Update of South Australia's National Pollutant Inventory

Aggregate emission data 2002–2003

MAY 2007

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EPA
South Australia

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SUMMARY

The South Australia Environment Protection Authority (EPA) contracted the Victorian EPA to update the 1998–99 National Pollutant Inventory aggregated emissions data to 2002–03 for 17 airsheds in SA. In 2005, emissions were updated with the then most recently available emission and speciation factors, and projected with population, fuel use, vehicle traffic and aircraft traffic data. Bakeries, natural gas leakage, liquid fuel combustion, pets and humans, and unpaved road dust were also added to the inventory.

The most significant difference between the 2002–03 and 1998–99 inventories was the lower emissions of particulate matter less than 10 µm estimated for 2002–03 due mostly to the reduced emission factors used for paved road dust. Generally, emissions of carbon monoxide were lower and oxides of nitrogen were higher in 2002–03 due to the revised motor vehicle emission factors used for this inventory. Most of the aggregate emissions were contributed by solid fuel burning, motor vehicles, domestic and commercial solvent and aerosol use, and architectural surface coatings in the SA airsheds.

This paper aims to explain the methodologies that were used to develop the inventory and to provide an overview of the emissions in the SA airsheds.

1 INTRODUCTION

The South Australia National Pollutant Inventory (NPI) aggregated emissions data, which cover emissions to air from small industrial facilities and commercial and domestic activities, is a valuable source of air pollution information. The data was five years out of date and updating the aggregated emissions data was considered to be an important part of the SA NPI program. The SA Environment Protection Authority (EPA) contracted EPA Victoria to update the 1998–99 NPI aggregated emissions data (Ciuk 2002) to reflect emissions for the 2002–03 period for 17 airsheds in SA.

This paper, first published in 2005, aims to explain the methodologies that were used to update the inventory and to provide an overview of the emissions in the SA airsheds.

The 17 airsheds, one metropolitan and 16 regional, represent a large cross-section of the state's population and commercial/industrial activities. Figure 1 shows the locations of the 17 airsheds, which comprise six major airsheds (as labelled in the figure) and 11 minor airsheds. Each minor airshed is located within the boundaries of a major airshed. These minor airsheds include:

- Lyndoch and Nuriootpa in the Barossa airshed
- Barmera, Berri, Loxton and Renmark in the Riverland airshed
- Millicent and Mount Gambier in the South East airshed
- Port Augusta, Port Pirie and Whyalla in the Spencer Gulf airshed.

The Barossa, Riverland, South East and Spencer Gulf airsheds are divided into grid cells of 5 × 5 km; the other airsheds are all 1 × 1 km to better represent the town's population and industrial activities.

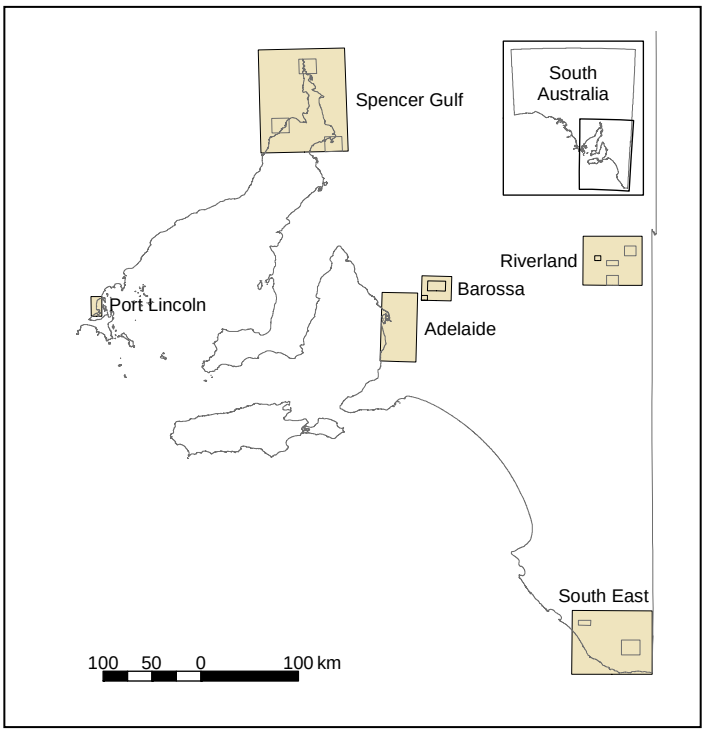

Figure 1 South Australian airsheds

The airsheds combined represent over 80% of the SA population and industry. Table 1 lists the population estimated for each major airshed and compares them with the 1998–99 estimates. The 2002–03 estimates were projected from the 2001 Census data (ABS 2003a). With the exception of Spencer Gulf, the population in each major airshed increased from that in 1998–99.

