NSW GOVERNMENT

Advisory Committee on Tunnel Air Quality

TP02: Air Quality Trends in Sydney

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Summary

- In the Sydney region carbon monoxide, nitrogen dioxide, sulfur dioxide and lead concentrations are consistently well below national standards.
- Ambient levels of ozone and particles can exceed national standards in the Sydney region, with no definite downward trend in the concentrations of these pollutants apparent.
- Total emissions of ozone precursors and particles have decreased in Sydney over the last decade despite the growth in vehicle activity, energy consumption, population and the economy.
- Reductions in on-road mobile source emissions have been significant over the last decade due to improved fuel quality and more stringent vehicle emission standards.
- Despite reductions in vehicle emissions, transport remains a major source of air pollution in Sydney, being the largest source of oxides of nitrogen and carbon monoxide emissions and contributing significantly to total emissions of volatile organic compounds and fine particles.
- Regional modelling for Sydney has indicated that the pattern of motor vehicle emissions is a major factor determining the timing and peak of ozone concentrations in the region.
- The NSW air quality monitoring network operated by the Office of Environment and Heritage (OEH) is located to meet the requirements of the National Environment Protection (Ambient Air Quality) Measure (AAQ NEPM). The purpose of the network is to measure air quality that is representative of that experienced by the general population rather than peak pollution near an industrial site or busy road.

1. Introduction

Motor vehicle emissions are a major source of urban air pollution, with exposure to air pollution linked to a range of health outcomes. Pollutants released include carbon monoxide (CO), oxides of nitrogen (NO_x), volatile organic compounds (VOCs), fine particles and sulfur dioxide (SO_2), with NO_x and VOCs interacting to form ozone (O_3).

The NSW Office of Environment and Heritage (OEH) was asked to provide a technical briefing paper on air quality related trends in Sydney to inform the deliberations of the Advisory Committee on Tunnel Air Quality. The paper is intended to provide an overview of ambient air quality statistics and issues for the Sydney metropolitan area so as to place vehicle emissions within the broader urban context. The scope of the paper was requested to include: air quality trends and projections for criteria pollutants (CO, NO_2, O_3, PM_{10}, SO_2, lead); overall trends in emissions and relative contributions of motor vehicle emissions; and to discuss differences in roadside and urban air pollution levels if such analysis is supported by available monitoring data.

Air quality and emission trends are described in Section 2 and 3 respectively, with reference made to monitoring data from OEH's ambient air quality monitoring network and air emissions inventory data published by the NSW Environment Protection Authority (EPA). The air quality monitoring network operated by OEH does not specifically include roadside monitoring.

2. Air quality in Sydney

Sydney is the largest metropolitan region in NSW, accommodating over 60% of the State's total population (ABS, 2011). The major urban areas are characterised by high population density, high traffic volumes, several industrial facilities and numerous social and economic activities. Pollutants emitted from major urban centres have a potential to impact the entire airshed, posing adverse health risks to both humans and ecosystems (EPA, 2012 a and b). This paper gives a brief summary of air quality trends in Sydney, aiming to provide an indication of the state of urban atmospheric pollution in NSW.

2.1. OEH air quality monitoring

To help protect the health of the Australian population, the National Environment Protection (Ambient Air Quality) Measure (AAQ NEPM) sets national ambient air quality standards for six criteria pollutants: ozone (O_3), carbon monoxide (CO), nitrogen dioxide (NO_2), sulphur dioxide (SO_2), particles (as PM_{10}) and lead (Pb) as well as an Advisory Reporting Standard for $PM_{2.5}$ (Table 1). The AAQ NEPM also prescribes the characteristics and operations of ambient air quality monitoring stations – in particular, the air quality 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".

The AAQ NEPM criteria pollutants have been measured in the Sydney basin continuously since the early 1990s. However, lead monitoring ceased in 2004, as ambient lead levels have fallen well below the national standard due to the phasing-out of lead in in the formulation of petrol (EPA, 2012b). The NSW OEH operates a network of around 40 air quality monitoring stations across the State. There are currently 15 monitoring stations across the Sydney region (Figure 1). These stations are located (as per the AAQ NEPM requirements) to record air quality data representative of that experienced by the general population within the region. The data are recorded continuously and available to the public online near real-time.

OEH does not conduct roadside monitoring within the ambient air quality monitoring network. It is therefore not possible to distinguish clearly between roadside and urban background concentrations based on data from this network.

