestic Solid Fuel Heaters) Regulation 1997, which reduced the limit for emissions of solid particles from new heaters from 5.5 to 4 grams per kilogram from July 2001.

EPA education programs have:

- provided practical advice on the correct use of woodheaters to reduce emissions through the environmental guideline *Selecting, Installing and Operating Domestic Solid Fuel Heaters* (EPA 1999) and a woodsmoke website
- promoted the use of better home heating fuels and the phasing out of oil and wood heaters, especially through the Woodsmoke Reduction Program which gives financial assistance to people in Armidale, the Blue Mountains, Cooma, Lithgow, Orange and Tumut who agree to replace old woodheaters with cleaner alternatives (see Section 4.7 for more on the program).

### *National and international initiatives*

In May 2001 Australia signed an international agreement, the Persistent Organic Pollutants Treaty, which requires, among other actions, development of a National Dioxin Program. Australian Environment Ministers, including NSW, recently agreed to such a program which will address these concerns in three stages:

- gather data on sources and bioaccumulation of dioxin
- assess health impacts
- develop a national strategy to manage dioxins based on the findings of the earlier stages.

# 3. ORGANICS

## 3.1 Introduction

Many organic compounds are found naturally but others have industrial or domestic sources. Some have the potential to adversely affect the health of humans or the environment after exposure to airborne concentrations over extended periods. These include some known human carcinogens, such as benzene.

This study measured the ambient or airborne concentrations of 41 volatile organic compounds, including 1,3-butadiene. The sampling and measurement procedure used in the study was US EPA method TO-14.

The TO-14 compounds represent a wide range of recognised 'hazardous air pollutants' (as the US EPA refers to them) plus many of the most significant ozone-depleting substances. This latter group of largely halogenated organics, such as Freon® 11, are known to damage the ozone layer which shields the earth from the sun's ultraviolet radiation. These ozone-depleting substances are of interest as global pollutants; they have been banned or are being phased out under the internationally agreed treaty, the Montreal Protocol.

## 3.2 Project design for organics measurements

The following 10 sites in the Sydney–Newcastle–Wollongong area were surveyed:

- Sydney CBD
- Rozelle, Sydney (inner urban)
- St Marys, Sydney (outer urban)
- Newcastle CBD (regional urban centre)
- Wallsend (lower Hunter)
- Beresfield (lower Hunter)
- Wollongong CBD (regional urban centre)
- Warrawong (Illawarra)
- Kembla Grange (Illawarra)
- Albion Park (Illawarra).

A 24-hour sample was taken every six days at five primary sites: for five years in the Sydney CBD, and at Rozelle and St Marys, and four years in the Newcastle and Wollongong CBDs. The six-day cycle is used so that samples are collected across every day of the week. This data set built on data for the Sydney sites gathered previously, enabling establishment of a baseline which takes inter-annual variability into account.

A supplementary (although less intensive) sampling program was also undertaken in the lower Hunter (Beresfield and Wallsend) and Illawarra (Albion Park, Kembla Grange and Warrawong) regions which confirmed that the Newcastle and Wollongong sites were representative of each region. The data from these five sub-regional sites showed a range of values comparable with those at the primary sites. It should be noted that the sub-regional data is not able to be directly compared with the annual averages used as international benchmarks, because of the shorter sampling period of 3-4 months at a time rather than continuously throughout the year.

Because of the strong association between motor vehicle emissions (including organic air toxics) and the concentration of vehicle numbers, the Sydney CBD site is likely to represent the maximum ambient levels in the Sydney region. The other Sydney sites are generally representative of typical urban ambient concentrations.

## 3.3 Results

Over 1000 samples were collected at the five primary measurement sites. The three Sydney sites were sampled continuously from early 1996 to August 2001, while sampling at the Newcastle and Wollongong sites ran from mid-1997 to mid-2001.

Each sample was analysed for the full range of TO-14 compounds with 1,3-butadiene also measured from mid-1998, following validation of the test method for this compound.

Twelve of the 41 targeted compounds were not detected in any of the samples collected (see Table 3).

**Table 3: Organic compounds not detected**

| | |
|---|---|
| 1,1,2,2-tetrachloroethane | 1,4-dichlorobenzene |
| 1,1,2-trichloroethane | *cis*-1,3-dichloropropene |
| 1,1-dichloroethene | Chlorobenzene |
| 1,2-dibromoethane | Chloroethane |
| 1,2-dichlorobenzene | Freon® 114 |
| 1,2-dichloropropane | *trans*-1,3-dichloropropene |

Of the 29 compounds detected, 10 were rarely encountered, being found in fewer than 1% of the samples taken (see Table 4).

**Table 4: Organic compounds in fewer than 1% of samples**

| | |
|---|---|
| 1,2-dichloroethane | Vinyl chloride |
| 1,3-dichlorobenzene | 1,2,4-trichlorobenzene |
| Chloroform | 1,1-dichloroethane |
| 3-chloropropene | Bromomethane |
| Hexachloro-1,3-butadiene | *cis*-1,2-dichloroethene |

Of the remaining 19 compounds which were detected in more than 1% of samples, most were present at very low levels. Figure 2 shows the source of these organic compounds at the five primary sites of the study.

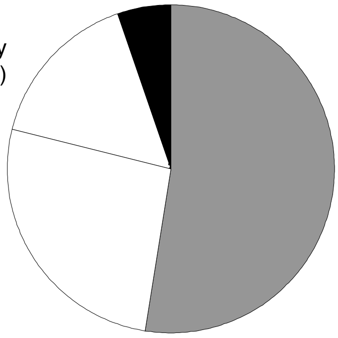


**Figure 2: Likely sources of major organic compounds detected at the five primary sites**

**Table 5: Organic compounds detected at the five primary sites classified by likely source**

| Source | Organic compound |
|---|---|
| **Motor vehicles** | Toluene |
| | Benzene |
| | Xylenes (para and meta) |
| | Xylenes (ortho) |
| | 1,2,4-trimethylbenzene |
| | Ethylbenzene |
| | 1,3-butadiene |
| | 4-ethyltoluene |
| | 1,3,5-trimethylbenzene |
| | Styrene |
| **Ozone-depleting substances** | Freon® (11, 12 and 113) |
| | Carbon tetrachloride |
| | 1,1,1-trichloroethane |
| **Industrial** | Dichloromethane |
| | Trichloroethylene |
| | Tetrachloroethylene |
| **Natural, domestic and industrial** | Chloromethane |

Figure 2 highlights that the majority of these pollutants are generated by motor vehicles. Industry is the primary source of only three of the compounds detected. One compound (chloromethane) is generated from industrial and domestic sources as well as naturally.

While ozone-depleting substances, including chlorofluorocarbons, are the next largest group of organics (after substances sourced from motor vehicles), they are no longer in production or use. The EPA found that the concentrations of these substances were not significantly higher than those at remote sites at Cape Grim (Tasmania) and Alaska.