Table 1 South Australian airshed population

Airshed	1998–99	2002–03
Adelaide	1,041,882	1,092,539
Barossa	14,893	16,411
Riverland	26,147	27,525
South East	37,988	39,470
Port Lincoln	12,333	13,862
Spencer Gulf	55,098	53,866

The sources of air pollutants studied in each airshed included a range of domestic, commercial and mobile activities. A total of twenty three emission sources were studied, including five new sources that were not covered in the 1998–99 inventory.

Emissions were estimated for 63 pollutants out of the 90 pollutants listed for the NPI (EA 1998). Emissions were only calculated for those pollutants for which emission factors were known.

2 METHODOLOGY

Emissions were updated with the then most recently available emission and speciation factors, and projected with population, fuel use, vehicle traffic and aircraft traffic data. Five new sources were also added to this inventory.

The update and management of the inventory were greatly facilitated by the use of the Emission Modelling and Data Management System or EMADMS (Ng 2005a). Emissions were projected, spatially allocated and speciated with EMADMS. The results and maps presented were based on reports and data generated from EMADMS.

2.1 Emission projections

Emissions from the following sources were projected by population: recreational boating, architectural surface coatings, domestic and commercial solvent and aerosol use, dry cleaning, lawn mowing, motor vehicle refinishing, printing and graphic arts, and sub-threshold industrial solvent. The last emission source refers to solvents used by industrial and commercial facilities that are not individually reported for the NPI. Under the NPI program, industrial facilities are required to report their emissions if their emissions or fuel consumptions exceed certain threshold values.

To project emissions by population, emissions in 1998–99 were multiplied by the ratio of population in 2002–03 and 1998–99 of each airshed. This ratio, referred as growth factor, was derived from the population data in Table 1. When projecting emissions for sub-threshold industrial solvent, emissions from reporting and sub-reporting facilities in 1998–99 were added and projected to 2002–03 as a whole. The emissions of sub-threshold industrial solvent in 2002–03 were then obtained by subtracting the reported emissions in 2002–03 from the projected emissions.

Table 2 shows the sources and growth factors that were used to project emissions by fuel use. The growth factor was the ratio of fuel consumption in 2001–02 to that in 1998–99 obtained from ABARE (2004). The 2001–02 data was used as ABARE (2004) did not have data for 2002–03 and beyond.

Table 2 Growth factors based on SA fuel consumptions

Source	Sector	Fuel	Growth factor
Railways	railway	ADO*	0.428
Ships	international bunkers	total	0.987
Commercial boats	coastal bunkers	ADO	1.25
Domestic gas fuel	residential	natural gas	1.05
		LPG†	1.05
Service stations	road transport	petrol	0.980
		diesel	1.11
		LPG	1.57

***** Automotive diesel oil

† Liquefied petroleum gas

Source	Sector	Fuel	Growth factor
Solid fuel burning	residential	briquettes	1.22
		wood	0.717
Sub-threshold fuel combustion	industrial	fuel oil	0.938
		natural gas	1.01
		LPG	0.429
	commercial	fuel oil	0
		natural gas	0.873
		LPG	0.211

Emissions from motor vehicles, cutback bitumen and paved road dust were projected by growth of vehicle kilometres travelled (VKT) from 1998–99 to 2002–03. ABS (2003b) reported VKT for capital cities and other areas, from which a growth factor of 1.01 was derived for Adelaide and 1.13 for all the other airsheds.

Emissions from aeroplanes were projected by aircraft traffic data (BTRE 2004a, 2004b). Table 3 shows the growth factors used for the SA airports.

Table 3 Growth factors for SA airports

Airport	Growth factor
Adelaide	1.05
Mount Gambier	1.10
Port Lincoln	0.912
Whyalla	0.914
Other airports	0.904

2.2 Emission factors

Apart from projection, most recent emission factors available in 2004 were used to update the emissions from motor vehicles, paved road dust and wood burning.

Since the publication of the NPI manual (EA 2000), there have been a number of studies for emissions from Australian vehicles and vehicles in the US. Emission factors from these studies have been incorporated in *AusVeh 1.0*, a software developed by EPA Victoria to estimate emission factors for Australian vehicles (Ng 2005b). Emission factors from AusVeh were used to update the motor vehicle emissions for SA. In addition, more recent SA fleet composition data was used (ABS 2003b). Table 4 shows the fleet average emission factors of primary pollutants and compares them with those for 1998–99. The emission factors would be expected to have decreased as the proportion of vehicles with better standards increased over time, however with the exception of carbon monoxide (CO), all the revised emission factors were higher than those for 1998–99.