In general, air quality in Sydney is comparable with other Australian cities, and is relatively good if compared with other urban regions overseas. Concentrations of CO, NO_2, SO_2 and Pb are low and stable, and consistently meet the national air quality standards. However, ozone and particle (PM_{10} and $PM_{2.5}$) levels can exceed the national standards from time to time locally or across the region (see Table 1), posing pollution-related health risks to local communities as well as the environment.

2. Air quality in Sydney

Figure 1: Locations of OEH operated air quality monitoring stations in the Sydney region.

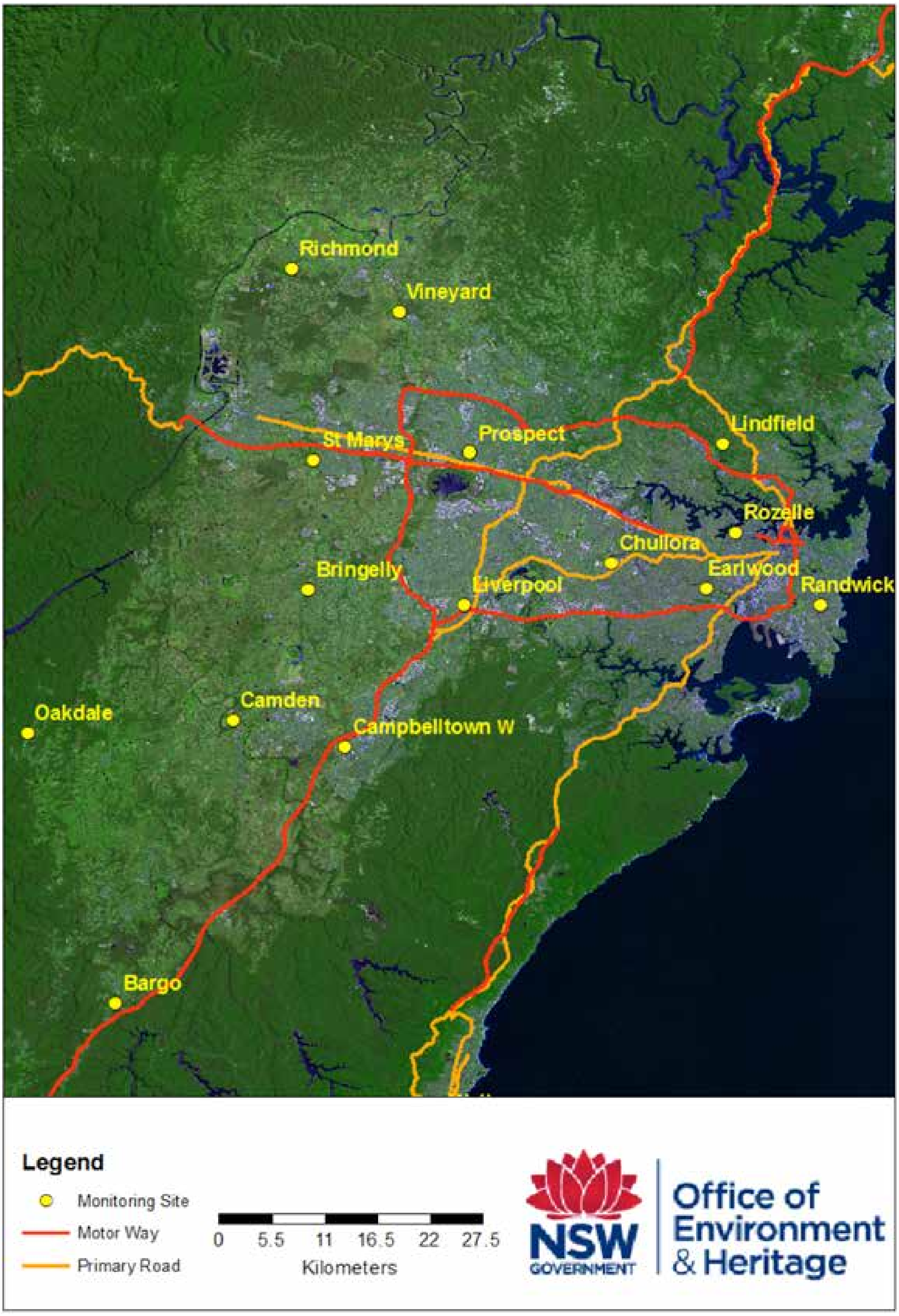


Table 1: AAQ NEPM air quality standards along with maximum ambient air pollutant concentrations in 2012.

