state of AUSTRALIAN CITIES

national conference >03

Carlton Hotel, Parramatta

3-5 December 2003

Overview- Air pollution and water problems in Australia's urban environments: Merging science and environmental management

Authored by:

Howard Bridgman
Leanne Graham

University of Newcastle

Howard.bridgman@newcastle.edu.au
leanne.g.graham@studentmail.newcastle.edu.au

ABSTRACT

This paper focuses on two major environmental problems in Australian cities, air pollution and water, and discusses possible management strategies. The air pollutants of most concern are photochemical smog and fine particle pollution. The major urban airsheds, located on coastal plains backed by low mountain ranges, re-circulate air pollutants within local and regional air flows. Air emissions inventories identify transport emissions as the most significant source of air pollution. Oxides of nitrogen and volatile organic compounds, from motor vehicle exhaust, combine with sunlight, high temperatures, clear skies and light winds to create high ozone levels, particularly in summer. Fine particulates from various burning processes create pollution problems in winter. Health studies link photochemical smog and fine particle pollution events with increased mortality in the major urban centers. Water problems are created by drought, increasing pressures on water sources by expanding populations, and concern about water quality.

New air quality management plans for the major urban centres merge the best available science with consultative strategy development, monitoring and review. These plans incorporate community involvement in decision-making and a partnership approach to implementation. A range of cost-effective actions target similar priorities. Integration of urban and transport planning, new vehicle emission standards, new fuel quality standards, and alternative fuels, target the reduction of transport-related emissions. New regulations on solid fuel burning for domestic heating, agriculture, and forest and bushfire management target reductions in particle pollution. Economic incentives target reductions in major industrial emissions. Water use management is focussed on recycling of “grey” water collected from urban residential rooftops and stored in tanks. A change in approach by state authorities and local councils is beginning to recognise that recycled water can used for everything except drinking, and has the potential to overcome major water availability problems in urban areas.

INTRODUCTION

The urban physical environment as an artificial entity, supposedly designed for human convenience and benefit. In reality, cities have a wide range of environmental, economic, social, and cultural problems, all of which work to interfere with these benefits. In order to assess these problems properly, they cannot be considered in isolation. Multi-disciplinary and trans-disciplinary team approaches are needed, a combined effort between those who specialise in the physical environment and those who study social and economic aspects. This paper highlights and summarises two of the major problems that occur in Australian cities, air quality and water. It extends and updates concepts and analyses presented in previous publications, such as Bridgman *et al* (1995).

AIR QUALITY AND ITS MANAGEMENT

Australian air quality management for the 21st century has moved towards nationally consistent broad objectives and policy frameworks employing a wide range of management tools. Major components include legislation, policies, management plans, and risk assessment with the explicit aim of protecting human health and well-being from the harmful effects of air pollution. This discussion is based on a much longer review recently published by Graham and Bridgman (2003). It follows the steps leading to air quality management presented in Table 1, as defined in Bridgman (2003). The discussion is illustrated by examples from four major urban areas: Sydney, Brisbane, Melbourne, and Perth.

In 1990, an intergovernmental agreement between the Australian Commonwealth, State, and local governments set the scene for developing a national framework for air pollution management (CoA 1992). Following this agreement, in 1994, the National Environment Protection Council (NEPC) was established to set broad statutory frameworks of agreed national objectives for environmental protection from air, water or soil pollution. These frameworks are set as National Environment Protection Measures (NEPMs) specifying goals and protocols for monitoring and reporting. Implementation of NEPMs is the responsibility of all levels of government (NEPC Act 1994).

During 1995-98, the Australian Commonwealth Government coordinated the development of a nationally consistent approach to air quality management. This process involved commissioning an independent inquiry into urban air pollution (AATSE 1997) which examined present and likely future trends, sources and emissions and management options for seven major urban air pollutants: airborne lead (Pb), oxides of sulfur (SO_x), oxides of nitrogen (NO_x), carbon monoxide (CO), particle matter less than 10 microns (μm) in diameter (PM_{10}) and photochemical oxidants, as ozone (O_3), including ozone precursors (volatile organic hydrocarbons, VOCs). AATSE (1997), found that Pb and SO_2 no longer appeared to be major issues within coastal city airsheds and that CO emissions generally have decreased and are mainly a local problem in heavily trafficked areas. NO_x, VOCs, PM_{10}, and O_3 however, remain as important concerns.

Table 1: Framework leading to active strategies for air pollution management (after Bridgman 2000)

a. Air Pollution Science			
Pollutants *(CO, NOx, VOC, SO2, PM10, 03, standards)*	Meteorology *(wind, stability, temperature, moisture)*	Sources *(industry, traffic, residential, off-road, natural)*	Emissions *(amounts, dispersion, cumulative impacts)*
Collation of Background Material; Computer Modelling (if needed)			
Identification of Potential Impacts			
Health *(respiratory, asthma, illness, acidity impacts)*	Social *(wellbeing, cleanliness, psychological)*	Economic *(crop damage, loss of work days, poor image)*	Environmental *(flora and fauna, diversity, aesthetics)*
Define the Overall Problem			
b. Air Pollution Management			
Develop Possible Management Options			
Tools *(communicate, compromise, technology, education, economic, etc.)*	Policy *(goals, options, consultation, integration)*	Level *(local, regional, state, national, global)*	Framework *(statutory, power, leadership, resources)*
Construct Airshed Management Plan			
Incorporate Airshed Action Strategies			
Implement *(political, procedural, cooperative)*	Monitor *(measurement, representative, research)*	Evaluate *(data analysis, interpretation, comparison, effectiveness)*	Feedback *(community, industrial, responsible agencies)*
Assess Level of Success and Revisit the Structure on a Regular Basis			

Air pollution science

Understanding the problems of air pollution beings with the investigation of the interaction between air pollutants and meteorology, inquiring into the characteristics, sources and impacts of air pollutants, air quality standards, quantification of air emissions, meteorological influences and computer modelling of air pollution dispersion. Table 2 (after NSWSOEa 2000) summarises the sources and effects of the major air pollutants. Pollutants, whether gases of particulate matter, may come from primary sources, where emission directly to the atmosphere occurs, or may be created by chemical reactions in the atmosphere as secondary pollutants. An example of the latter is ozone (O_3) in photochemical smog.

Airborne particles may be solid or liquid and are produced by a wide range of natural and human activities. Inhaleable particles, especially PM_{10}, are associated with respiratory illnesses including increases in the daily prevalence of respiratory symptoms, hospital admissions and mortality. Increasing evidence suggests that $PM_{2.5}$ (particles less that 2.5μm diameter) may be the major influence on the health effects associated with PM_{10}, since $PM_{2.5}$ may be inhaled more deeply into the lungs (NEPMb 1995).