Table 4 Motor vehicle fleet average emission factors (g/km) for SA airsheds

Pollutant	1998–99 inventory	2002–03 inventory
carbon monoxide	15.6	11.7
oxides of nitrogen	1.98	2.63
particulate matter less than 10 µm	0.0616	0.0823
sulfur dioxide	0.0698	0.0713
volatile organic compounds	1.87	2.09

CSIRO recently carried out research on emissions from wood heaters (EA 2002) and were used to update the emission factors for controlled heaters. Table 5 compares the emission factors with those for the 1998–99 inventory, which were based mostly on USEPA (2003). The emission factors are generally comparable except for sulfur dioxide (SO_2), which was much lower in the CSIRO's study.

USEPA (2003) revised the emission factors for paved road dust. The revised emission factors were further reduced to 15% of the original values to account for estimating of emissions in the ambient air far away from roads (Veranth *et al* 2003). In addition, recent SA fleet composition and vehicle weight data were used to derive the emission factors (ABS 2003b). Table 6 compares the emission factors derived for the 1998–99 and 2002–03 inventories for particulate matter less than 10 µm (PM_{10}). As a result the emission factors for all airsheds decreased to less than 10% of the 1998–99 values. Generally, airsheds with higher average daily traffic had lower emission factors due to reduced silt loading on roads.

Table 5 Emission factors (g/kg) for controlled wood heaters

Pollutant	1998–99 inventory	2002–03 inventory
carbon monoxide	70.4	110
oxides of nitrogen	1	0.62
particulate matter less than 10 µm	5.5	4.3
sulfur dioxide	0.2	0.014
volatile organic compounds	6.75	9.9

Table 6 PM_{10} emission factors (g/km) for paved roads

Airshed	1998–99 inventory	2002–03 inventory
Adelaide	0.753	0.0363
Barossa	1.85	0.172
Riverland	0.753	0.0681
South East	0.753	0.0681
Port Lincoln	1.85	0.172
Spencer Gulf	0.753	0.0681

As leaded petrol has been phased out since 2002, emission factors for leaded petrol were replaced by those for unleaded petrol in estimating emissions for motor vehicles, recreational boating, lawn mowing and service stations.

2.3 New sources

Bakeries, natural gas leakage, liquid fuel combustion, pets and humans, and unpaved road dust were added to the current inventory.

Emissions from bakeries were estimated from an ethanol emission factor of 173 g/capita/yr (Carnovale *et al* 1996). Ethanol emissions reported for the NPI by the bakery product manufacturing sector were subtracted from the total estimated emissions. Emissions were estimated for 1998–99 and projected to 2002–03 by population in the airsheds.

Emissions from natural gas leakage were calculated in units of terajoules in the 1998–99 NPI, but the emissions were not included in the inventory. In this inventory, the emissions were converted to tonnes assuming an energy content of 51.9 MJ/kg and projected with a growth factor of 1.05, based on the natural gas consumption in the residential sector of SA.

Emissions from domestic liquid fuel were estimated from the consumption of lighting kerosene and automotive diesel oil in the residential sector of SA (ABARE 2004). Emission factors were based on those for fuel oil combustion (USEPA 2003) and emissions were proportioned to each airshed by population.

Emissions from pets and humans were estimated based on an ammonia emission factor of 239 g/capita/yr (Sutton *et al* 1995). Emissions were estimated for 1998–99 and projected to 2002-03 by population in the airsheds.

VKT on unsealed roads, as collected for the 1998–99 inventory, were used to estimate unpaved road dust emissions. As for paved roads, a growth factor of 1.01 was used to project the VKT in Adelaide and 1.13 in all the other airsheds. Emission factors were based on those from USEPA (2003). However, as in paved roads, the emission factors for unpaved road dust would be too high for estimating emissions in the ambient air away from roads. A PM_{10} emission factor of 3.29 g/km, which has been reduced to 1% of the original value, was hence used. The 1% value was an order of magnitude estimate so that the inventory would not be overwhelmed by unpaved roads.

2.4 Speciation

Speciation is used to estimate emission of an air toxic as a fraction of PM_{10} or volatile organic compounds (VOC). Inorganic air toxics, such as arsenic and fluoride, are usually estimated from PM_{10} and organic air toxics, such as benzene and formaldehyde, from VOC.