The highest annual average levels for the 19 organic compounds were found consistently in the Sydney CBD. St Marys, Newcastle CBD and Wollongong CBD had good air quality with respect to organic air toxics. Rozelle had satisfactory average concentrations, although it demonstrated a more pronounced effect from motor vehicle sources.

## 3.4 Comparison with international benchmarks

A comparison of the results against current international goals found no substance exceeded the goals at any time. Only the concentrations at some sites of benzene and 1,3-butadiene came near to reaching the current goals. At all sites the annual average concentrations of benzene were below the UK (2003) goal of 5 parts per billion by volume (ppbV). Even the more stringent long-term European Commission annual average goal of 1.5 ppbV (to be achieved by 2010) was met at all sites, except the Sydney CBD with its heavy traffic. The concentrations of benzene in outer urban Sydney, Newcastle and Wollongong were also well below both of these goals (see Figure 3).

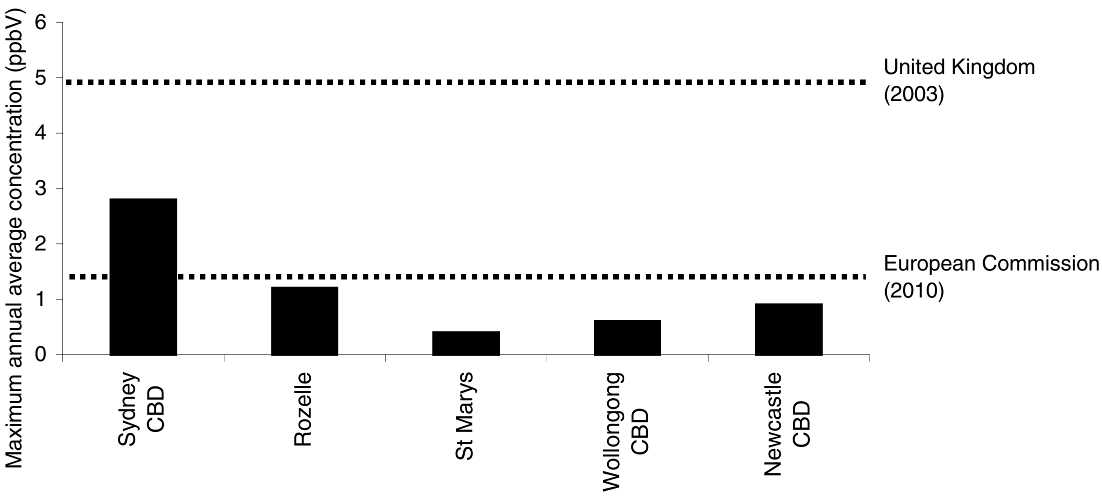


**Figure 3: Highest annual average benzene levels in NSW (1996–2001) compared with future EC and UK goals**

The levels of 1,3-butadiene were below the UK annual average goal of 1 ppbV at all sites. The highest annual average of 0.6 ppbV was also measured at the Sydney CBD site (see Figure 4).

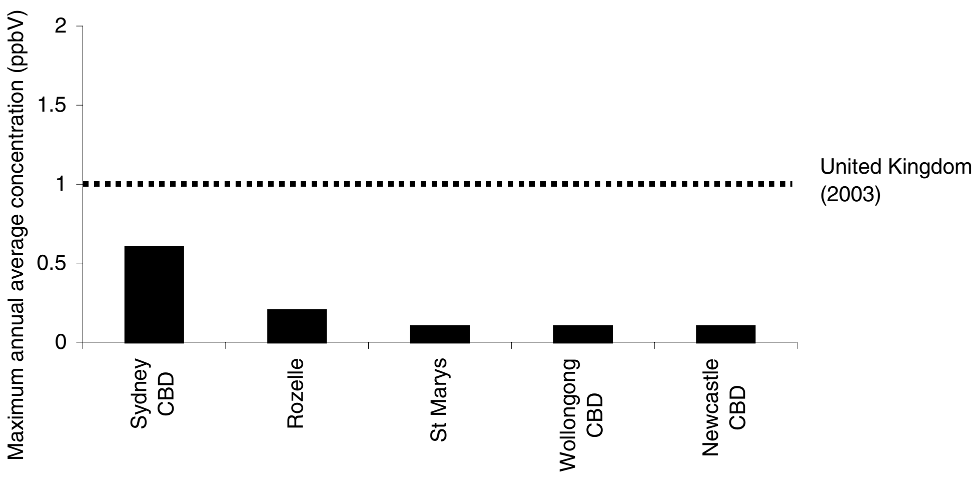


**Figure 4: Highest annual average 1,3-butadiene levels in NSW (1996–2001) compared with future UK goal**

The results for benzene and 1,3-butadiene in this study are broadly consistent with the levels found in comparable overseas locations.

The European Commission goal for benzene is based on fuel control measures which came into effect in Europe in 2000 when a 1% benzene limit in petrol was put in place, allowing a 10-year lead time to achieve the goal. Australia will introduce a 1% benzene limit in 2006.

## 3.5 Conclusions

The annual average concentrations of organic air toxics measured in this study, which were generally representative of urban parts of the Sydney–Newcastle–Wollongong area, were very low. Many of the commonly recognised organic air toxics were not detected in any samples.

The measured levels of those organic air toxics which have current international goals met those goals.

While the results of this study are reassuring about the presence of organic air toxics in major NSW regional areas, the data does not allow for complacency on benzene and 1,3-butadiene. International agencies recognise benzene as a human carcinogen and 1,3-butadiene is categorised as a probable human carcinogen. Health-based recommendations from these agencies suggest that current goals may need to be reduced further to control the risks posed by these two substances.

## 3.6 Management strategies

The EPA's air toxics management strategies focus on controlling sources of benzene and 1,3-butadiene as priorities.

### *Motor vehicles*

As motor vehicles are the major source of benzene (see predicted emissions for a model city in Table 6) and 1,3-butadiene, strategies to reduce the contribution they make are vital. Significant gains to air quality have been achieved by improvements in fuel quality and vehicle emission performance.

**Table 6: Predicted daily releases of benzene within a model Australian urban centre**

| Source of benzene emissions | % |
|---|---|
| Mobile sources, including motor vehicles and watercraft | 79 |
| Industrial sources | 11 |
| Lawnmowers | 6 |
| Service stations | 3 |
| Domestic solid fuel burning | 2 |
| TOTAL | 100 |

**Source:** *Draft Priority Existing Chemical Assessment Report—Benzene*, National Industrial Chemicals Notification and Assessment Scheme, Commonwealth of Australia, June 2001

While Table 6 only models emissions for a model Australian urban centre, actual emissions in Sydney are expected to be similar to these figures.

