

ANNUAL REVIEW OF AIR QUALITY MONITORING DATA – CITYLINK PROJECT

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SUMMARY

Previous reviews of the impact of the CityLink project on local air quality have been conducted on quarterly (seasonal) data provided to EPA. Now that the Domain and Burnley Tunnels have been in operation for over 12 months, EPA has reviewed all air quality data (dating back to 1997) from Translink Operations (TLO) relating to the Domain and Burnley Tunnel stacks and ambient air monitoring at Grant Street and Madden Grove. The TLO data has been compared with data from the EPA network, with the following results:

- Emissions from the ventilation stacks are well below the licence limits for nitrogen dioxide (NO₂), carbon monoxide (CO), and particles.
- PM₁₀¹ levels monitored at Madden Grove and Grant Street are similar to the EPA network medians. No change has been detected in the levels relative to the EPA network post-opening of the tunnels. Whilst exceedences of the PM₁₀

objective² (50 µg/m³) at both Madden Grove and Grant Street have occurred, elevated PM₁₀ levels are observed in the EPA network when this occurs. These results tend to indicate that CityLink emissions are not the primary source of the particle levels monitored. In 2001, the first full year of operation of both CityLink tunnels, the SEPP (Ambient Air Quality) goal of no more than five PM₁₀ exceedences per year was met at both Madden Grove and Grant Street.

- PM_{2.5}³ levels monitored at Madden Grove and Grant Street are similar to the EPA network medians. No change has been detected in the levels relative to the EPA network post-opening of the tunnels. Whilst exceedences of the PM_{2.5} target⁴ (25 µg/m³) at both Madden Grove and Grant Street have occurred,

² When assessing a works approval, the Victorian State Environment Protection Policy (SEPP) sets design ground level concentrations (dglc) that must be met to protect beneficial uses of the air environment. The dglc set for PM₁₀ was 50 µg/m³, equivalent to the objective in the current Ambient Air Quality SEPP. During the works approval process, assessment against the dglc is performed by a plume calculation procedure.

³ PM_{2.5} = particles with a diameter less than 2.5 µm.

⁴ The dglc set for PM_{2.5} was 25 µg/m³. There is currently no SEPP objective for PM_{2.5}.

¹ PM₁₀ = particles with a diameter less than 10µm

elevated PM_{2.5} levels are observed in the EPA network at these times. These results tend to indicate that CityLink emissions are not the primary cause of the particle levels monitored.

- CO levels monitored at Madden Grove and Grant Street are similar to the EPA network medians, and well within SEPP objectives.
- NO₂ levels monitored at Madden Grove and Grant Street are similar to the EPA network medians, and are well within SEPP objectives.

The analysis of air quality data has detected no impact of the emissions from the CityLink project on local air quality. EPA, however, will maintain its oversight of the project in order to detect any possible long-term trends and detrimental impacts.

1. INTRODUCTION

1.1 Background to Air Quality Monitoring at CityLink

Under the CityLink works approval, TLO is obliged to undertake a wide range of air quality monitoring and to report this information to EPA. Monitoring includes:

1. In-tunnel
2. Ventilation stack
3. Local
4. Special

In-Tunnel Monitoring

TLO's licence issued by EPA requires monitoring of visibility, carbon monoxide (CO) and oxides of nitrogen (NO_x) at several points within the tunnels. Data from this monitoring is used to control the operation of the ventilation systems for the tunnels. Air speed and direction are also continuously monitored at the exit portals. TLO operates under a licence that requires no portal emissions. All emissions are discharged via the stacks (except in the case of an emergency).

Ventilation Stack Monitoring

CO, NO_x, particulate matter (PM₁₀ and PM_{2.5}) and temperature are monitored continuously at the discharge stacks. TLO operates with a licence setting mass rates (kg/hr) for the stack discharge. Licence objectives have been set to ensure ambient air quality objectives are not exceeded.