Air quality standards and human health

The Air NEPM standards (last column Table 2) are designed to protect human health and well-being, for the majority of the population, and are legally binding on each level of government. The main health risk for Australians, in terms of mortality, arises from particulate matter and from hydrocarbons. The results of recent studies on the relationship between air quality and mortality in Sydney (Morgan 2000), Brisbane (Simpson *et al.* 2000) and Melbourne (EPAVM 2000) indicate that in Brisbane and Sydney, short-term mortality (respiratory deaths not due to cancer) is related to increases in concentrations of particulate matter and ozone. In contrast, statistics for Melbourne indicate that short-term mortality is related to nitrogen dioxide and ozone. In addition, hydrocarbons have long-term health effects for Melbourne (Hearn 1995). Extrapolating results to all of Australia, gives estimates of about 1,250 to 1,785 deaths per year as a result of hydrocarbons, excluding deaths ascribed to the particulate matter in the hydrocarbons.

Ambient air quality in Australia's four major urban centres

Figure 2 shows the trend in maximum concentrations of O_3, NO_2, CO, and PM_{10} in Australia's four major urban centres. Although there has been a steady decline in the maximum hourly O_3 concentrations (Figure 2a), there is no downward trend in the maximum value of O_3 when averaged over four hours. The number of days that exceed the Air NEPM standards has increased. NO_2 concentrations show a downward trend, with exceedences of the Air NEPM standard occurring only in Sydney and Brisbane since the early 1990s (Figure 2b). The exceedences may result from the drift of industrial emissions into the urban areas, in combination with vehicle emissions. The slight downward trend in urban CO concentrations (Figure 2c) reflects successive introduction of new emission standards (AASTE 1997, CASOE 2001). Exceedences of the 8-hour Air NEPM standard occur in areas of high traffic density and low traffic flow in the centres of urban areas.

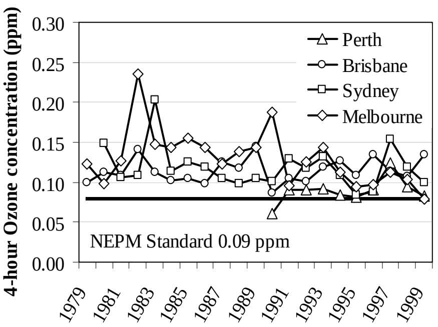
Table 2: Major air pollutant sources, effects, and National Environmental Protection Measure Standards (after NSWSOEa 2000; NEPMb 1995)

Pollutant	Sources	Human health and environmental effects	NEPM (ppm)	Averaging Period
O_3	Secondary pollutant indicating the presence of photochemical smog, formed from reaction of NO, and VOCs in presence of sunlight.	Irritation of eyes and air passages, decreased lung function, lung inflammation, aggravation of asthmatic conditions, increased susceptibility to infection Damage to vegetation, reduced plant growth and crop yields, increased susceptibility to pests. Damage to fabrics, rubber and construction materials. Long-term low-level exposure is of concern.	0.10[a] 0.08	1 hour 4 hours
Particles - Coarse	Grinding, quarrying, mining, diesel fuel vehicles, sea salt, soil, pollens, spores, biomass burning	Nuisance fallout on materials and vegetation.	50 (as PM_{10})[b] ($\mu g/m^3$)	1 day
- Fine	Motor vehicles, domestic wood combustion.	Increased rates of respiratory illnesses and symptoms, decreased lung function, excess mortality from heart and lung disease, aggravation of asthmatic conditions.	Not yet Available (as $PM_{2.5}$)	
NOx	Approximately 10% emitted as NO_2 in the presence of sunlight. Motor vehicles, power stations, bushfires, lightning, biological activity in soil.	Decreased lung function, lung inflammation, aggravation of asthmatic conditions, increased susceptibility to respiratory infections. Leads to the formation of photochemical smog pollutants, i.e. ozone and NO_2. Effects on vegetation, damage to leaf surface, reduced plant growth. Limited research has been done on	0.12[a] 0.03	1 hour 1 year

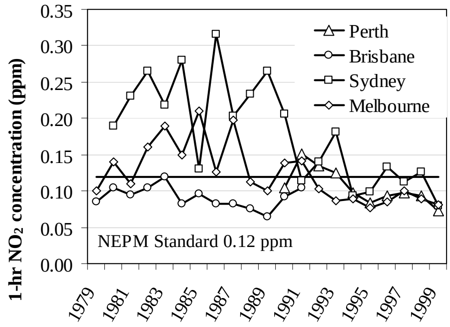
Pollutant	Sources	Human health and environmental effects	NEPM (ppm)	Averaging Period
		Australian native vegetation.		
VOCs	Motor vehicles and combustion processes.	Eye irritant, coughing & wheezing. Precursor to the formation of ozone in the presence of NOx and sunlight.	n/a	
CO	Motor vehicles, domestic wood burning, power generation.	Reduces the capacity of blood to carry oxygen; decreased exercise capacity and aggravation of cardiovascular disease.	8	8 hours
SO_2	Power generation and metal smelting. Bacteria, volcanic activity.	Decreased lung function; lung inflammation, wheezing, aggravated asthma. Plant damage and growth inhibition, acidification of soils and lakes changes the availability of minerals to plants. Corrosion of construction materials.	0.20[a] 0.08[a] 0.02	1 hour 1 day 1 year
Pb	Lead in motor vehicle fuel, metal smelting, and incineration. Erosion of lead ore bodies.	Particularly effects children. Altered neurobiological function in children, i.e. impaired intellectual development, increased human blood pressure and impaired renal function. Accumulates in soil and food chain.	0.5	1 year

Notes: ppm = parts per million; $\mu g/m^3$ = micrograms per cubic metre; Allowable exceedences: a = 1 day/year; b = 5 days/year.

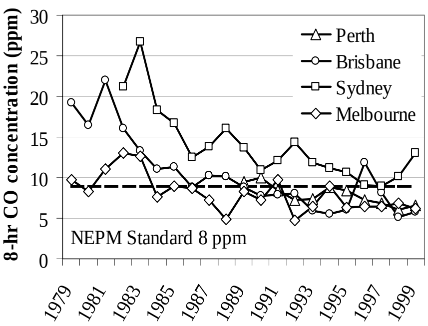
2a) Ozone



2b) Nitrogen dioxide



2c) Carbon monoxide



2d) PM_{10}

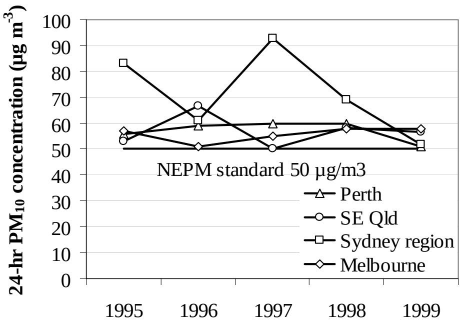


Figure 2: Major air pollutant maximum concentrations in Australia's four major urban centres (CASOE 2001, primary data from State environmental authorities (NSWSOEa (2000); EPAVEI (1998); QSOE (1999); DEPSK 2000)

PM_{10} concentrations (Figure 2d) show a slight downward trend although there are occasional years when very high levels may occur. Although maximum 24-hour concentrations exceed the Air NEPM standards, median values (50th percentile) and 90th percentile values are well below the Air NEPM standard (CASOE 2001), suggesting that exceedences are infrequent events. Higher concentrations reflect bushfires or controlled burning of vegetation to reduce bushfire hazard near urban centres. The composition of PM_{10} concentrations in Sydney, Melbourne and Brisbane shows particles with two distinct distribution peaks, indicating the source of the particles to be from both combustion and mechanical processes. Higher peaks in autumn and winter indicate the effects of wood smoke.