Pollutant	Averaging period	Standard	Maximum concentration in 2012	% of the Standard
Carbon Monoxide (CO)	8 hours	9.0 ppm	2.2	24
Nitrogen Dioxide (NO_2)	1 hour	0.12 ppm	0.062	52
	1 year	0.03 ppm	0.013	43
Sulphur Dioxide (SO_2)	1 hour	0.20 ppm	0.025	13
	1 day	0.08 ppm	0.005	6
	1 year	0.02 ppm	0.001	5
Photochemical oxidants (as ozone O_3)	1 hour	0.10 ppm	0.095	95
	4 hour	0.08 ppm	0.084	105
Particles as PM_{10}(b)	1 day	50 µg/m^3	99.2	199
Particles as $PM_{2.5}$(b)	1 day	25 µg/m^3(a)	116.7	467
	Annual	8 µg/m^3(a)	8.5	107

(a) AAQ NEPM Advisory Reporting Standard – the NEPM purpose is to collect sufficient $PM_{2.5}$ data to develop national standards.

(b) PM_{10}: particles smaller than 10 micrometres in diameter; $PM_{2.5}$: particles smaller than 2.5 micrometres in diameter.

2. Air quality in Sydney

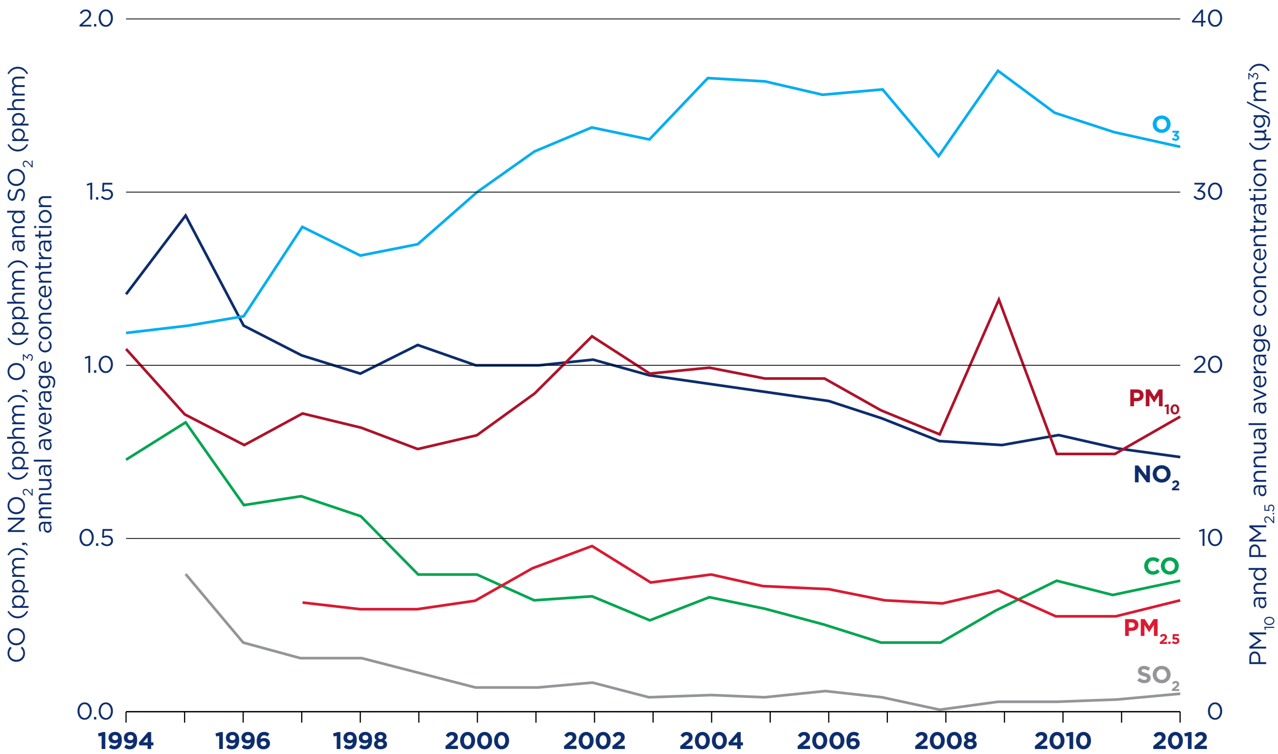
2.2. Long-term trends

Air quality in Sydney has improved significantly since the 1980s with initiatives to reduce emissions implemented across industry, business, homes and motor vehicles. Annual average CO, NO_2 and SO_2 concentrations have declined between 1995 and 2008, with little change in SO_2 and NO_2 since 2009 and a slight increase in CO (Figure 2).