Local Air Monitoring

EPA requires TLO to operate local air quality stations at Grant St (Southbank) and Madden Grove (Burnley) to monitor CO, NO_x, particulate matter (PM₁₀ and PM_{2.5} by TEOM⁵ and HiVol⁶) and meteorological data (temperature, wind speed and direction).

TLO has been monitoring particles (by HiVol) since April 1997, with on-line

⁵ TEOM = Tapered Element Oscillating Microbalance - an on-line method for the measurement of particles.

⁶ HiVol = Particle measurement via a high volume sampler, operating one day in six. Particles are collected on a filter paper and weighed.

measurement of particles (by TEOM), CO and NO₂ commencing in December 1999.

Special Monitoring

Numerous special monitoring programs have been initiated as part of the CityLink project. These include:

EPA Audit of TLO Stations – EPA’s mobile air monitoring laboratory (MOLAB) was located adjacent to TLO’s Southbank station from July–September 2000, in order to audit and review the TLO station.

Stack Wake Monitoring – TLO’s licence issued by EPA requires monitoring near the ventilation stack at Burnley to investigate the effect of stack wake on the dispersion of emissions. This study was initiated as a result of the independent review commissioned by EPA into Emission Control Technology on the CityLink Tunnels. EPA’s MOLAB (mobile laboratory) was located at this site prior to TLO obtaining its own mobile laboratory. The EPA study did not detect any downwash effects near the base of the Burnley ventilation stack.

Community Monitoring Station – EPA requires TLO to operate a community air

monitoring station, at sites to be nominated by a community panel. This station will be available for monitoring at completion of the stack wake monitoring program. The community panel is currently considering potential sites for this station.

1.2 Reporting of Air Quality Information

In-tunnel data is reported to EPA via E-mail on the following day.

Ventilation stack data (unvalidated) is displayed on the following day on EPA’s Web site (via a link to the Transurban Web site) (http://www.epa.vic.gov.au/Air/Citylink/stack_data.asp). A breach of the emissions limit must be reported to EPA within 24 hours of the incident. The notification must include the cause of the breach and action taken to avoid a repeat breach.

Local data (unvalidated hourly CO, NO₂ and PM₁₀) is displayed in real time on EPA’s Web site (Figure 1) (<http://www.epa.vic.gov.au/Air/Bulletins/aqbhour.asp>).

REGION	STATION	DATA READINGS						AIR QUALITY INDEX(AQI)	
		Carbon Monoxide	Ozone	Nitrogen Dioxide	Sulfur Dioxide	Particles as PM10	Visibility Reduction	STN. AQI	STN. SUMMARY
	Units	ppm	ppb	ppb	ppb	ug/m3	Bscat		
CITYLINK	Burnley	0.3		10		16.2		32	VERY GOOD
	GrantSt	0.2		5		14.4		29	VERY GOOD

Figure 1: CityLink monitoring stations on EPA’s Web site

The validated data from the *local* and *ventilation stack* monitoring is provided to EPA on a quarterly (seasonal) basis. The monitoring activities are reported in a National Association of Testing Authorities (NATA) endorsed report that is reviewed by an independent auditor. TLO prepares a quarterly report for the Community and Local Councils.

EPA has been performing a review of the quarterly data provided, which includes a comparison of the local air quality to the EPA network. The resulting report is targeted specifically to produce information that is understandable by the general public and includes some simple statistical analysis. It is tabled at the regular meetings of the Environment Management Committee (EMC), which consists of representatives from TLO, Transurban, EPA, Local Councils and the community.

2. ANALYSIS OF AIR QUALITY INFORMATION

Data was received from TLO under its licence to operate the Burnley and Domain tunnels' ventilation stacks at Madden Grove and Grant Street respectively. TLO provides EPA with:

- emission data from the stacks (total volumetric flow rates and concentrations of CO, NO₂, PM₁₀ and PM_{2.5} from each stack); and
- air quality data from TLO monitoring stations in the vicinity of each stack

(five minute and hourly concentrations of CO, NO₂, PM₁₀ and PM_{2.5}).