Motor vehicles are also the major sources of other organic air toxics, such as toluene, xylene, ethylbenzene and styrene. Reducing emissions from motor vehicles will lower levels of these substances as well.

A broad reform program for vehicle performance will reduce these emissions over the next 10 years:

- **Fuel quality standards** (based on European regulations) will reduce emissions from vehicles. From 2006, the benzene content of petrol will be limited to a maximum of 1%, compared with the current legal maximum of 5%. This reduction will have an immediate and sustained impact on ambient benzene levels.
- **New vehicle standards:** European emission standards have been adopted and will dramatically reduce emissions from all new vehicles. The adoption of the European standards started in 2002 for diesel and commences in 2003 for petrol vehicles. Further emission reductions are required for new petrol vehicles from 2005 and new diesel vehicles from 2006. The NSW Government's Cleaner Vehicles Plan will promote the early uptake of vehicles meeting the even more stringent emission standards which will be required in Australia in the medium term, such as Euro 3 and Euro 4.
- **Low volatility program:** The NSW Government has a Memorandum of Understanding with the oil industry to reduce the volatility of petrol during summer. This will result in less evaporation of volatile organic compounds, including benzene. The currently voluntary agreement will be legally formalised as a Regulation to ensure achievement of the desired reductions of volatile organic compounds and consistent compliance across the industry.
- **Emissions testing for cars:** The Roads and Traffic Authority has established two emissions testing stations at Botany and Penrith where owners can have their cars tested on a voluntary basis. The testing provides a short diagnostic report indicating the levels of emissions from each vehicle relative to all vehicles tested to date.
- **Reduced vehicle use:** The Government's *Action for Air* strategy contains a range of programs to address the issue of vehicle use. These include the promotion of appropriate land-use planning and infrastructure development to reduce reliance on motor vehicles and thus overall emissions. Actions agreed to at the Government-sponsored Clean Air Forum in November 2001 will further enhance existing programs. Key actions include the draft State Environmental Planning Policy (SEPP) on Integrating Land Use and Transport and the improvements and enhancements to the public transport system contained in *Action for Transport 2010*.
- **Vehicles using alternative fuels**, such as hybrid electric vehicles and those running on compressed natural gas (CNG) and liquefied petroleum gas (LPG), will also reduce emissions. State Transit has already converted 200 of its buses to CNG in the Sydney region, with 200 more to follow by the end of 2002.

### *Industrial and commercial sources*

Benzene has been eliminated in all but trace amounts in most industrial and domestic chemical products. The main individual industrial sources of benzene and related substances (such as toluene and xylene) are fuel refining, the manufacture of chemicals and combustion in cokeworks at steel plants.

A major element of the EPA's strategy to control recognised industrial emissions from existing sources has been through pollution reduction programs (PRPs) attached to environment protection licences. Standards for new developments have also been strengthened over time as technology and knowledge have improved. Together, these have substantially reduced emissions from point sources.

As one of the largest sources of benzene and other air toxics, BHP's Port Kembla steelworks has been covered by several five-year PRPs to reduce these emissions. This has included a $93-million program to collect and reduce fugitive emissions from the coke ovens and $2 million to control emissions from gas processing. The need for further controls on gas processing will be assessed after studies of emissions monitoring data.

In a comprehensive study in 2000–01, BHP assessed the sources and contribution of air toxics emissions from its Port Kembla steelworks. The study has allowed the identification of priorities for future reduction strategies which are currently being negotiated with BHP.

Oil refineries are another industrial source of benzene and related air toxics. Almost 95% of emissions of benzene from refineries are fugitive or evaporative. Current reduction programs include detection of leaks and their repair to prevent the escape of benzene and other toxics from production processes; licensing fees based on pollutant loads to encourage better performance; and pollution reduction programs as part of environment protection licences.

Emissions from 'fuel marketing' are generally vapours lost from service stations and fuel depots, and transfers to bulk transport, such as road tankers and ships. The Clean Air (Plant and Equipment) Regulation 1997 requires vapour recovery systems to be attached to bulk fuel-handling facilities and Sydney service stations to reduce benzene emissions. The EPA is evaluating further controls on other fuel-handling equipment, such as controls at petrol stations to collect fugitive vapours.

The use of licence fees based on the load of pollutants produced ('load-based licensing' or LBL) will continue to provide a financial incentive for licensed premises to find ways to reduce their emissions. The current LBL regime includes fees for a number of air toxics, such as benzene. The number of air toxics covered by LBL could be extended if necessary.

Current EPA cleaner production and education initiatives aimed at lowering emissions from dry-cleaning premises should reduce localised exposures to the organic air toxic tetrachloroethylene. Similar programs for spray painting and panel repair shops, and the surface coating industry are expected to yield further localised reductions in emissions of toluene and xylene. The fibreglass and composites industries also have a program to lower local exposure to styrene.

The EPA will continue to assess new industrial proposals for compliance with current goals and identify local air toxics issues in conjunction with local councils.

### *Solid fuel heaters*

Benzene is emitted from solid fuel heaters through the combustion of carbon-based fuels, such as wood and coal. Poor combustion is the leading factor in the emission of benzene from these heaters. NSW has a comprehensive program to reduce emissions from solid fuel heaters through a combination of regulation for new heaters and education programs to promote the effective use of existing heaters. Section 4.7 has more about the Woodsmoke Reduction Program.

### *Stratospheric ozone-depleting substances*

Current NSW legislation controls the distribution of ozone-depleting substances by requiring the authorisation of their suppliers and users, and the training and authorisation of those who work on equipment containing them. The legislation also restricts the uses of ozone-depleting substances and makes it an offence for their release to the atmosphere.

The measured levels of ozone-depleting substances are only marginally higher than background levels. This suggests that existing strategies are having the desired effect. All new sources of ozone-depleting substances are being controlled.

# 4. POLYCYCLIC AROMATIC HYDROCARBONS

## 4.1 Introduction

Polycyclic aromatic hydrocarbons (PAHs) are a mixture of organic compounds released into the atmosphere as gases or particles during the incomplete combustion of organic material.

PAHs have a number of sources including:

- mobile—cars, trucks, ships and aircraft
- industrial—power generation, steelworks, coke ovens, aluminium production, cement kilns, oil refining and waste incineration
- domestic—primarily combustion for heating and cooking, especially solid fuel heaters using wood and coal
- fires—burning of vegetation in agricultural processes and bushfires.

The smallest member of the PAH group is naphthalene, a two-ring compound, which is a gas at normal temperatures. Three- to five-ring PAHs occur as either gases or particles in air. PAHs with five or more rings tend to be solids which attach themselves to the surface of other particulate matter in the atmosphere.