Annual average O_3 concentrations increased from 1994–2004 but have remained stable in subsequent years. Particle concentrations ($PM_{2.5}$ and PM_{10}) show large year-to-year variation in response to annual changes in weather, bushfires and dust storms with no clear long-term trends apparent.

Given that concentrations of O_3 and particles in Sydney can, and possibly continue to, exceed the national standards (Section 2.1), and show no discernible downward trend, further discussion of these pollutants is provided in the next two sections (Sections 2.3 and 2.4).

Figure 2: Maximum annual average pollutant concentrations recorded at the monitoring stations in Sydney during 1994–2012.



2.3. Particles

Particle pollution varies significantly from year to year (Figure 3). High PM_{10} and $PM_{2.5}$ levels are typically recorded during years affected by large bushfires or dust storm events, such as bushfires in 2001–2003 and state-wide dust storms in September 2009. Local sources such as hazard reduction burns, industrial and construction activity, and wood heater emissions can also result in higher particle levels at some monitoring sites.

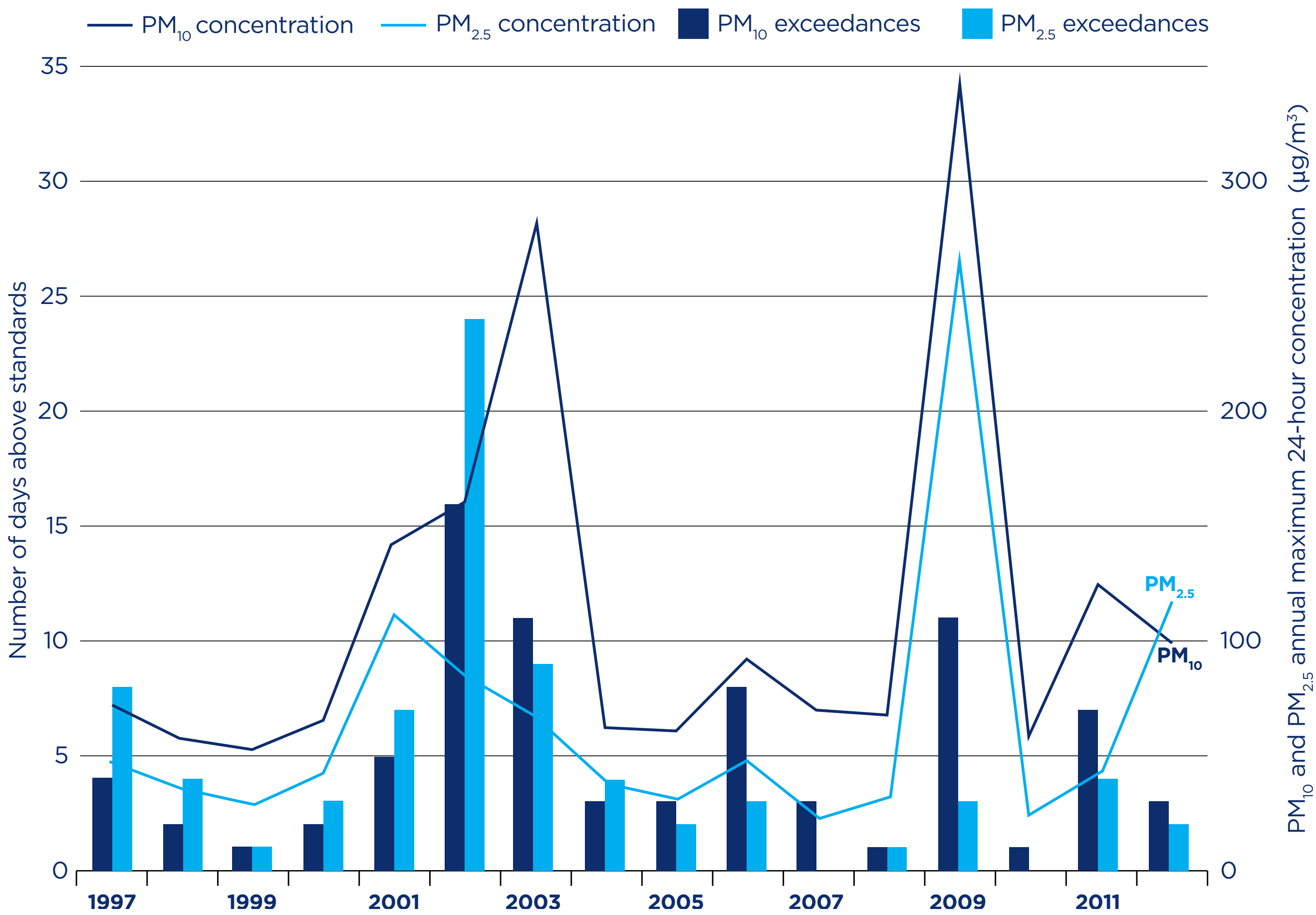
2.4. Ozone

Ozone is formed in the lower atmosphere when a number of "precursor" compounds, mainly oxides of nitrogen (NO_x) and volatile organic compounds (VOCs), react in warm, sunny conditions. Factors affecting ozone concentrations in Sydney include changes to precursor emissions, meteorological conditions and changes in background ozone concentrations.