In order to interpret the TLO data having regard to seasonal variations and meteorological conditions, comparative data was extracted from EPA's air monitoring network.

2.1 Stack Emissions

TLO's licence is granted on the basis of controlling mass flows of pollutants from the two ventilation stacks. The licence limits, which reflect a worst case scenario under heavy, congested traffic, are detailed in Table 1.

Pollutant	Licence Limit (kg/hr)	
	Domain Tunnel	Burnley Tunnel
CO	185	417
NO ₂	4.5	10.2
PM ₁₀	1.7	5.3
PM _{2.5}	1.4	4.4

Table 1: Tunnel licence limits

Based on the total volumetric flow rates and concentrations of CO, NO₂, PM₁₀ and PM_{2.5}, the mass flows of each pollutant from each stack have been calculated since the opening of the tunnels. No breaches of the licence limits have occurred. Median hourly mass flows are typically no greater than 10% of the limits. Maximum hourly flows are typically 20–40% of the limits for the gaseous pollutants and 30–50% for particles. Figures 2–5 present monthly 1-hour median and 1-hour maximum emissions for the two stacks (expressed as percentages of the licence limits).

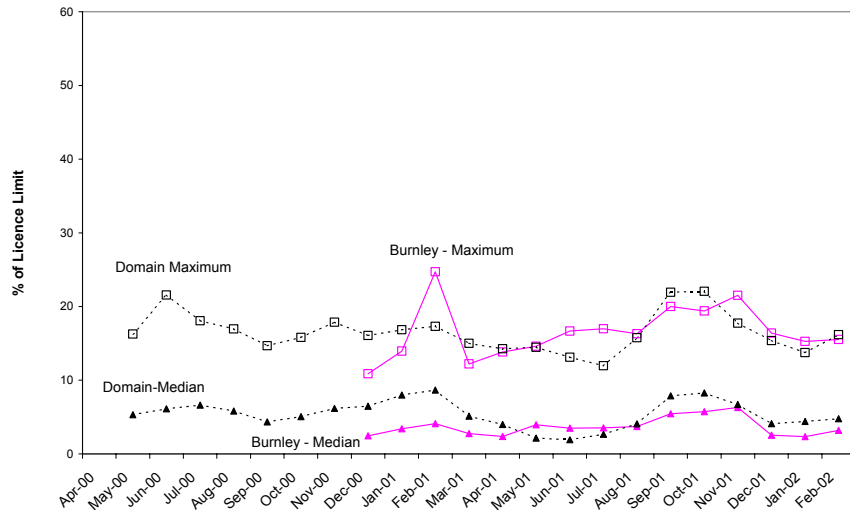


Figure 2: NO₂ Stack Emissions

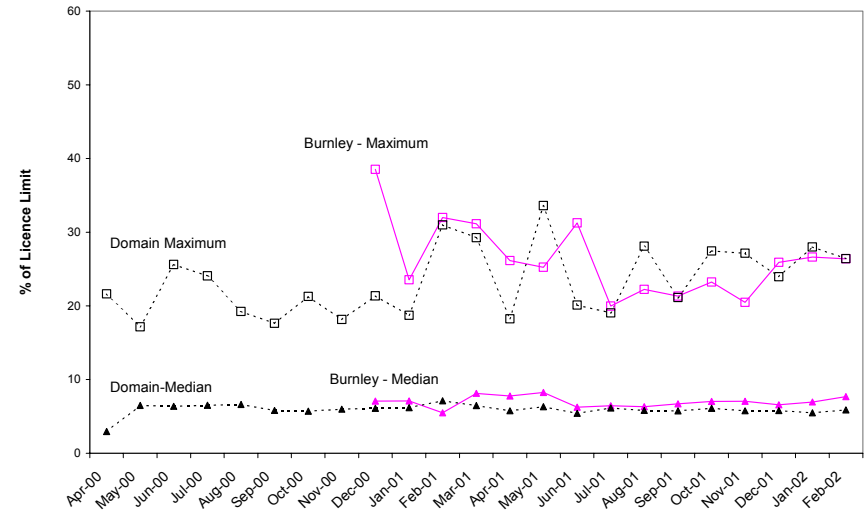


Figure 3: CO Stack Emissions

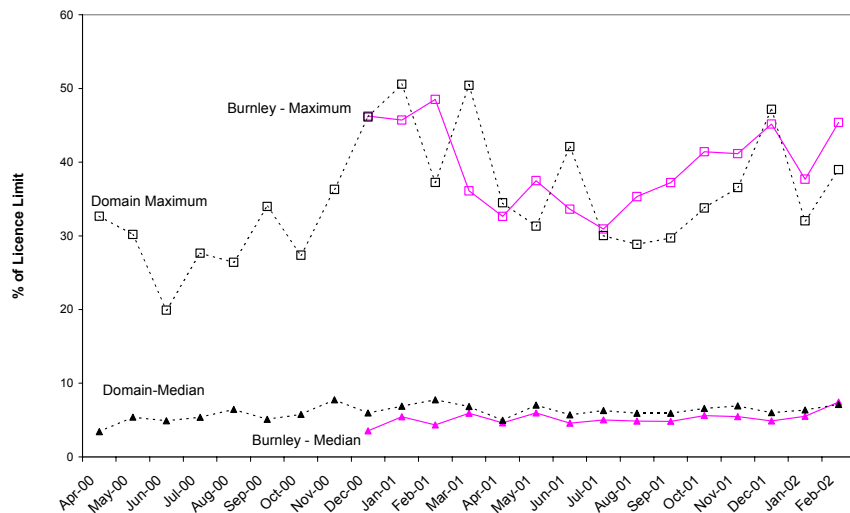


Figure 4: PM₁₀ Stack Emissions

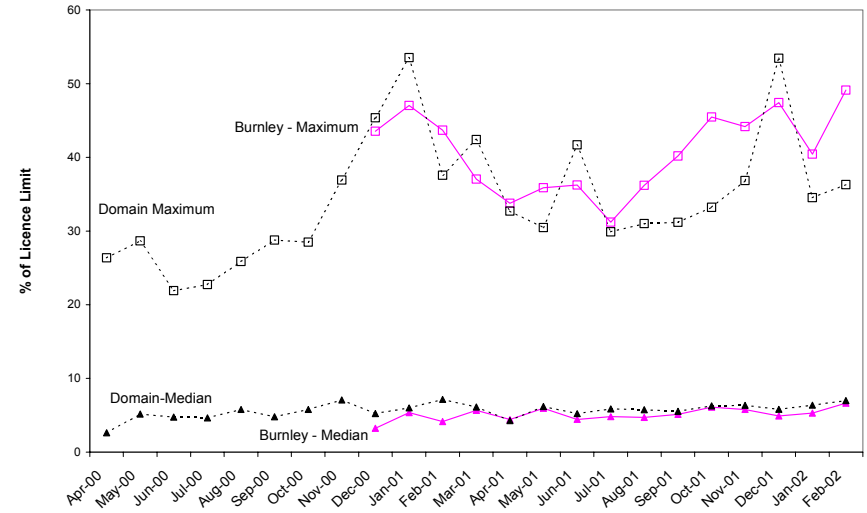


Figure 5: PM_{2.5} Stack Emissions

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Note - This document was obtained from EPA's internet site (www.epa.vic.gov.au)

2.2 LOCAL AIR QUALITY

Comparisons of data from the CityLink air monitoring stations at Madden Grove (near the Burnley Tunnel ventilation stack) and Grant St (near the Domain Tunnel ventilation stack) have been made with EPA's ambient air monitoring network. The aim of the comparisons was to determine whether:

- local air quality changed after opening of the CityLink project; and if
- there are trends in air quality at the CityLink sites different to those observed elsewhere in Melbourne.