Air Emissions Inventories

An air emission inventory gives a breakdown, by significant sources, of the estimated total mass of specific air pollutants emitted in a study area for a given year. In Australia this is summarized through the National Pollution Inventory (www.npi.gov.au). It also includes the spatial and temporal allocation of emissions. Inventories typically group significant sources of air pollution into four general categories: major industrial point sources; motor vehicles; area based (smaller commercial and domestic aggregated) sources; and biogenic and natural sources. An inventory aids the development and assessment of air quality management options by identifying emission sources that are the major contributors to the inventory, as well as sources where emission reductions readily may be achieved. Emission estimates provide input data for computer modeling to predict air pollution dispersion and photochemical smog formation.

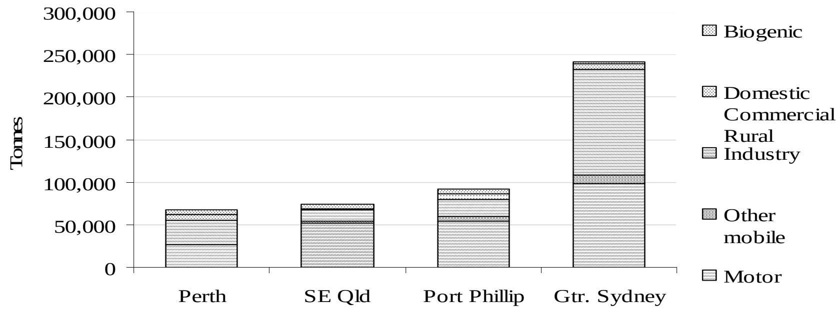
.

Figure 3 illustrates the broadly similar trends in air emissions estimates for NO_x, CO and VOCs in the 4 major urban areas. Motor vehicles are the major emitters of air pollutants in the four major urban areas. Transport emissions contribute more than 75% of CO emissions, most of the NOx, and a major portion of the VOCs. Emissions inventories for the major urban areas reflect some individual differences relating to local variations in climate, modes for home heating and cooling as well as industry mix.

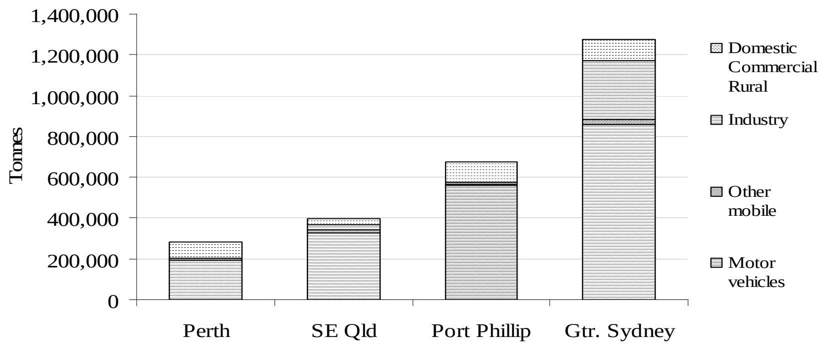
For example, the Port Phillip air emissions inventory (Greater Melbourne) indicated considerable seasonal variation in emissions from some sources, particularly domestic wood heating, contributing 40% of PM_{10} and 46% of $PM_{2.5}$ emissions. In winter, this source contributes about 60% of PM_{10} and 68% of $PM_{2.5}$ to annual emissions. While domestic, commercial and rural sources are the biggest contributors to annual particle emissions, motor vehicles are also a significant contributor to PM_{10} and $PM_{2.5}$. Industry is a significant contributor to total annual emissions of NOx, PM_{10}, VOCs and SO_2. Other mobile sources, particularly large ships are significant contributors to SO_2 emissions (EPAVTS 1997; EPAV 2000).

The Perth inventory (DEPEI 2002) confirms the significant contribution made by motor vehicles to emissions of CO, NOx, and total VOCs. Furthermore, total VOCs and particulate emissions from area-based sources account for a large proportion of overall emissions into the airshed. Domestic solid fuel (wood) combustion contributes 34% of the area-based total VOCs and 51% of the area-based particulate emissions. The most significant source of SO_2 is from industry. More than 99% of the industrial SO_2 contribution is from the supply of electricity, gas and water.

3a) NOx



3b) CO



3c) VOCs

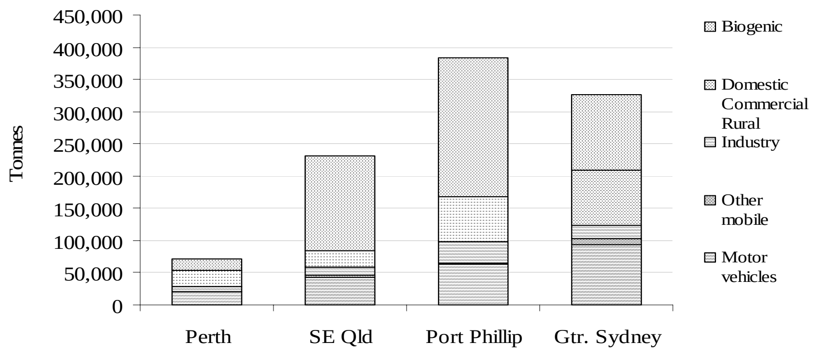


Figure 3: Australian urban emissions of NOx, CO, and VOCs for Perth, Brisbane (Southeast Queensland), Melbourne (Port Phillip) and Greater Sydney (CASOE 2001, primary data from State environmental authorities NSWSOEa 2000; EPAVEI 1998; QSOE 1999; DEPSK 2000)

Meteorology

In Australia's major urban airsheds, local meteorology is strongly influenced by thermal contrasts between land and water, and by moderately complex topography. Figure 4 illustrates the generic circulation patterns that enhance air pollution episodes in the four major urban centres.

Sydney's urban area extends across a sedimentary basin surrounding the harbour, backed by low ranges (Figure 4a). Elevated air pollution concentrations in Sydney normally are associated with a high-pressure system located in the Tasman Sea (Hyde *et al.* 1997). Under these conditions, light to moderate local and regional winds predominate. Air pollutants including ozone may be retained, transported and re-circulated in the airshed (EPANMP 2001).