Although many different PAHs have been identified,there is limited published toxicological data on them. One of the best characterised and most toxic PAH is benzo(a)pyrene, which is generally used as the indicator PAH. The US EPA has identified 16 priority PAHs, based on concerns that they do or might cause cancer in animals and humans.

## 4.2 Seasonal concentrations of pollution

The focus of the EPA study was to sample during winter when conditions are conducive to higher levels of many pollutants. Some data was also collected in other seasons to test the hypothesis that PAH levels peaked in winter. Several factors contribute to higher concentrations of PAHs in winter:

- There is less mixing in the atmosphere because of stronger and more frequent temperature inversions. As a result, pollutants can be trapped in a shallow layer at ground level. This is often compounded by still conditions, further limiting dispersion of pollutants.
- The use of solid fuel heaters in winter adds to overall emissions.

## 4.3 Project design for PAHs

In winter some parts of Sydney and a number of larger towns in the Great Dividing Range suffer from visibly high levels of smoke associated with solid fuel heating and still weather conditions. The study set out to determine the types and indicative concentrations of PAHs in ambient air in these problem areas with a focus on the predicted winter seasonal peak.

Twenty-two representative sites in the urban areas of Sydney, Newcastle and Wollongong, and selected country regional centres were sampled for PAHs. There were six sites in Sydney, three in or near Newcastle, seven in and around Wollongong plus Nowra to the south, and five sites in the Great Dividing Range (Armidale, Cooma, Lithgow, Tumut, as well as Orange for a shorter sampling period). The last five sites in the Great Dividing Range are all high in altitude, making them very cool in winter with widespread use of solid fuel heaters.

At all sites except Orange, measurements were made once every six days using a high-volume sampler which draws air through a filter paper at a fixed flow rate for 24 hours per sample. (In Orange, sampling occurred over a different period and for 16 hours. The results for this site are therefore reported separately from the others.) The filter papers were then weighed, their contents extracted with solvent and the individual PAHs separated and measured by gas chromatography–mass spectrometry to derive the types of PAHs present and their mass.

The study analysed 11 PAHs present in particulate form, which is how they are usually found after solid fuel combustion. As gaseous PAHs could not be measured using the available technique, the results may underestimate contributions from some mobile sources, such as diesel engines.

A total of 268 samples was collected across the sites between August 1997 and February 2001. The majority of the samples were in winter (201), with the balance spread between summer (47), autumn (6) and spring (14).

Values presented as 'Total PAHs' in this report are the totals of the following 11 PAHs found as particles:

- benzo(a)anthracene
- benzo(a)pyrene
- benzo(b)fluoranthene
- benzo(ghi)perylene
- benzo(k)fluoranthene
- chrysene
- dibenz(ah)anthracene
- perylene
- indeno(123-cd)pyrene
- benzo(e)pyrene
- coronene.

## 4.4 Results

Table 7 (an average of the Sydney, Newcastle and Wollongong sites plus all other sites, except Orange) and Table 8 (Sydney sites) summarise and compare the winter and summer data for each sampling region or point.

Figures 5 and 6 also present these results graphically. The concentrations are reported in nanograms per cubic metre ($ng/m^3$). A nanogram is $1 \times 10^{-9}$ grams or 0.000000001 grams.

**Table 7: Total PAHs (24-hour averages: ng/m³) winter and summer—Sydney, Newcastle and Wollongong sites (average of each group) and all other sites (except Orange)**

| | Nowra | Sydney (average of all sites) | Wollongong (average of all sites) | Newcastle (average of all sites) | Tumut | Cooma | Armidale | Lithgow |
|---|---|---|---|---|---|---|---|---|
| **WINTER** | | | | | | | | |
| Average | 0.92 | 4.47 | 1.71 | 2.68 | 7.16 | 7.68 | 8.62 | 23.8 |
| Max. | 1.67 | 17.5 | 9.62 | 13.0 | 14.7 | 17.7 | 24.0 | 52.3 |
| Samples | 6 | 52 (6 sites) | 59 (7 sites) | 31 (3 sites) | 14 | 13 | 5 | 14 |
| **SUMMER** | | | | | | | | |
| Average | – | 0.62 | 0.62 | 0.56 | 0.82 | 0.33 | 0.28 | 0.69 |
| Max. | – | 1.39 | 1.79 | 2.82 | 2.55 | 0.59 | 0.32 | 1.42 |
| Samples | Nil | 14 (4 sites) | 8 (2 sites) | 11 (3 sites) | 4 | 4 | 2 | 4 |

As the results for all seven Wollongong sites are similar, they are reported as a group average. This is also the case with the Newcastle results. There is greater variability in the results across the six Sydney sites.

The seven samples collected in Orange (all in winter and over a shorter sampling period than other sites) averaged 10.9 ng/m$^3$ with a maximum of 30.7 ng/m$^3$. These results were higher than the levels in Armidale, Cooma and Tumut but lower than those in Lithgow.

**Table 8: Total PAHs (24-hour averages: ng/m³) winter and summer—Sydney sites**

| | Richmond | Lindfield | Rozelle | Blacktown | Sydney CBD | Earlwood |
|---|---|---|---|---|---|---|
| **WINTER** | | | | | | |
| Average | 1.56 | 3.59 | 3.97 | 4.29 | 7.17 | 7.35 |
| Max. | 3.07 | 13.2 | 11.4 | 14.3 | 14.3 | 17.5 |
| Samples | 8 | 12 | 8 | 10 | 4 | 10 |
| **SUMMER** | | | | | | |
| Average | 0.22 | – | 0.80 | 0.67 | – | 0.97 |
| Max. | 0.29 | – | 1.39 | 0.92 | – | 1.30 |
| Samples | 4 | Nil | 4 | 4 | Nil | 2 |