As both the Grant Street and Madden Grove stations are near the CBD of Melbourne, where thousands of motor vehicles travel each day, elevated particle concentrations would be expected in comparison to stations in the suburbs. In addition, elevated particle levels at Grant St were noted before and after opening of the tunnels, due to the construction of an adjacent high rise building.

The indicators used in the comparisons were:

- daily average $PM_{2.5}$ ($\mu\text{g}/\text{m}^3$) and PM_{10} ($\mu\text{g}/\text{m}^3$) as measured by TEOM, compared to the EPA stations at Alphington and Brighton;

- daily average PM_{10} ($\mu\text{g}/\text{m}^3$) as measured by HiVol, as compared with the EPA station at Alphington;
- 8-hour average CO (ppm), compared to the EPA station at Alphington; and
- 1-hour average NO_2 (ppb), compared to the EPA station at Alphington.

Monthly medians and maxima have been calculated and time series corresponding to the stations have been plotted alongside each other for visual comparison (Figures 6 to 18). In addition to these time series plots, EPA has also performed:

- an analysis of short-term (1-hour average) PM_{10} levels at the CityLink sites and the EPA station at Alphington;
- a statistical analysis comparing results at the CityLink sites and the EPA network (see Appendix 1 for details of the methodology); and
- an analysis of any exceedences recorded.

Results of these analyses are presented in the following sections.

2.2.1 Airborne Particles – PM_{10}

Time Series Plots (Figures 6–9)

PM_{10} levels (both median and maximum) appear to be elevated at Grant Street and Madden Grove in comparison to the EPA

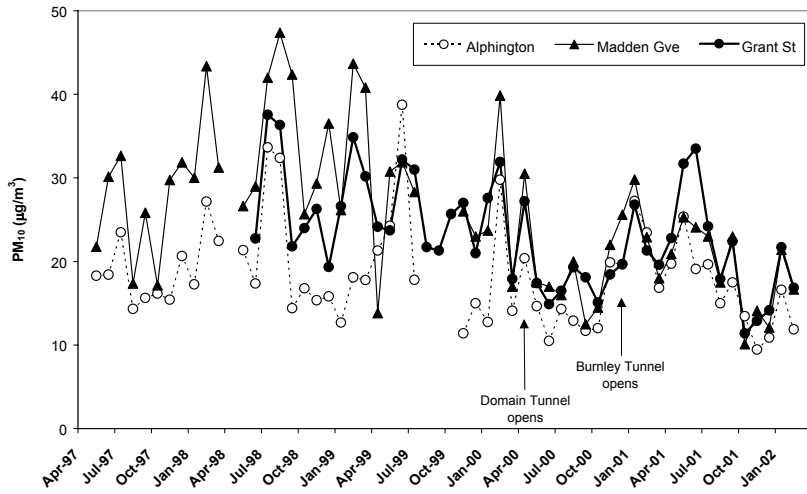


Figure 6: Monthly Median of 24-hr PM_{10} (HiVol)