In Melbourne night time flows move pollutants offshore across Port Phillip Bay. During summer and autumn, afternoon sea breezes re-circulate photochemically generated ozone onshore across Melbourne suburbs. The re-circulation, known as the Spillane or Melbourne Eddy, is a major mechanism for ozone pollution events (Figure 4b). During winter and late autumn, slow-moving anticyclones, typified by light winds and low mixing heights, create conditions for poor dispersion, a major mechanism for PM_{10} pollution events (EPAVMP 2001).

In Brisbane (Figure 4c) calm and stable meteorological conditions are associated with high levels of ozone and photochemical smog. Two main types of conditions are identified: near-calm, hot conditions under the influence of light north-westerly synoptic winds in summer; and very light north-north westerly synoptic winds in late autumn to early spring (QDE 1997). Concentrations of pollutants increase significantly when these re-circulation patterns are repeated over several consecutive days (EPAQMP 2001).

In Perth during the hot dry summer, pollutants blown offshore within morning easterly winds are frequently re-circulated onshore in the southwesterly sea breeze, known as the Fremantle Doctor, a regular feature of Perth's summer meteorology (Figure 6d). The worst smog days occur when an offshore low-pressure trough, another common feature of summer meteorology, directs westerly winds onshore (PAQMP 2000). On many winter nights, very stable conditions, virtually calm under cloudless skies, trap high concentrations of wood smoke and motor vehicles emissions near ground level.

In all the major cities of Australia, photochemical smog occurs when there are high temperatures, clear skies and light winds. Analyses of archived long-term records of the Australian Bureau of Meteorology have produced an indicative measure of smog pollution propensity (Table 3). Values are based on the both the mean number of days with a maximum temperature greater than 30°C and the mean number of clear days. A combination of low rainfall and strong winds can create high air pollution events from wind-blown dust. In high temperatures, bushfires elevate concentrations of particles, nitrogen oxides, and ozone.

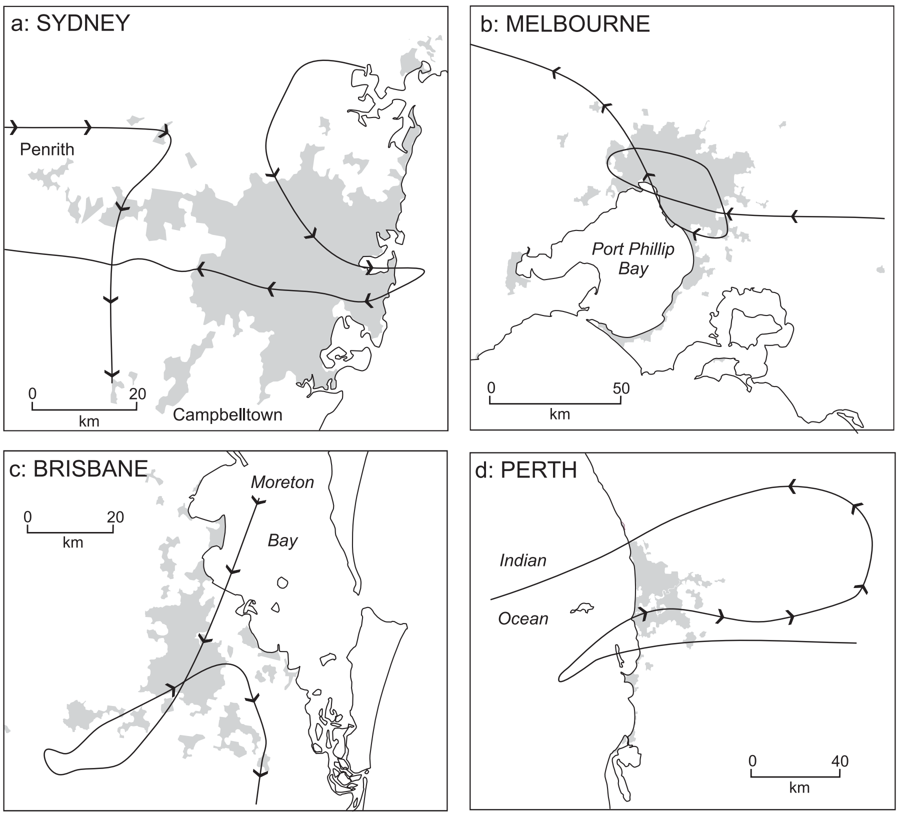


Figure 4: Air pollution re-circulation over major cities (CASOE 2001)

Table 3: Smog pollution propensities across Australian capital cities (Newton 1997)

	J	F	M	A	M	J	J	A	S	O	N	D
Sydney	9	8	9	9	9	9	11	12	9	8	8	9
Melbourne	12	12	9	4	2	2	3	2	2	3	5	9
Brisbane	13	10	7	4	3	4	5	5	5	6	8	13
Perth	31	29	24	12	7	5	5	7	8	10	14	22

Air Pollution Management

To achieve Air NEPM goals by 2008 in the major urban areas, State Governments have developed action plans, improvement plans and strategies (referred to as air quality management plans (AQMPs) in this discussion). The following sections summarise the key issues in the AQMPs prepared for the greater metropolitan regions of Sydney, Melbourne, Brisbane and Perth.

Sydney

The New South Wales (NSW) Government's 25-year Air Quality Management Plan *Action for Air* (EPANAA 1998) focuses on the Greater Sydney region (which includes Wollongong and Newcastle), which includes about 70% of the state's population, as well as the major industrial areas. *Action for Air* integrates urban planning with emission reduction strategies to tackle both photochemical smog and brown haze from fine particle pollution. The actions are grouped, generally, into the following strategic areas (see Table 4):

Integrated urban and transport planning, including transport alternatives,

* Cleaner industries, businesses and homes,
* Managing the impact of open burning, and
* Monitoring and reporting of air pollution levels and progress in air quality management.