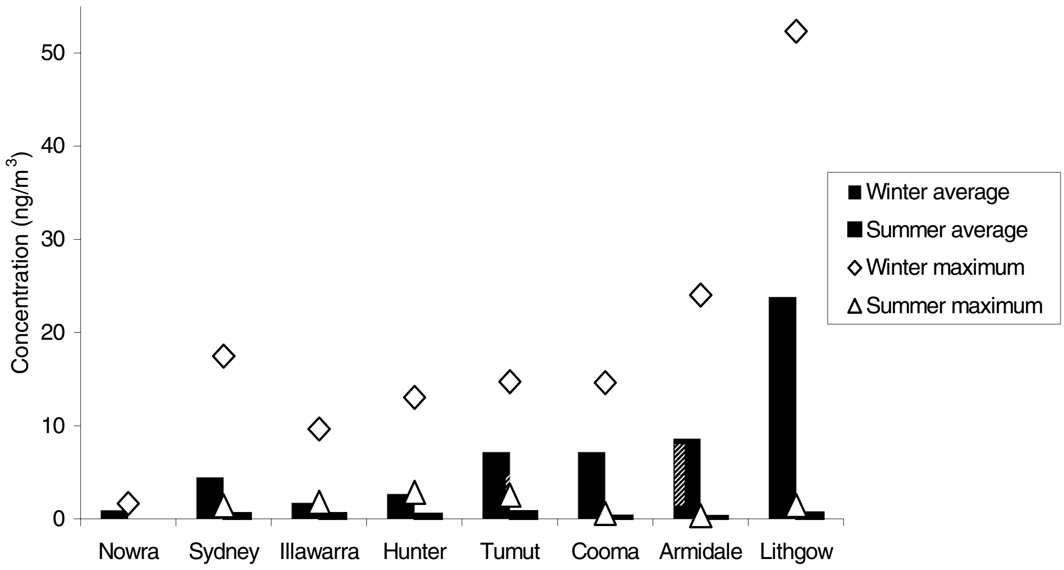


**Figure 5: Seasonal variations in PAHs (24-hour averages: ng/m$^3$)—Sydney, Newcastle and Wollongong sites (average of each group) and all other sites (except Orange)**

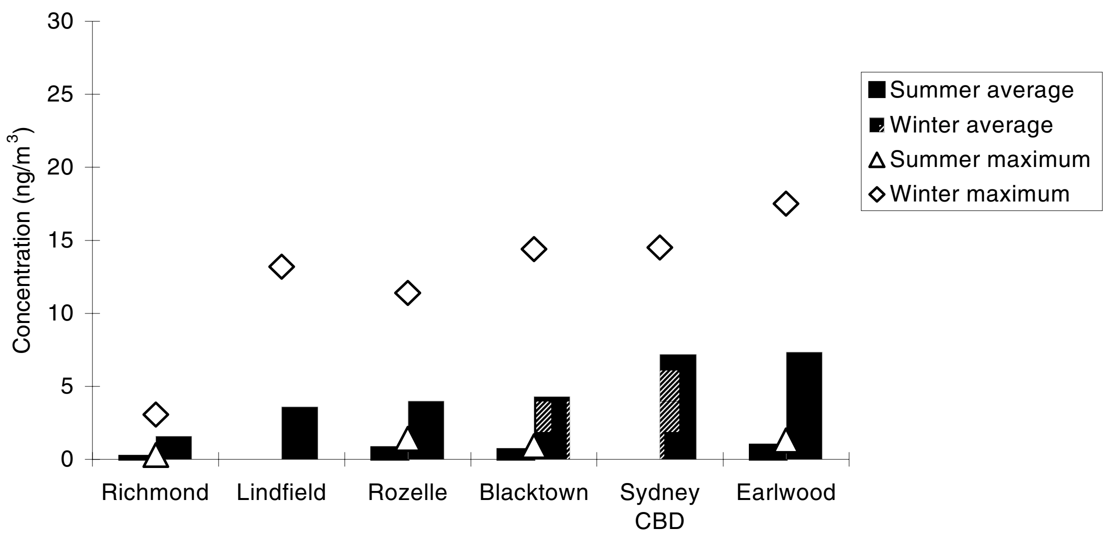


**Figure 6: Seasonal variations in PAHs (24-hour averages: ng/m$^3$)—Sydney sites**

Given the study's focus on winter and the limited data from other seasons, only general comparisons are possible between seasons. Overall, the average winter PAH values were between 2 and 10 times higher than the summer samples at coastal urban sites, but between 8 and 35 times higher in the colder Great Dividing Range locations.

Average winter PAH concentrations in Lithgow were high: two to three times those in other Great Dividing Range towns. From observations in the field this is suspected to be a result of the greater use of coal for heating and cooking during the colder months and localised meteorological conditions.

Although there were only a few measurements in autumn (Armidale: 1; Tumut: 5) and spring (Lithgow: 8; Tumut: 6), they were much lower than winter levels of PAHs, consistent with the interpretation that the major source in the colder months is the burning of solid fuels, mostly for home heating.

## 4.5 Comparison with international benchmarks

In general, no ambient air quality standards have been set for PAHs. However, proposals and guidelines have been developed for the PAH, benzo(a)pyrene (BaP), in Europe. The UK has proposed an annual average goal of 0.25 ng/m$^3$ for BaP from 2010. The European Commission is also considering a proposal for a BaP goal of between 0.5 and 1.0 ng/m$^3$ to be implemented in 2005.

The UK goal was based on research which indicated:

- the relative proportion of BaP in total PAH for each sample does not vary greatly
- BaP is currently estimated to be the most toxic of the common PAH compounds and, even though found in modest concentrations, is the largest contributor to overall toxicity.

BaP is therefore used as a surrogate measure for total PAH and the numerical value of the goal reflects this.

Sampling in this study was primarily in winter rather than throughout the year, which makes direct comparison with the available international goals difficult because they are expressed as annual average concentrations.

To facilitate comparison with the proposed international standards for benzo(a)pyrene, Tables 9 and 10 report the BaP results from the study.

**Table 9: Total BaPs (24-hour averages: ng/m$^3$) winter and summer—Sydney, Newcastle and Wollongong sites (average of each group) and all other sites (except Orange)**

| | Nowra | Sydney (average of all sites) | Wollongong (average of all sites) | Newcastle (average of all sites) | Tumut | Cooma | Armidale | Lithgow |
|---|---|---|---|---|---|---|---|---|
| **WINTER** | | | | | | | | |
| Average | 0.07 | 0.46 | 0.16 | 0.30 | 1.12 | 1.12 | 1.30 | 4.21 |
| Max. | 0.07 | 2.25 | 1.21 | 1.92 | 3.06 | 3.02 | 3.77 | 8.99 |
| Samples | 6 | 52 (6 sites) | 59 (7 sites) | 31 (3 sites) | 14 | 13 | 5 | 14 |
| **SUMMER** | | | | | | | | |
| Average | – | 0.03 | 0.03 | 0.06 | 0.09 | 0.03 | 0.02 | 0.03 |
| Max. | – | 0.07 | 0.07 | 0.40 | 0.27 | 0.04 | 0.02 | 0.07 |
| Samples | Nil | 14 (4 sites) | 8 (2 sites) | 11 (3 sites) | 4 | 4 | 2 | 4 |

The seven Orange samples (collected over a shorter period than the other sites and over winter) found an average BaP result of 1.45 ng/m$^3$ and a maximum of 4.34 ng/m$^3$.