Ozone is typically higher during the warmer months with peak levels in Sydney occurring during the ozone season of November to March. Since 1994, ozone concentrations in Sydney have exceeded the 1-hour standard on up to 17 days per season, with the 4-hour standard exceeded on up to 21 days (Figure 4). Poor ozone days peaked for both standards during the 1997/1998 season. In general, the year-to-year variations in 1-hour and 4-hour exceedences follow a similar pattern.

Trends in ozone concentrations are difficult to distinguish from large interannual variations in

Figure 3: PM_{10} (a) and $PM_{2.5}$ (b) maximum 24-hour average concentrations and numbers of days exceeding national 24-hour standards in Sydney



(a) The AAQ NEPM permits maximum allowable exceedences of the PM_{10} standard of 5 days per year.

(b) Air NEPM Advisory Reporting Standard – the NEPM goal is to collect sufficient $PM_{2.5}$ data to develop national standards.

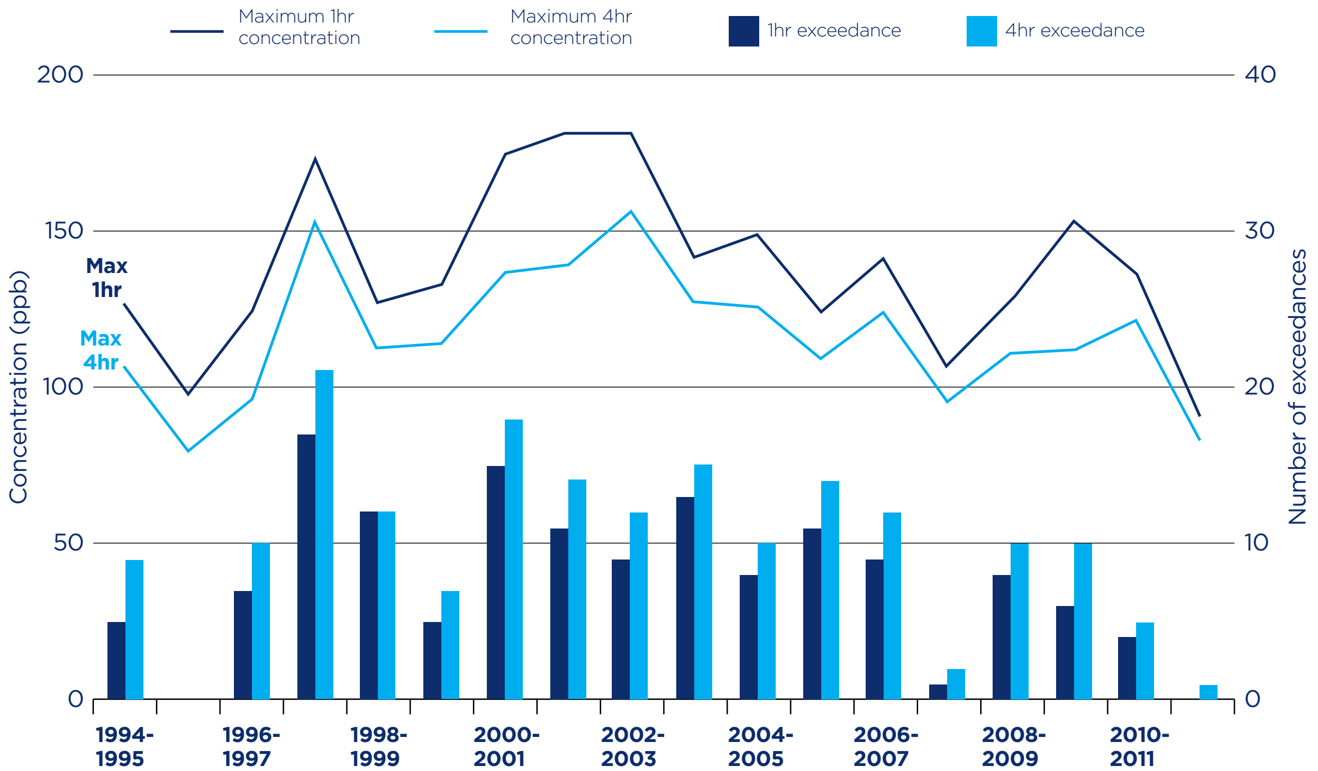
meteorology. Indications are that there has been a decrease in the number of poor ozone days since 2003, however a comprehensive statistical analysis over the period 1994–2010 concluded that there is no significant recent ozone trend in Sydney (Johnston and Quigley, 2013).