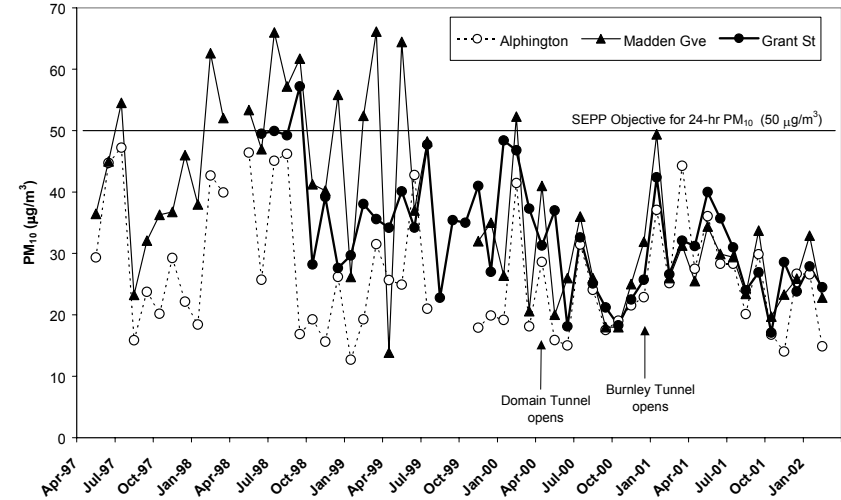


Figure 7: Monthly Maxima of 24-hr PM_{10} (HiVol)

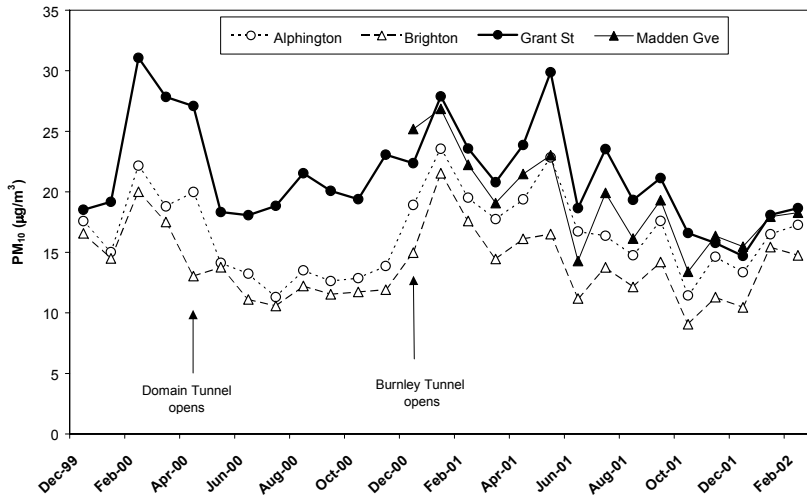


Figure 8: Monthly Median of 24-hr PM_{10} (TEOM)

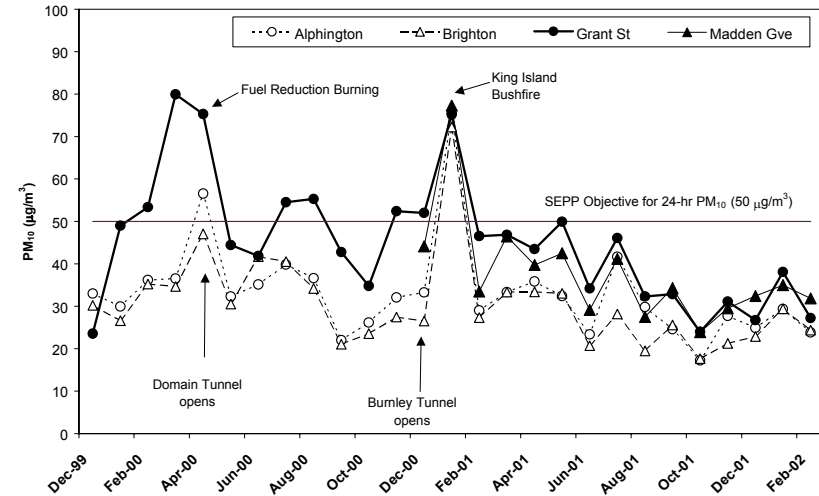


Figure 9: Monthly Maxima of 24-hr PM_{10} (TEOM)

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Note - This document was obtained from EPA's internet site (www.epa.vic.gov.au)

network⁷, not an unexpected result given the high traffic densities near the CBD. It is important to note, however, that this observation was apparent even before any of the CityLink tunnels opened, indicating that inner city sources of particles by themselves have caused the elevation in levels. The elevation appears stronger for Grant St than Madden Grove. Median levels near CityLink range from 13–31 $\mu\text{g}/\text{m}^3$, in comparison with 10–24 $\mu\text{g}/\text{m}^3$ at the EPA stations. Again, the CityLink stations tend to track the general trend in levels observed in the EPA network.