Table 4 Examples of air pollution management action strategies for Sydney (EPANNA 1998)

Integrated Urban and Transport Planning	Cleaner Industries, Businesses and Homes	Managing the Impact of Open Burning
Improve public transport systems Link rail with cycleways & pedestrian walkways Freight transport by rail or water Mandatory motor vehicle inspections Buses powered by natural gas Reduce VOCs by reducing petrol volatility Mix land use to minimize travel distance Traffic calming Dust suppression on construction sites Community education	Enforce stronger regulations Improve economic incentives Load-based licencing Codes of best management practice Reuse and recycle materials	Fuel heater industry code of practice Improve heater design standards Guidelines for wood suppliers Local government regulatory action Reduce smoky chimneys Incentives to remove or replace wood heaters Improved planning for bushfire hazard reduction Smoke management guidelines

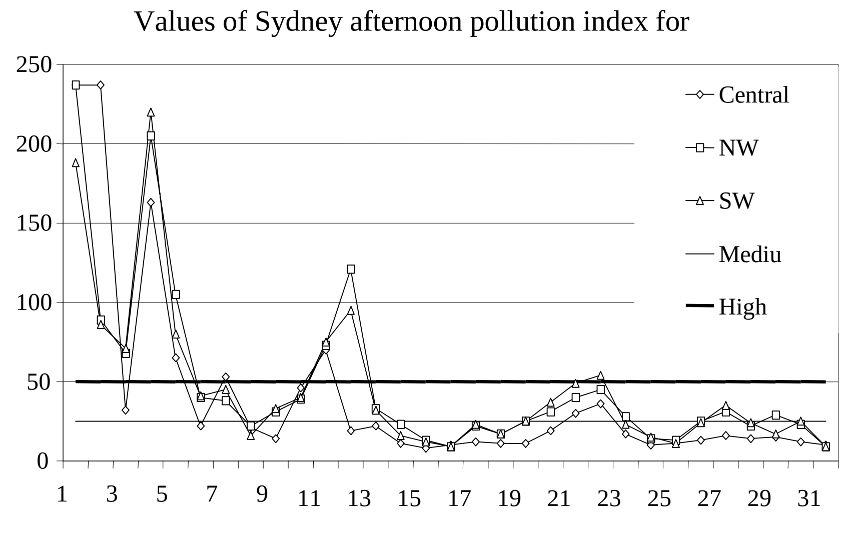
Figure 5 presents the Sydney air pollution index, an example of the type of useful communication to the public which keeps them informed about air pollution levels.

Air pollution control authorities have found it useful, when presenting air quality information to the public, to use an air quality index (or an air pollution index) as a means of combining information about a range of the pollutants. Expressing air quality as an index makes it easier to compare pollutant levels and air quality at different monitoring stations at a glance.

The New South Wales EPA calculates a regional pollution index (RPI) based on measured concentrations of visibility, fine particles, ozone and nitrogen dioxide in the lower atmosphere. Each variable is compared to the Air NEPM Standard, and a value equal to the NEPM standard is taken as 50. Values above 50 are considered highly polluted. Values above 25 indicate medium-level pollution.

The Sydney afternoon air pollution index for January 2000 indicates

Figure 5: Values of the Sydney afternoon air pollution index for January 2000 (CASOE 2001) .



Melbourne

The goal of the Melbourne *Draft Air Quality Improvement Plan* (*AQIP)* is a safe and ecologically sustainable air environment for a large area defined as the Port Phillip Region (EPAV 2000). The *Draft AQIP* builds on a comprehensive inventory of air emissions (EPAVEI 1998), and a series of projections of air quality to the year 2020 (EPAV 2000). The *Draft AQIP*, in common with Sydney's *Action for Air*, prioritises actions to reduce pollution from motor vehicles, industry, households and a range of miscellaneous sources. The actions (Table 5) are grouped into the following strategic areas:

* Motor vehicle emissions, travel demand and driver behaviour,
* Eco-efficiency and product stewardship in industry,
* Domestic wood combustion and other emission sources, and
* Knowledge as a basis for action.

Table 5 Examples of air pollution management action strategies for Melbourne (EPAV 2000)

Motor vehicle emissions, travel demand & driver behavior	Eco-efficiency and product stewardship in industry	Domestic wood combustion and other area sources	Knowledge as a basis for action
Reducing emissions from vehicles New emissions standards Increase vehicle servicing Low sulfur fuels Integrate land use and transport planning Promote alternatives to the car Driver education Zero-emission vehicles	Stronger regulations Raise awareness New standards New technologies Cleaner production Manage fugitive emissions Minimise resource consumption Rigorous emissions monitoring	New emission standards Codes of practice for flue heights/installation Better fuel quality standards Reduce emissions from ships Reduce emissions from waste burning Reduce particulate emissions from diffuse sources	Two-way flow of information Short-term air quality predictions Address local impacts Neighborhood Environmental Improvement Plans Cooperative management

Brisbane

The *South-East Queensland Regional Air Quality Strategy* (*SEQRAQS)* plans to protect the health and well-being of present and future residents, and to preserve the region's ecological integrity and amenity (EPAQ 1999). The pollutants of immediate concern in the region are photochemical smog, and visibility-reducing, inhaleable particles. The actions generally are grouped into the following strategic areas:

* Transport emissions and landuse planning
* Industrial emissions
* Domestic activities and controlled burning
* Monitoring, modelling and research of regional airshed issues, and
* Raising awareness and meeting community expectations

To assess the progress of the Strategy, targets for emission reductions have been set (Table 6), representing goals rather than prescriptive limits. Brisbane's *SEQRAQS* provides details for strategy implementation as well as implementation of individual actions.

Outcome	2011 Target
Achievement of targets related to passenger vehicle use, occupancy and average trip time, set by Inter-Regional Transport Plan for SE Queensland.	Inter Regional Transport Plan for SE Queensland targets to be achieved.
Harmonisation with world standards for passenger vehicles.	100%
Increased share of land freight task by low-polluting vehicles, eg. Rail, or vehicles using low-emission fuels such as CNG or LPG.	25% of land freight task.
Demonstrable reduction in emissions of VOCs, NOx and particles from industrial and commercial sources.	15% reduction of mass weighted.
Demonstrable reduction in non-transport derived emissions of priority pollutants.	15% reduction in per capita emissions.
Despite population growth, no increase in emissions of VOCs, NOx and particles from domestic sources.	No change relative to 1998.
Expansion in regional airshed monitoring and modelling.	75% increase in annual monitoring measurements recorded.
Demonstrated reduction of VOCs, NOx and particles in emissions from the transport sector.	18% reduction of mass emissions.
Reduction in the number of complaints about air quality.	50% reduction in the number of incidents reported to Local Government or EPAQ compared with 1999 (or other approved base year).

Table 6: Performance Targets for *SEQRAQS* (EPAQ 1999)

Perth

The *Perth Air Quality Management Plan* (PAQMP 2000) was developed to achieve and maintain clean air throughout the Perth metropolitan region over the next 30 years. The *PAQMP* is a combination of state and local government regulatory and planning measures, education, and voluntary actions. A staged implementation plans to deliver 126 actions over 30 years. The actions are grouped into eight strategic areas:

* Health effects research,
* Monitoring, modelling and research,
* Land use and transport planning,
* Vehicle emissions management,
* Domestic activities emissions,
* Burning emissions management,
* Industry emissions management, and
* Community information and education.

As examples, the need to improve methodologies for investigating the community health impacts of air pollutants, especially smoke, is highlighted. Actions proposed for modelling, monitoring and research, in common with Melbourne's *Draft AQIP*, emphasize the importance of a well-maintained air emissions inventory, a representative monitoring network, and the need to enhance modelling capability to assist research into the nature and sources of emissions. The process identified 6 key actions (Table 7). The *PAQMP* allocates to each of the 126 actions: an identified output; expected outcomes; agencies responsible for coordination and support; a time frame for commencement and completion; and expected status after 5 years.