While all parts of Sydney can experience ozone concentrations above the AAQ NEPM standards at some time, ozone levels are generally higher in the west and south-west of the city as a result of the dominant summertime atmospheric circulation within the Sydney Basin.

Bushfires and hazard reduction burns can be significant sources of ozone precursors and therefore impact ozone pollution levels. However, even without the influence of bushfires, emissions from human activities are sufficient to cause high ozone pollution in Sydney when the prevailing meteorology is conducive to ozone formation.

As high ozone levels occur more frequently in summer, ozone levels may be exacerbated by future climate change, which is expected to result in more hot and sunny days. The NSW and ACT Regional Climate Modelling (NARCliM) project being led by OEH aims to deliver fine-scale climate projections for the state to support impact studies including investigations into potential climate change impacts on ambient ozone and fine particle concentrations.

Figure 4: Maximum 1-hour and 4-hour average ozone concentrations and number of exceedance days during November (previous year) to March (following year).



3. Emissions

3.1. Trends in emissions in Sydney

Emissions estimates for Sydney have been made for base years 1991, 2003, and 2008 (Carnovale et al., 1997; DECC, 2007; EPA, 2012a). These estimates show a reduction in total emissions in Sydney during this period despite economic and population growth. From 1992 to 2008, emissions steadily decreased, with NO_x decreasing by 27%, VOCs by 40% and PM_{10} by 20% (Figure 5). These decreases occurred despite increases in gross state product (68%), vehicle kilometres travelled (VKT) (26%), energy consumption (28%) and population (18%).