In addition to these time series plots on the daily PM_{10} data, a comparison of the short-term (1-hour) PM_{10} TEOM data has been made between the CityLink operated

stations and the EPA station at Alphington, over the period since both tunnels have opened. These results again indicate the same small elevation in levels at Grant St and Madden Grove (as with the daily data). A similar comparison in 1-hour PM_{10} levels is seen between the CityLink stations at Grant St and Madden Grove and the EPA station at Alphington (see Figure 10). Very high 1-hour PM_{10} levels ($>100 \mu\text{g}/\text{m}^3$) are evident less than 0.1–0.2% of the time⁹. Median 1-hour PM_{10} levels are similar between the Alphington and the CityLink stations (see Table 2). Selected higher percentiles are also shown in Table 2. After excluding the effect of the King Island fire in January 2001, the highest maximum 1-hour PM_{10} level was recorded at Alphington.

1-hour PM_{10} by TEOM ($\mu\text{g}/\text{m}^3$)				
Period	Value	Grant St	Madden Gv	Alphington
Both Tunnels Open	Median	18.8	17.1	15.8
	90 th Percentile	37.8	34.6	29.8
	99 th Percentile	71.4	62.5	50.0
	Maximum ⁸	138.4	136.7	151.8

Table 2: Median and maximum particles (1-hour PM_{10})

⁷ Alphington and Brighton were used as the EPA comparative stations.

⁸ Data from the period of the King Island fire was not included in calculating the maximum 1-hour PM_{10} .

⁹ The majority of the high 1-hour PM_{10} levels were recorded across Melbourne during the King Island fire in January 2001.

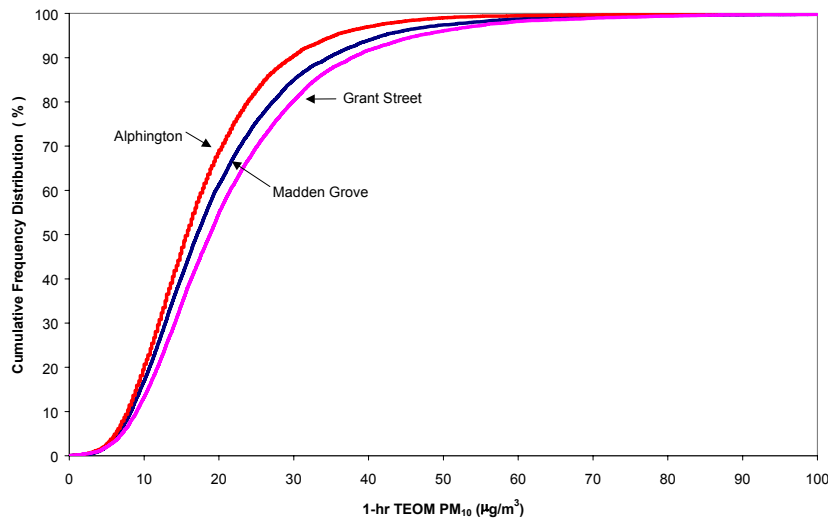


Figure 10: Frequency distribution of 1-hour PM₁₀ levels (both tunnels open)

Statistical Analysis

Comparisons of median and maximum PM₁₀ levels (both TEOM and HiVol) between Madden Grove and Grant Street and the EPA network are shown in Tables 3 and 4. For PM₁₀, the air quality at both CityLink sites is similar to the EPA network median. PM₁₀ levels at the two CityLink sites post-opening of both the tunnels are only slightly elevated above EPA network median levels (~3–5 µg/m³ higher). Note that this elevation is a continuation of the trend observed prior to opening of the tunnels (when the elevation may have been even higher). Median levels also have not increased since opening of the tunnels. Results of t-tests¹⁰ performed are shown in Appendix 1.