Duffy *et al* (1999) measured the VOC composition of exhaust and evaporative emissions from petrol vehicles in Australia. The results from this study were used to speciate the VOC emissions from recreational boating, ballast (for unloading petrol from ships), lawn mowing and service stations.

A study published by EA (2003) measured the VOC composition from diesel vehicles in Australia. The results from this study were used to speciate the VOC emissions from railways, shipping and commercial boating. In the 1998–99 inventory, speciation profiles from diesel vehicles in the US were used.

Tran *et al* (2003) measured the particle composition from exhaust of Australian vehicles. The results from this study were used to speciate the PM_{10} emissions from railways, recreational boating and lawn mowing.

Motor vehicle emissions were speciated with AusVeh 1.0, which has included the results from the above three studies. Emissions from natural gas leakage were speciated with the natural gas composition data collected for the 1995–96 Port Phillip Region inventory of Victoria. Emissions from wood burning were speciated with the profiles obtained by CSIRO (EA 2002).

Speciation profiles for domestic gas fuel, domestic liquid fuel, briquettes and sub-threshold fuel were based on the emission factors from USEPA (2003). For domestic and sub-threshold gas fuel, chromium was split into 40% chromium (III) and 60% chromium (VI) based on the emission factors for refinery gas (CARB 2000).

For most other sources, the version of the USEPA speciation program *Speciate 3.2* (USEPA 2002) was used to speciate the emissions. VOC from aeroplanes, bakeries, domestic and commercial solvent and aerosol use, motor vehicle refinishing, printing and graphic arts, and PM_{10} from paved roads and unpaved roads were speciated with Speciate 3.2.

For PM_{10} from aeroplanes and VOC from architectural surface coatings, speciation profiles from CARB (2003) were used.

2.5 Spatial allocation

Emissions were spatially allocated to grid cells based on the methodology in the NPI manuals. The spatial allocations used in the 1998–99 inventory were adopted without change for most sources. However, distributions of population and housing were updated to that of the 2001 Census. This affected the spatial distributions of architectural surface coatings, domestic and commercial solvent and aerosol use, lawn mowing and solid fuel burning. The population data in the 2001 Census was also used to spatially allocate emissions from bakeries, domestic liquid fuel, natural gas leakage, and pets and humans.

For unpaved roads, emissions were spatially allocated according to the VKT distribution of unsealed roads. However, for the Adelaide airshed, such data was not available and the emissions were spatially allocated according to inverse population.

3 RESULTS

Table 7 compares the aggregated emissions of primary pollutants estimated for 2002–03 with those obtained for 1998–99 in the Adelaide and the five major regional airsheds. The most significant change was the lower PM_{10} emissions estimated for 2002–03 due mostly to the reduced emission factors used for paved road dust. The change was less for the regional airsheds due to the inclusion of unpaved roads, which contributed significantly to regional PM_{10} emissions. Generally, CO emissions were lower in 2002–03 due to the lower motor vehicle emission factors for CO, and oxides of nitrogen (NOx) emissions were higher due to the higher motor vehicle emission factors for NOx.

Table 7 Aggregated emissions (t/yr) in Adelaide and SA regional airsheds

Airshed	Pollutant	1998–99 inventory	2002–03 inventory
Adelaide	CO	170000	130000
	NOx	22000	28000
	PM_{10}	8400	2700
	SO_2	1200	1200
	VOC	40000	41000
Regional airsheds	CO	16000	13000
	NOx	5400	6000
	PM_{10}	2900	1800
	SO_2	420	400
	VOC	7600	8000

Table 8 shows the combined emissions and contributions from aggregated sources in the six major airsheds. The contribution column represents all aggregated sources and reporting facilities in 2002–03. Only pollutants with the highest contributions from an aggregated source are shown. Pollutants for which industry contribute most of the emission are not listed in the table. Not including industry, most of the emissions were contributed by solid fuel burning, motor vehicles, domestic and commercial solvent and aerosol use, and architectural surface coatings in the SA airsheds.