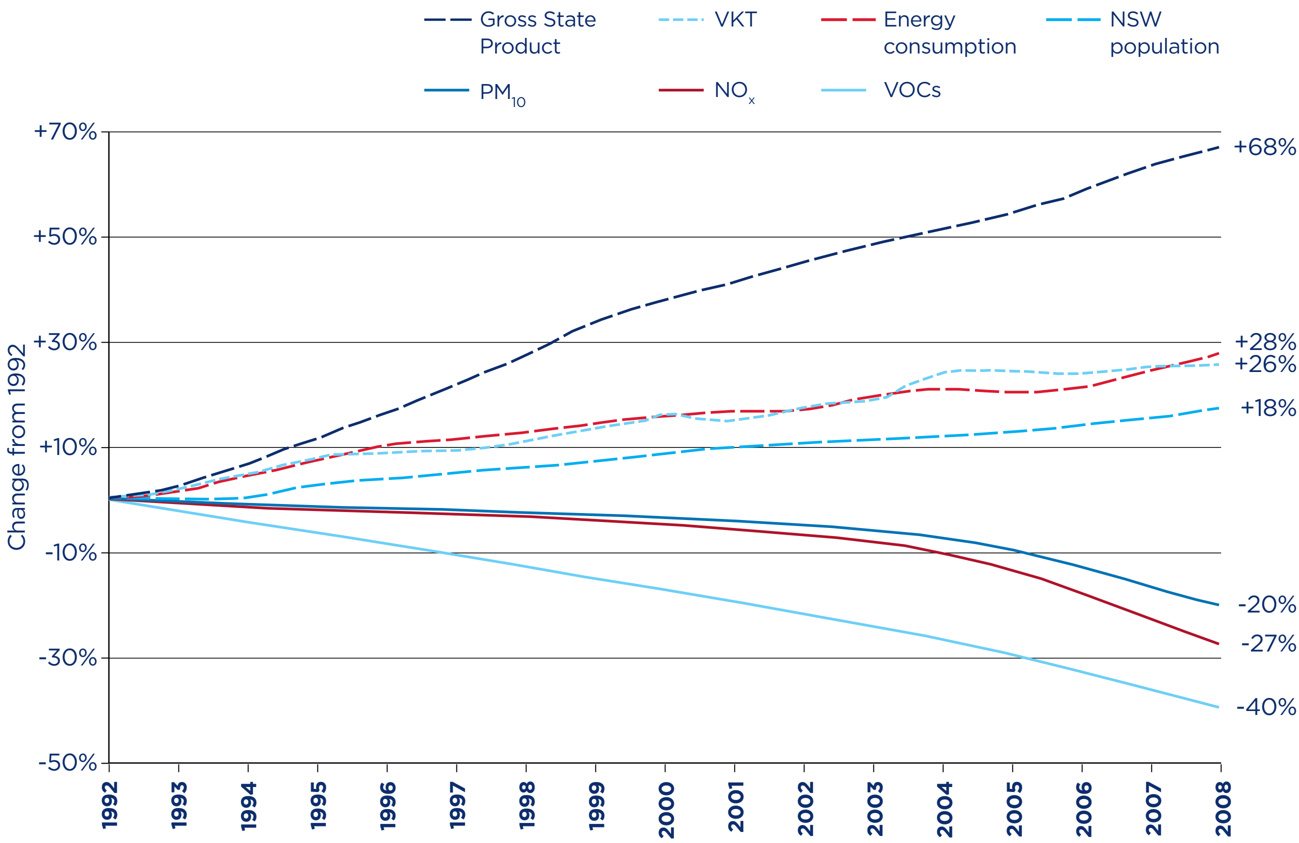
Reductions in emissions during the 1992 to 2008 period are due to more stringent regulation of industry, residential wood heaters, fuel quality and motor vehicle emissions (EPA, 2012a).

3.2. Trends in emissions from on-road mobile sources

A number of key initiatives have been implemented over the past decade to reduce emissions from on-road motor vehicles by making fuels and vehicles cleaner, and encouraging people to use their cars less in favour of other transport options. These initiatives have delivered significant reductions in emissions from transport (EPA, 2012b).

For example, as shown in Table 2, emissions from on-road mobile sources (ie emissions from motor vehicles travelling on-road) decreased significantly from 2003 to 2008, with the highest reductions in CO (71%) and SO_2 (83%). Emissions of ozone precursors, NO_x (53%) and VOCs (31%), decreased as did $PM_{2.5}$ emissions (36%).

Figure 5: Trends in total emissions in Sydney compared with key NSW statistics. Source: adapted from EPA (2012b).



3. Emissions

Table 2: Emissions from on-road mobile sources in Sydney for 2003 and 2008 (DECC, 2007; EPA, 2012a)

	On-road mobile source emissions in tonnes/year		Change (%)
	2003	2008	
PM_{10}	2,552	2,110	-17.3
$PM_{2.5}$	2,426	1,553	-36.0
NO_x	65,996	45,392	-31.2
Total VOCs	50,171	23,512	-53.1
SO_2	1,254	210	-83.3
CO	431,270	123,712	-71.3