Table 7: Perth AQMP key actions (PAQMP 2000)

Action	Output	Expected Outcome	Air quality impact	Time	Expected status after 5 years
Continue with travel behaviour programs such as TravelSmart	Campaigns, reports, annual review	Improvement to system, behaviour change	Direct	1999 to 2010	Reports, campaigns, reviews in progress
Implement program to reduce in-service emissions from motor fleet	Program	Improvement to system	Direct	2002 to 2005	Program in progress
Regulate fuel quality standards	Regulation, review 2005	Basis for future decisions	Direct	2000	Regulation completed, review in progress
Encourage national action on cleaner fuels	Regulation	Basis for future decisions	Indirect	2000 to 2029	Regulation completed, review in progress
Promote CNG and LPG for passenger and freight transport	Report	Basis for future decisions	Indirect	2001 to 2002	Report completed
Reduce industrial NOx and VOC emissions	Report	Basis for future decisions	Indirect	2003	Report in preparation

SUMMARY

As outlined in the preceding sections, the air quality management plans for the four major urban areas address similar key strategic areas. These are summarised in Table 8. The most important issues are reducing emissions from transport, industrial and commercial premises, and domestic activity, as well as and controlled burning in Perth and Brisbane.

Table 8: Number of actions and percentages (approximate) by strategic areas in air quality management plans

Key strategic area / emissions	*Sydney*		*Melbourne*		*Brisbane*		*Perth*	
	No.	*%*	*No*	*%*	*No.*	*%*	*No*	*%*
Transport	33	59%	29	34%	53	30%	36	30%
Industrial and commercial	10	18%	20	23%	27	15%	14	10%
Domestic	4	7%	14	16%	15	8%	13	10%
Open burning	3	6%	3	4%	18	10%	19	15%
Monitoring, modelling, research	6	10%	15	17%	30	17%	21	17%
Health research					3	2%	13	10%
Communication, awareness			5	6%	8	4%	10	8%
Landuse planning					18	10%		
Implementation, review					7	4%		
Total	56	100%	86	100%	179	100%	126	100

Water in the Urban Environment

The availability, use and mis-use of fresh water is an environmental problem of global proportions (UNEP web). Despite high populations, and in many cities a high density of population, urban water use is only 5-10% of overall global water use, even where sewage and drainage systems are highly developed. Water use per person in developed countries averages about 300 m^3 per year, while that in developed countries averages about 20 m^3 per year. On a global scale, by far the largest use of water is for agriculture. Australian water use follows this pattern, with per capita use well above the global average.

Table 9 Use of fresh water in Australia (after Eamus 2003)

Sector	Volume of water used (GL/y)	Percentage of total water use in 1997
Agriculture	15,520	70
Industry, Commerce and Mining	3,067	14
Domestic	1,826	8
Other	1,770	8
Total	22,185	100

Table 9 presents the relative use of water in percentage terms for Australia (Eamus, 2003). Although over 80% of Australia's population lives in urban environments (Bridgman *et al.* 1995), only 8% of the water is consumed there. Much attention is given to agricultural use, and the politics and arguments about managing the resource (*i.e.* Smith 1998, Young 2000). Until recently, less attention has been given to water use in urban environments.

The periods of recent droughts, during the 1990s and the first years of the 21st century (BOM web), have highlighted Australia's water availability problems. Australia is the driest inhabited continent on earth. Rainfall is not only low, it is irregular (Sturman and Tapper 2000). Extremes of drought and flood are common. Despite the physical limitations of water availability, Australians use their water resources wastefully.

If cities in Australia use only 8% of the total water used, then why all the fuss? Urban environments treat fresh water rather badly (Bridgman *et al.* 1995). It is considered to be an unwanted resource. Rainfall is removed rapidly across cement and bitumen, pouring into sewers and storm water systems. Runoff in a city peaks much more rapidly than in a rural environment. Although most Australian cities have considerable areas devoted to parkland, infiltration and water storage in urban environments is small. Too much water from storms can lead to flash flooding. Water discharge levels can then exceed the capacity of the storm water system, creating overflows. Water quality, affected by litter, oil, acids and other contaminants, is often reduced in the overflow catchment areas, such as the coastal oceans.

As well, the majority of fresh water storage for use in cities comes from dams (Young 2000). Dams store vast amounts of water. According to Smith (1998), the major dams in Australia store over 900,000 Gigalitre of water. UNEP (web) suggests that evaporation of water from dams can exceed consumption of water by industrial and domestic users. In times of crisis, during drought, the water stored in dams can fall to very low levels, and urban water usage is then restricted. Water organisations, such as Sydney Water, spend a good deal of time and money trying to convince a reluctant public not to waste water, through advertising campaigns and via punitive legislation.

Examples of Water Use

In Australian cities, uses of water fall into five categories: domestic; sewage; lawns and gardens; industrial; and commercial. Water quality is as much a concern as water quantity. For purposes of this discussion, the focus will be on domestic water use, using examples from the four major cities.

Figure 6 presents the breakdown of domestic water use in Perth (Perth web). Perth is the only capital city that depends on groundwater for drinking water (about 5.5% of the total supply). By far the most dominant use is watering the garden. All other uses are 16% of the total or less. On average, the per capita water use is 120 kL/y, and increase of 20% since the early 1980s. If garden watering was banned, and immediate saving of about 55 kL/y of water per person would occur, increasing the supply for other, more essential uses.

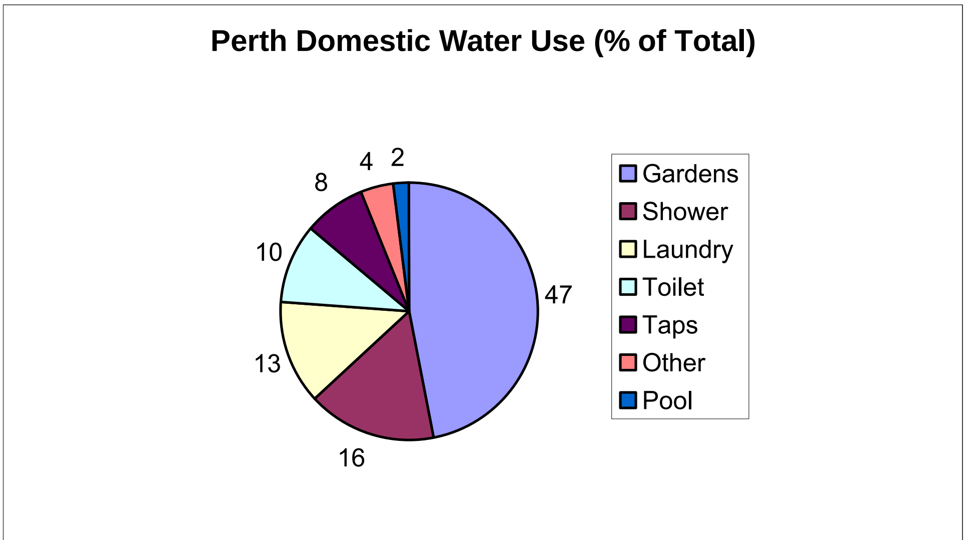


Figure 6. Domestic water use in Perth (Perth web)

A focus on domestic water use and conservation also is part of the Brisbane City Council approach to water services (BBC web). On average, a family in Brisbane uses 699 litres of water per day, more than double the average amount for developed countries on a global scale (UNEP web). The breakdown in usage is similar in percentage to Perth, but the Council provides more specific detail, as shown in Table 10. Watering the garden and lawn in Brisbane, on average, uses more water than the total of all other uses, except filling a swimming pool.