Table 8 Emissions and contributions from aggregated sources in SA airsheds

Pollutant	Emission (t/yr)	Contribution (%)
Solid fuel burning		
Acetaldehyde	60	41
Acetic acid	290	80
Acrylonitrile	7.3	100
Cadmium & compounds	0.17	38

Pollutant	Emission (t/yr)	Contribution (%)
Chloroethane	0.034	55
1, 2-Dibromoethane	0.00097	100
1, 2-Dichloroethane	0.032	100
Di-(2-Ethylhexyl) phthalate	0.059	43
Formaldehyde	240	51
Styrene	18	40
Vinyl chloride monomer	0.89	100
Motor vehicles		
Benzene	650	60
1, 3-Butadiene	67	50
Carbon monoxide	120000	62
Cobalt & compounds	0.087	50
Cyanide compounds	100	98
Cyclohexane	17	57
Ethylbenzene	123	65
n-Hexane	290	46
Toluene	980	38
Volatile organic compounds	22000	37
Domestic and commercial solvent and aerosol use		
Acetone	250	61
Chloroform	2.0	98
Ethanol	1500	64
Ethylene oxide	13	100
Glutaraldehyde	3.9	100
Methanol	350	80
Polycyclic aromatic hydrocarbons	30	39
Architectural surface coatings		
Dibutyl phthalate	0.042	95
Ethylene glycol	230	87
Methyl isobutyl ketone	120	62

Pollutant	Emission (t/yr)	Contribution (%)
Methyl methacrylate	0.23	93
Methylenebis(phenyliso-cyanate)	0.21	92
Toluene-2, 4-diisocyanate	0.035	67
Paved/Unpaved roads		
Copper & compounds	9.5	82
Lead & compounds	2.4	50
Aeroplanes		
Chromium (VI) compounds	0.32	61
Selenium & compounds	0.10	59
Dry cleaning		
Tetrachloroethylene	130	80
Service stations		
Cumene	3.1	57

Figure 2 shows the spatial distribution of VOC emissions from aggregated sources in the SA airsheds. As expected, emissions were highest around Adelaide, while emissions from the Barossa and Port Lincoln airsheds are also significant.

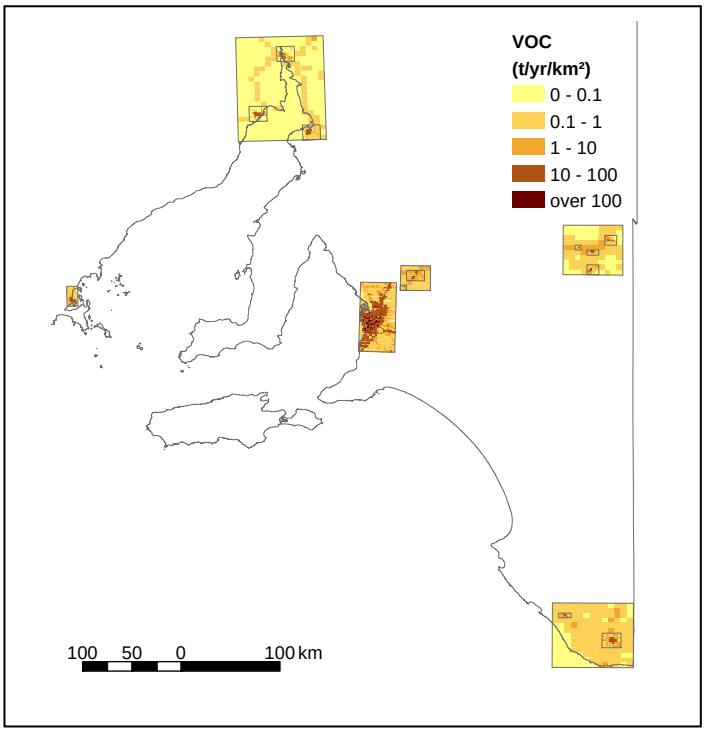

Figure 2 VOC emissions from aggregated sources in South Australian airsheds 2002–03

4 CONCLUSION

An update of the SA NPI aggregated emissions data to 2002–03, covering 17 airsheds, has been successfully completed in 2005. Emissions were updated with the latest emission and speciation factors*, and projected using population, fuel use, vehicle traffic and aircraft traffic data. Five new emission sources were added to the current inventory.

The most significant difference between the 2002–03 and 1998–99 inventories was the lower PM_{10} emissions estimated for 2002–03 due mostly to the reduced emission factors used for paved road dust. Generally, emissions of CO were lower and NOx were higher in 2002–03 due to the revised motor vehicle emission factors used for the current inventory. These improvements in the emission data will allow a greater confidence when using this data which represents one of the most comprehensive pollutant inventories in SA.

The projection methodology used in this study is based on readily available activity data, and does not require expensive and time-consuming surveys and data collections. This methodology is suitable for updating an inventory in which emissions have been estimated accurately before.

The use of EMADMS will allow further updates to be undertaken on a more regular basis, as this system provides the ability to project emissions by growth factors.

* Available at that time

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