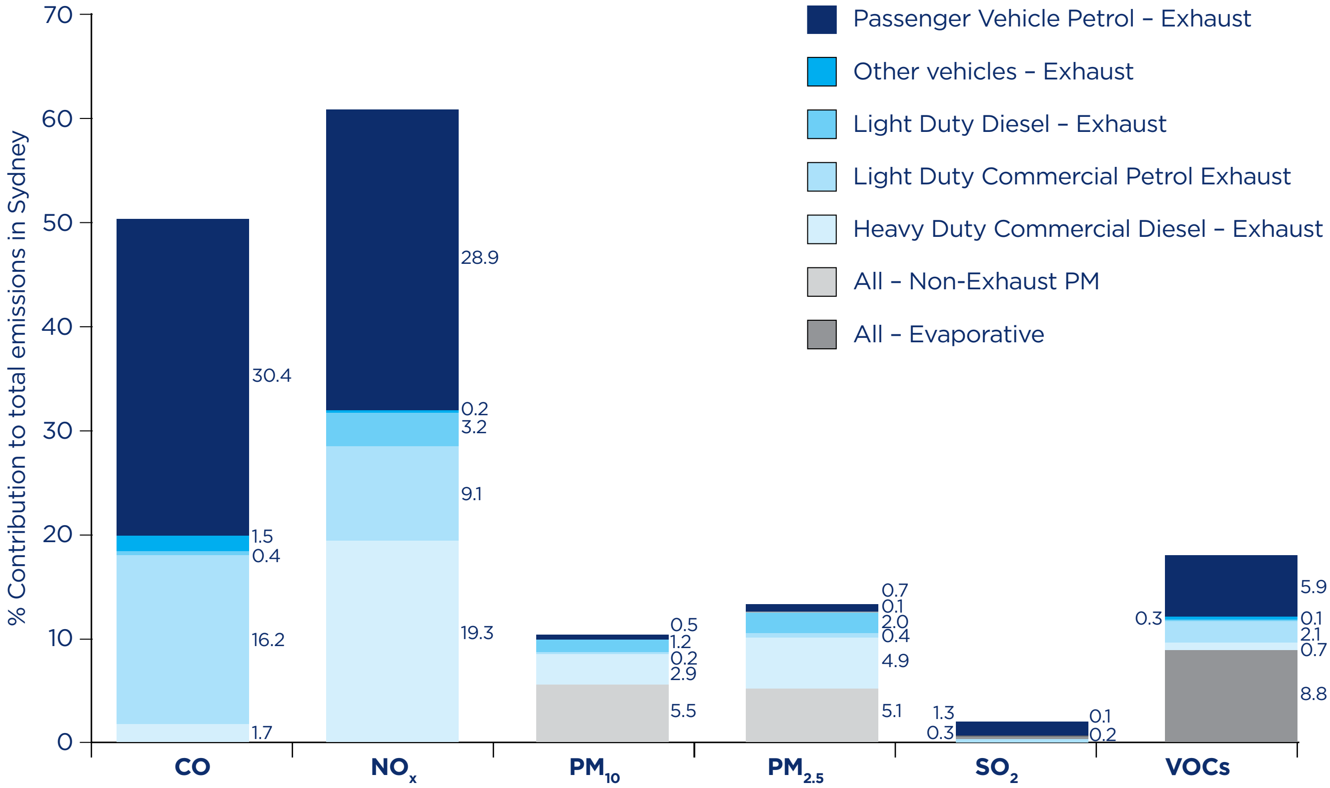
3.3. Contributions of on-road mobile sources to Sydney emissions

Despite reductions in on-road vehicle emissions (Table 2; EPA, 2012a) and their contribution to total emissions (Table 3), motor vehicles remain a major source of air pollution in Sydney. Based on the 2008 emissions inventory, on-road mobile sources are the largest source of NO_x (61% of total emissions) and CO (50% of total emissions) in the Sydney region. On-road mobile sources are also estimated to contribute 18% of the total VOCs emissions and 13% of the fine particle emissions in the region.

Table 3: Contribution of on-road mobile sources to total emissions in Sydney for 2003 and 2008 (DECC, 2007; EPA, 2012a)

	On-road mobile source contribution to total emissions (%)		Change (%)
	2003	2008	
PM_{10}	12.8	10.3	-2.4
$PM_{2.5}$	15.7	13.2	-2.5
NO_x	69.9	60.8	-9.2
Total VOCs	30.4	17.9	-12.5
SO_2	9.1	1.9	-7.1
CO	77.7	50.2	-27.5

Figure 6: Contribution of on-road mobile sources to total Sydney emissions in 2008 (EPA, 2012a).



Passenger petrol and heavy duty diesel vehicle exhausts are the largest sources of NO_x emissions within the on-road mobile source group (Figure 6). Non-exhaust emissions (eg break and tyre wear) and heavy duty commercial diesel exhaust emissions are the most significant on-road sources of particle emissions.

3.4. Modelling of source contributions to ozone formation in Sydney

The relative importance of mobile and other (non-mobile) sources in contributing to ozone formation in Sydney was investigated by Duc et al. (2013) using airshed modelling over the summer periods of 2002–2006.

The early morning and afternoon peaks in NO_x and VOCs emissions from motor vehicles was found to be the most significant influence on the timing of peak ozone concentrations. Ozone formation is strongly determined by the amount of VOCs and NO_x available for the photochemical process during the peak in solar radiation shortly after midday. The modelling study concluded that controlling the growth in motor vehicle emissions represents a viable option for reducing peak ozone concentrations in the Sydney basin.

4. References

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