**Table 10: Total BaPs (24-hour averages: ng/m³) winter and summer— Sydney sites**

| | Richmond | Lindfield | Rozelle | Blacktown | Sydney CBD | Earlwood |
|---|---|---|---|---|---|---|
| **WINTER** | | | | | | |
| Average | 0.14 | 0.39 | 0.38 | 0.43 | 0.77 | 0.76 |
| Max. | 0.32 | 1.67 | 1.35 | 1.92 | 1.68 | 2.25 |
| Samples | 8 | 12 | 8 | 10 | 4 | 10 |
| **SUMMER** | | | | | | |
| Average | 0.02 | – | 0.05 | 0.04 | – | 0.02 |
| Max. | 0.02 | – | 0.07 | 0.07 | – | 0.02 |
| Samples | 4 | Nil | 4 | 4 | Nil | 2 |

Figure 7 presents the BaP winter and summer averages for an average of the Sydney, Newcastle and Wollongong sites plus all other sites, except Orange. Figure 8 shows the BaP winter and summer averages for each of the Sydney sites.

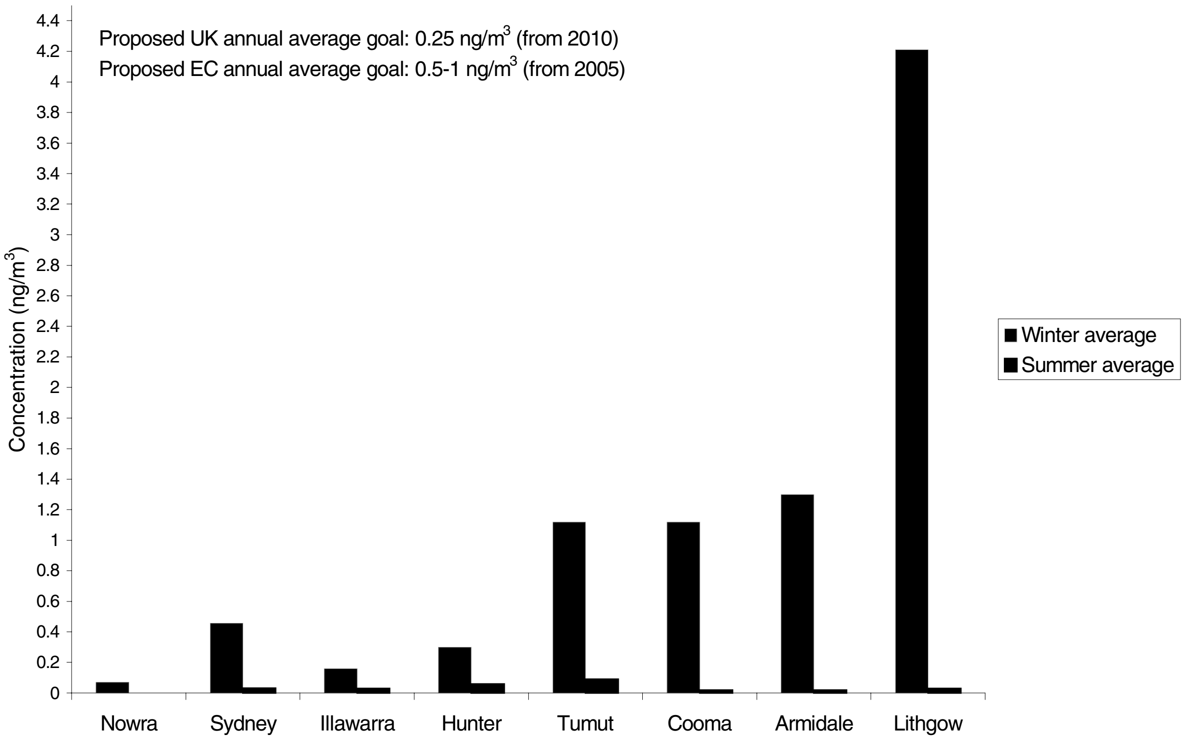


**Figure 7: Seasonal variations in BaP—Sydney, Newcastle and Wollongong sites (average of each group) and all other sites (except Orange)**

It is worth noting that the emissions at the Armidale, Cooma, Lithgow and Tumut sites comprised a relatively higher proportion of BaP compared with the city sites. This is consistent with the use of solid fuel heaters in these areas, although BaP is not exclusively produced by these appliances.

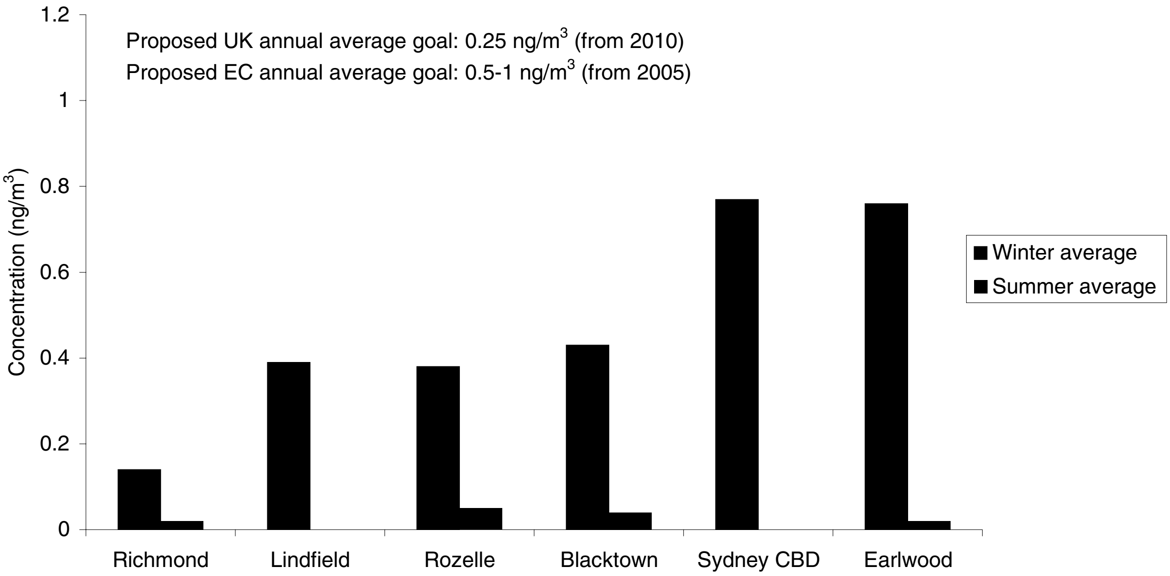


**Figure 8: Seasonal variations in BaP—Sydney sites**

## 4.6 Conclusions

Most of the NSW data was collected in winter, which showed the highest PAH readings compared with the lower concentrations in autumn and spring and the very low concentrations of summer. An annual average measure at each site (the standard favoured overseas) is therefore expected to be between a quarter and a half of the winter concentration found in the study.

The suggested overseas goals for annual average concentrations of BaP range from 0.25 $ng/m^3$ (UK proposed by 2010) to a 2 $ng/m^3$ standard for a 'limit' value in Croatia. In between, the European Commission is considering setting a standard between 0.5 and 1.0 $ng/m^3$ for 2005, with indications that it is likely to be towards the higher end of that spectrum.