Table 10. Average Domestic Water Use in Brisbane (BCC web)

Water Use Activity	Average Total Water Used (litres)
Shower without water-saver rose	120 per shower
Shower with water-saver rose	68 per shower
Single-flush toilet	120 per day
Dual-flush toilet	40 per day
Washing machine (twin tub)	40 per day
Washing machine (top loader)	170 per day
Washing machine (front loader)	80 per day
Dishwasher	20 – 50 per day
Cooking, cleaning, drinking	150 per day
Brushing teeth (water running)	40 per day
Bath	50 – 150 per bath
Watering garden & lawn	2000 per day
Drip watering system	96 per day
Hosing path & driveway	200per 10 minutes
Washing car (hose running)	100 – 300 per car wash
Filling swimming pool	up to 55,000

Approaches to domestic water use management

The crisis over fresh water availability and use in Australia has been placed on the agenda for the National Environmental Protection Council (NEPC web). A major feature of the agenda is to recommend ways to reduce water use and wastage in cities. Approaches include permanent water restrictions and a national labeling system for water efficiency on appliances and other products that use water. NEPC estimates that such measures will save about 5% of the water use by households, or on the order of 87,200 ML/y. This seems small, but it is a step in the right direction.

NEPC will also produce guidelines for the use of recycled wastewater, or “grey” water, by the end of 2004. This includes rainwater collected and stored in water tanks, a feature of the rural environment but, until recently, banned in urban areas based on health concerns. The use of recycled water would be for watering gardens and lawns, various industrial activities, fire protection and so forth. Recent experiments with recycled water in housing estates in Newcastle and other cities suggest that rainwater can be used safely for all activities involving hot water.

The water authorities in all cities of the major cities are also encouraging the use of recycled water or rainwater. For example, Brisbane provides tips on their web site about how domestic users can save water, and currently offers a rates rebate of $500 for water tank installation. BCC (web) estimates that the use of tank water will could reduce the use of mains water by 30-40%. Melbourne also encourages water recycling and water saving, providing a range of public information on the benefits (Melbourne web). Sydney has produced a five-year drinking water management plan that addresses water quality, health, and availability issues (SWC 2000).

There has also been a major focus during the last few years on sustainable water use in cities through watr sensitive urban design (Coombes 2002). At the residential level, this means property and landscape design, which will enhance the capture and reuse of storm and rainwater. Stormwater drains could be redesigned to grassy verges, with vegetation and a rubble base to encourage infiltration. Rainwater overflow could be stored in underground aquifers. Coombes (2002) presents a strategy for overall house and property design, which would be highly appropriate for new developments. Household self-sufficiency could reduce the dependence on mains water by 80% or more. Success depends on public acceptance. Changing the attitude of the Australian public away from uncontrolled water use in the urban environment will be a major task over the next few years.

CONCLUSION

Research and strategic policy development in Australia in recent years have created a strong policy framework for air quality management. Nationally consistent air quality standards set explicit goals for action. Leadership at the national level in decision-making for social, economic and environmental responsibility has created attitudinal change, towards greater accountability by industry, and more equitable cost sharing across the whole community. National mechanisms for effective monitoring, review and community reporting operate via the National Pollution Inventory, the NEPM ambient air quality monitoring network, State of the Environment Reporting, as well as annual reporting by the coordinating body, the National Environment Protection Council. Health effects research, emissions inventories and atmospheric dispersion modelling have enhanced current understanding of the nature, sources and impacts of air pollutants. Applications of air pollution science, and knowledge of trends at the local and regional level, have played a key role in the process of developing management options. AQMPs for major urban areas identify priority actions for reducing emissions as well as priorities for future research. Clear commitment to regular review and reporting is evident. Consultative policy development has created effective implementation networks between researchers, industry, the community and governments at national, state and local government levels.

A significant period of drought over the past two decades has created further emphasis on better use of Australia's freshwater resources. Although domestic water use only is 8% of total water use in Australia, more than 85% of that domestic use occurs in cities. Water authorities are beginning to realise that water has to be viewed as a resource, not an item of waste. The recent trends toward encouraging installation of rainwater collection tanks in the city environment, and the recycling of grey water for uses except drinking are examples of more positive uses of water, which, over time, should help relieve the stress on water storage areas during dry periods.

Air quality and water availability and quality in cities, are two of the major environmental concerns in Australia. Coordinated efforts to assess the impacts of these in conjunction with other urban problems (social, economic, cultural and so forth) are lacking. Cities will provide the living and working environment for the vast majority of Australia's population during the 21st century. A multidisciplinary, transdisciplinary approach to urban environments will ensure the best possible understanding for the future.

ACKNOWLEDGMENTS

The authors acknowledge: Olivier Rey-Lescure, Cartographer, University of Newcastle, NSW, Australia, for providing Figures 1 and 4; and Dr Peter Manins, Chief Research Scientist, Australian Commonwealth Scientific and Industrial Research Organisation, for providing data for Figures 2 and 3.

REFERENCES

AATSE, *Urban Air Pollution in Australia,* Australian Academy of Technical Sciences and Engineering, Parkville, Australia, 1997 http://www.ea.gov.au/atmosphere/airquality/urban-air/index.html

BCC (web), Brisbane City Council water services, www.brisbane.qld.gov.au/residential_services/water_sewerage, 2003

BOM (web), Bureau of Meteorology, www.bom.gov.au, 2003

Bridgman, H, Warner, R., and Dodson, J., *Urban Biophysical Environments*, Oxford University Press, Melbourne, 1995

Bridgman, H., Air pollution management in Australia: The example of Newcastle, NSW., *Air Quality Management*, Eds. Longhurst, J.S.W., Elsom, D.M., and Power, H., WIT Press, Southampton UK, pp 159-198, 2000.