Assuming, as suggested above, that an annual average reading would be one-quarter to one-half of the current winter average at each of the NSW sites, all of them except Lithgow would meet a standard of 1 $ng/m^3$. Most would probably meet a standard of 0.5 $ng/m^3$; and the Sydney CBD, Earlwood and some Great Dividing Range sites would fail only the toughest standard of 0.25 $ng/m^3$.

On existing knowledge, it is likely that emissions in the Sydney CBD are primarily from motor vehicles with some contribution from woodsmoke. The Earlwood site is located at the bottom of a valley where temperature inversions are likely to trap air, carrying emissions from both vehicles and woodheaters, especially in winter. Both of these sites, while estimated to have BaP levels in the vicinity of the more stringent international goals, will benefit in the short to medium term from improvements in vehicle emissions and programs to reduce smoke from woodheaters.

The general conclusion on some regional NSW centres, Lithgow in particular, is that concentrations of PAHs are elevated and ongoing action is required to reduce those emissions.

The EPA will continue to review progress in international standards to determine whether additional action needs to be taken.

## 4.7 Management strategies

### *Domestic sources*

This report clearly indicates that reducing emissions from solid fuel heaters is a high priority in some higher altitude regional centres in the Great Dividing Range with topography that tends to collect air for long periods.

These emissions have already been tackled on a number of fronts. A revised Australian Standard adopted in NSW sets emission limits for particles from new solid fuel heaters. Lower particle emissions will lead to a proportional reduction in emissions of PAHs. This standard has been formally adopted in the Clean Air (Domestic Solid Fuel Heaters) Regulation 1997.

The NSW Government has committed $1 million to the Clean Air Fund in 2002 to reduce smoke in the regional areas identified in the study as having high levels of pollution: Armidale, Cooma, Lithgow, Orange and Tumut (plus the Blue Mountains). Under the program, home owners and businesses are offered a financial incentive to replace older, more polluting heaters with new, cleaner alternatives. The program is also supporting local council education and enforcement programs to ensure heaters are operated properly and do not emit excessive smoke.

The Government has actively promoted better use of solid fuel heaters through education campaigns, including publication of the EPA 1999 guideline, *Selecting, Installing and Operating Domestic Solid Fuel Heaters*. Other education programs include 'Don't light tonight, unless your heater's right' alerts when weather conditions threaten the dispersal of particle pollution in the metropolitan region; screening of information on better operation of heaters on regional television; and a comprehensive website on woodsmoke.

Under State planning legislation, local councils are able to tailor local planning instruments to prevent or restrict the installation of solid fuel heaters. Pittwater and Waverley Councils have recently amended their Development Control Plans and Local Environmental Plans to restrict the installation of new heaters in their local areas. Other councils, such as Blue Mountains, Eurobodalla, Rockdale and Wollongong have published revised local approvals policies which clearly specify their requirements for installing heaters.

Local councils are also able to prevent owners allowing their heaters to emit excessive smoke by issuing notices under the *Protection of the Environment Operations Act 1997*. In 2001, Armidale Dumaresq Council actively promoted its capacity and willingness to use these notices at times when householders ignore council requests for better operation of woodheaters. The council has reported some improvements in local air quality as a result of this program.

A review of the Clean Air (Domestic Solid Fuel Heaters) Regulation 1997 is considering giving councils additional powers to issue on-the-spot fines for poor operation of solid fuel heaters.

The effectiveness of this comprehensive program on solid fuel heaters will continue to be monitored to determine whether additional initiatives are needed to achieve the necessary reductions in woodsmoke and associated PAHs. The incentive scheme for the replacement of solid fuel heaters will be specifically reviewed in late 2002 to evaluate its effectiveness and consider whether to extend the program to other local government areas.

### *Mobile sources*

A number of strategies to reduce emissions of organic pollutants from mobile sources are also effective in reducing emissions of PAHs. Those that will have a direct impact on PAHs are:

- New **vehicle emission standards** will mean vehicles will have to meet tighter performance targets for a range of pollutants (which will also lead to reductions in PAHs). For many vehicles, new-generation catalysts will be required, which will reduce emissions of PAHs. The most significant improvement will be lower emissions from diesel vehicles. To meet these standards, many vehicles will require catalysts or particulate traps which will reduce emissions of PAHs as particles.

  As vehicle technology gradually improves and the vehicle fleet turns over, older more polluting vehicles will travel less and gradually make a smaller overall regional contribution to emissions. This effect will be particularly significant as pre-1986 cars without catalytic converters disappear from the road.

- **Fuel quality standards:** Some of the PAHs in diesel exhaust are a consequence of the PAH content of the fuel. New fuel regulations will set limits on total aromatic content of diesel fuel from 1 January 2006, which will in turn reduce PAH emissions across the whole fleet and not only new vehicles.

- The **Diesel National Environment Protection Measure** (NEPM) has outlined strategies for the States to follow to reduce emissions from diesel vehicles. While PAHs are not explicitly targeted, diesel vehicles are known to be a significant source of many air toxics and so programs to reduce diesel emissions will lead to a commensurate reduction in PAHs. Regular testing of all diesel buses in the State Transit fleet has begun and those that do not meet emission standards, according to respective bus type and age, are repaired.

Some of the vehicle-related benefits will be undermined if vehicle use increases. The Government's *Action for Air* and *Action for Transport 2010* strategies include a range of measures to reduce vehicle use.

The EPA smoky vehicle enforcement program is an effective way of reducing the number of smoky vehicles on the road and thus associated PAH emissions. The EPA receives over 700 reports from the public each month on smoky vehicles. Since early 2002 it has been possible to report smoky vehicles via the EPA website.

### *Industry*

PAHs are usually generated as a by-product of the incomplete combustion of organic material. The EPA regulates PAHs by controlling the effectiveness of combustion processes, as indicated by the carbon monoxide or particle emissions they produce. By controlling these pollutants, the PAHs produced are also controlled. Where an industrial process is particularly associated with PAH emissions, a specific monitoring program may be required to confirm that emission levels are acceptable.

Similarly, pollution reduction programs to capture and control emissions of particles and organic compounds will also reduce PAHs. The reduction programs described in Section 3.6 ('Industrial and commercial sources') have resulted in significant reductions in PAH emissions, as borne out by ambient monitoring by BHP of four sites at Port Kembla since 1989.

### *Flexible controls on open burning*

The revised Clean Air (Control of Burning) Regulation was gazetted in September 2000 to control burning in the open and incinerators. The key features of the Regulation are:

- a focus on controlling what is burnt—councils can choose to regulate all burning or allow burning of vegetation or waste in parts of their areas
- bans on home-unit incinerators from 1 September 2001

- increased penalties for burning offences

Authorised bushfire hazard reduction burning is exempt from this Regulation.

The EPA may also issue ‘no burn’ notices under section 133 of the *Protection of the Environment Operations Act 1997* to prohibit or control burning. Section 133 notices are generally issued when forecast weather conditions are likely to result in high pollution levels. The EPA liaises with the Rural Fire Service before issuing any notices and provides exemptions to allow strategically important hazard reduction burns to proceed during these no burn periods.

# 5. HEAVY METALS

## 5.1 Introduction

Unlike many organic compounds, the heavy metals considered in this part of the study are primarily sourced from industrial processes. The 12 metals studied were:

- antimony*
- arsenic*
- beryllium*
- cadmium*
- cobalt*
- copper
- lead*
- manganese*
- nickel*
- selenium*
- vanadium
- zinc.

Eleven metals have been nominated as ‘hazardous air pollutants’ by the US EPA and nine of these (marked with an asterisk above) were included in the group of metals in the study. The other two US EPA metals (mercury and chromium VI) were not included as they could not be analysed by the method used here. Three other metals—copper, vanadium and zinc—were also analysed.

## 5.2 Project design for metals

This was a limited study designed to determine regional concentrations of these metals and to indicate if any further work is warranted.

Samples were collected for a total of four days from mid-August to early September 2000, when concentrations were expected to be high because of the still weather conditions. Particles up to 10 micrometres in diameter (known as ‘$PM_{10}$’) were collected and analysed.

Samples were collected over 24-hour periods using a high-volume sampler with a $PM_{10}$ inlet on a one-day-in-six cycle. This technique draws air through a pre-weighed filter paper at a fixed rate for the 24 hours. The filter papers were recovered, reweighed, a portion digested in nitric acid and the digested sample sent to the CSIRO for analysis by inductively coupled plasma–mass spectroscopy to determine the concentration of each target metal.

There were eight measuring sites in the Sydney–Newcastle–Wollongong area:

- Sydney CBD
- Rozelle
- Earlwood
- Blacktown

- Richmond
- Newcastle CBD
- Wollongong CBD
- Albion Park.

## 5.3 Results

Within the limited scope of this study, the measured levels of all metals were low and generally below recognised international goals, although direct comparison with annual goals was not possible.

All results (Table 11) are reported as nanograms per cubic metre (ng/$m^3$) where 1 nanogram is 1 x $10^{-9}$ grams or 0.000000001 g. They showed that:

- beryllium was below the limit of detection at all sites
- cadmium, cobalt and selenium were detected at 1 ng/$m^3$ or less at all sites
- antimony and arsenic were detected at less than 5 ng/$m^3$ at all sites
- the remaining six metals—copper, lead, manganese, nickel, vanadium and zinc—accounted for over 95% of the total metal concentration at any site.

## 5.4 Comparison with international benchmarks

There are few international goals for heavy metals against which the levels found in the study can be compared. The World Health Organization's *Air Quality Guidelines for Europe* (2nd Edition, 1996) and the European Commission's draft standards for certain heavy metals are all based on annual averages, i.e. the average of all 24-hour samples collected over one year. Given the different sampling used in this study, only general inferences are possible.

Table 11 compares the study data with those international goals available. For beryllium, an assessment based on available US EPA risk factors was used rather than a goal.

None of the metals sampled exceeded international goals where they existed and many were well below those goals.

The mean 24-hour results shown in Table 11 are likely to be high readings for these heavy metals. This is because the data collected for the study was sampled during winter when regional concentrations of air-borne heavy metals are thought to be elevated. As a consequence, annual average concentrations calculated from data across the whole year are likely to be lower than these readings and below current (annual average) international goals.

**Table 11: Heavy metals—Study results and internationally recognised goals**

| Metal | Mean of samples (24-hour: ng/m$^3$) | Range of samples (24-hour: ng/m$^3$) | Ambient air goals (annual average: ng/m$^3$) | Source |
|---|---|---|---|---|
| Antimony | 1.2 | 0.04–4.6 | None available | |
| Arsenic | 0.6 | 0.1–2.5 | 1–20 | EC[1] |
| Beryllium | ND | ND | 0.4 | US EPA |
| Cadmium | 0.18 | 0.03–1.0 | 0.5–15 | EC[1] |
| Cobalt | 0.19 | 0.10–0.39 | None available | |
| Copper | 8.2 | 2.4–28 | None available | |
| Lead | 29.9 | 3.4–99 | 500 | NEPM[2] & WHO[3] |
| Manganese | 18.0 | 4.4–119 | 150 | WHO[3] |
| Nickel | 3.6 | 1–20 | 3–50 | EC[1] |
| Selenium | 0.2 | 0.10–0.65 | None available | |
| Vanadium | 2.6 | 0.16–49 | 1000 (daily average) | WHO[3] |
| Zinc | 32.6 | 11–71 | None available | |

ND: not detected

[1] European Commission goals are proposals only and a range of values is under discussion.

[2] NEPM: This is the Australian goal for lead set in the National Environment Protection (Ambient Air Quality) Measure.

[3] WHO: World Health Organization goals are based on guidelines for the risk of health impacts.

## 5.5 Conclusion

For the heavy metals which have ambient goals, none was likely to exceed the corresponding goals.

Beryllium was not detected in any samples.

There are no relevant international ambient air goals for cobalt and selenium, but the results for these metals were at very low levels (< 1 ng/m$^3$) and, given their relatively low toxicity, they should not represent a concern at a regional level. Similarly antimony, copper and zinc do not have relevant international ambient air goals, but the measured concentrations of these relatively low-toxicity metals was low.

All samples for lead, manganese and vanadium were well below current Australian and international goals. Although conforming with appropriate goals, the maximum manganese concentration in Newcastle was elevated (119 ng/m$^3$), compared with other sites. It is thought that these levels are associated with dust containing manganese from remediation of the former steelworks site next to the monitoring site. There will be further investigation to confirm the source of these emissions.

The measured concentrations of arsenic, cadmium and nickel were lower or at levels comparable with current international goals. These results are consistent with overseas measurements.

## 5.6 Management strategies

The study shows that heavy metals do not pose a regional air quality problem in NSW but strategies to target specific local point sources should continue to ensure that this performance is maintained.

The risks to public health from lead have been well established. The NSW Government introduced unleaded petrol in 1986 and leaded petrol was phased out completely in January 2002. This has dramatically reduced ambient lead levels, as demonstrated in the study, where the maximum lead level was one-fifth of the national goal and the average level approximately one-twentieth of the national goal.

Future concerns about lead arise from potential exposure in homes from lead-based paints and education campaigns are continuing to ensure that the community is aware of those risks and how to manage them.

Given that this study indicates that regional levels of these metals are not a concern, the EPA will examine options for identifying individual industrial sources of emissions and explore opportunities for emission reduction programs at those sites.