CASOE, *Australia State of the Environment Report, Atmosphere*, Commonwealth of Australia, 2001 http://www.ea.gov.au/soe/

CoA, *Intergovernmental Agreement on the Environment,* Commonwealth of Australia, Canberra, 1992 http://www.ea.gov.au/esd/national/igae/index.html

Coombes, P., *Water sensitive urban design: an introduction*, www.lhccrems.nsw.gov.au/projects/wsud/Fact_Sheet_Introduction.pdf

DEPEI, *Perth Airshed Emissions Inventory Update 1998-1999,* Technical Series 110, Department of Environmental Protection, Perth, Australia, 2002 http://aqmpweb.environ.wa.gov.au:8000/air_quality/Publications/

DEPSK, *Perth air quality management plan: State of knowledge*, 2000, Department of Environment, Perth, Australia, http://www.environ.wa.gov.au/DEP/aqmp

Eamus, D., 2003, The real cost of agriculture, *Australasian Science*, 24:35-37

EPANAA, *The NSW Government's 25-year Air Quality Management Plan, Action for Air,* NSW Environment Protection Authority, Sydney, Australia, 1998 http://www.epa.nsw.gov.au/air/actionforair/index.htm

EPANMP, *National Environment Protection Measure for Ambient Air Quality, Monitoring Plan for NSW*, NSW Environment Protection Authority, Sydney, Australia, 2001

EPAQ, *The South-East Queensland Regional Air Quality Strategy,* Environment Protection Agency of Queensland, Brisbane, Australia, 1999 http://www.epa.qld.gov.au/cgi-bin/w3-msql/environment/environment/airfeature/msqlwelcome.html?page=introduction.html

EPAQMP, *Ambient air monitoring plan for Queensland,* Environment Protection Agency of Queensland, Brisbane, Australia, 2001 http://www.epa.qld.gov.au/cgi-bin/w3-msql/environment/science/air/msqlwelcome.html?page=introduction.html

EPAV, *Draft Air Quality Improvement Plan, Port Phillip Region,* Environment Protection Authority of Victoria, Melbourne, Australia, 2000, http://www.epa.vic.gov.au/Air/aqip.asp

EPAVEI, *Air emissions inventory: Port Phillip region*, Publication 632, Environment Protection Authority of Victoria, Melbourne, Australia, 1998 http://www.epa.vic.gov.au/Air/Emissions_Inventory

EPAVM, *Melbourne mortality study: Effects of ambient air pollution on daily mortality in Melbourne 1991–1996*, Publication 709, Environment Protection Authority of Victoria, Australia, 2000, http://www.epa.vic.gov.au/Air/health.asp

EPAVMP, *Victorian Air Quality Monitoring Plan* –, Environmental Protection Authority of Victoria, Melbourne, Australia, 2001 http://www.epa.vic.gov.au/Air/Monitoring/vicaqmp.asp

EPAVTS, *Air Quality Management Plan: Taking Stock*, Publication 535, Environment Protection Authority of Victoria, Melbourne, Australia, 1997

Graham, L. and Bridgman, H., 2003, Air Quality Management in Australia, in *Air Quality Management II*, eds. J. Longhurst and D. Elsom, WIT Press, Southampton, UK, in press.

Hearn, D., Health risks due to motor vehicle emissions in Melbourne, *Clean Air*, 29, 37–441, 1995

Hyde, R., Young, M., Hurley, P., Manins, P*., Metropolitan Air Quality Study – Meteorology – Air movements*, Consultants Report to the NSW EPA, NSW Environment Protection Authority, Sydney, Australia, 1997

Melbourne (web), Melbourne Water, conservewater.melbournewater.com.au/content/conserve/useage.htm, 2003

Morgan, G., Air quality and health risk in Sydney, in *Air pollution and health risk,* Beer, T., Ed., CSIRO and Clean Air Society of Australian and New Zealand, Melbourne, Australia, pp 101–116, 2000

NEPC Act, *National Environment Protection Council Act 1994,* Commonwealth of Australia, Canberra, 1994 http://www.austlii.edu.au/au/legis/cth/consol_act/nepca1994432/index.html

NEPC (web), National Environment Protection and Heritage Council, www.ephc.gov.au, 2003

NEPMb, *National environment protection measure, and impact statement, for ambient air quality*, National Environment Protection Council, NEPC Service Corporation, Adelaide, 1998

Newton, P., *Re-shaping cities for a more sustainable future*, Research Monograph No. 6, Australian Housing and Urban Research Institute, Melbourne, Australia, 1997

NSWSOE, *NSW State of Environment 1997,* NSW Environment Protection Authority, Sydney, Australia, 1997 http://www.epa.nsw.gov.au/soe/97/index.htm

NSWSOEa, *New South Wales State of Environment Report 2000*, NSW Environment Protection Authority, Sydney, Australia, 2000 http://www.epa.nsw.gov.au/soe/soe2000.htm

PAQMP, *Perth Air Quality Management Plan,* Department of Environmental Protection, Government of Western Australia: Perth, Australia, 2000 http://aqmpweb.environ.wa.gov.au:8000/air_quality

Perth (web), Perth Water Corporation, www.watercorporation.com.au, 2003

QDE, *Air emissions inventory – south-east Queensland airshed*, Department of Environment, Brisbane, Australia, 1997

QSOE, *State of the Environment Queensland 1999,* Environmental Protection Agency of Queensland, Brisbane, Australia, 1999 http://www.epa.qld.gov.au/cgi-bin/w3-msql/environment/science/environment/msqlwelcome.html

Simpson, R. W., Williams, G., Petroeschevsky, A., Rutherford, S., Mitchell, C., and Thalib, L., Air quality and health risk studies in Brisbane, in *Air pollution and health risk,* Beer, T., Ed., CSIRO and Clean Air Society of Australian & New Zealand, Melbourne, Australia, pp 79-90, 2000

Smith, D., 1998, *Water in Australia*, Oxford University Press, Melbourne.

Sturman, A. and Tapper N., 2000, *The Weather and Climate of Australia and New Zealand*, Oxford University Press, Melbourne.

SWC, *Drinking Water Quality Management Plan*, Sydney Water Corporation, Sydney NSW, 2000.

UNEP (web), Freshwater, United Nations Environment Programme, www.unep.org/themes/freshwaterT, 2003

Young, A., 2000, *Environmental Change in Australia since 1788*, Oxford University Press, Melbourne.

STATE OF AUSTRALIAN CITIES NATIONAL CONFERENCE

SYDNEY, 2003

SPONSORS

University of Western Sydney

Australian National University

The University of New South Wales

Griffith University

The University of Melbourne

Victorian Department of Sustainability and Environment

NSW Department of Infrastructure, Planning and Natural Resources

ACT Planning and Land Authority

►►► **For all enquiries, please contact:-**

University of Western Sydney

Urban Frontiers Program

Building 22, Campbelltown Campus

Locked Bag 1797, Penrith South DC NSW 1797

Phone +61 2 4620 3443

Fax +61 2 4620 3447

Email urbanfrontiers@uws.edu.au

Web www.urbanfrontiers.uws.edu.au