¹⁰ The 'Student t-test' is a widely used tool for testing statistical significance.

Exceedences of the PM₁₀ Objective

Exceedences of the SEPP PM₁₀ objective of 50 µg/m³ (which is a reflection of the National Environment Protection Measure – NEPM) have been observed at Grant Street and Madden Grove. However, elevated particle levels (including exceedences) were seen across the EPA network on the days that exceedences occurred at Madden Grove or Grant Street. Table 5 lists PM₁₀ exceedences¹¹ of the SEPP recorded at the CityLink operated monitoring stations. A comparison to the maximum EPA network¹² value is also given in this table. The SEPP goal is to have no more than five exceedences per year (within 10 years).

¹¹ PM₁₀ exceedences are shown as recorded by HiVol and TEOM monitoring. From 2002 onwards, EPA will be applying a NEPM approved adjustment factor to its TEOM measurements, in order to give equivalence to HiVol data.

¹² All stations in the EPA network are considered in the comparison shown in Table 5.

24-hour PM ₁₀ by TEOM (µg/m ³)							
Period ¹³	Value	Grant St	EPA Network	Difference	Madden Gv	EPA Network	Difference
Prior to Opening of Tunnels	Median	25.9	17.3	+8.6	-	-	-
	Max	79.9	56.6	-			
Domain Tunnel Open	Median	20.5	13.1	+7.4	28.4	19.0	+9.4
	Max	55.3	41.7	-	44.1	41.7	-
Both Tunnels Open	Median	20.5	15.1	+5.3	18.7	15.2	+3.5
	Max	75.2	75.5	-	77.3	75.5	-

NB. EPA Network = Alphington and Brighton

Table 3: Median and maximum particles (24-hour PM₁₀) as measured by TEOM

24-hour PM ₁₀ by HiVol (µg/m ³)							
Period	Value	Grant St	EPA Network	Difference	Madden Gv	EPA Network	Difference
Prior to Opening of Tunnels	Median	26.6	17.5	+9.1	29.3	18.2	+11.1
	Max	57.2	52.4	-	66.1	52.4	
Domain Tunnel Open	Median	17.4	13.9	+3.5	18.0	13.3	+4.7
	Max	37.0	31.4	-	36.0	31.4	-
Both Tunnels Open	Median	20.8	16.7	+4.1	21.2	16.7	+4.4
	Max	42.4	44.7	-	49.4	44.7	-

NB. EPA Network = Alphington

Table 4: Median and maximum particles (24-hour PM₁₀) as measured by HiVol

¹³ The median is calculated using data from the EPA network at the same times as when valid readings are available from the TLO monitoring site being investigated. As a consequence, the network medians used in the Grant Street and Madden Grove comparisons may differ slightly. However, this will allow more rigorous comparisons to be made. See Appendix 1 for further details on the periods being compared.

Tunnels Opened	Year	Date	Grant St	Madden Gv	EPA Network		Comments
					Max	Station	
Prior to Opening of the Tunnels	1997	1 Jul	-	54.5	54.9	Collingwood	HiVol
	1998	26 Feb	-	62.6	55.6	Collingwood	HiVol
		22 Mar	-	52.1	54.2	RMIT	HiVol
		3 May	-	53.3	50.0	Collingwood	HiVol
		14 Jul	49.9	66.0	55.8	Collingwood	HiVol
		31 Aug	49.2	57.2	41.4	Paisley	HiVol
		30 Sep	57.2	61.7	22.4	Paisley	HiVol
		11 Dec	-	55.8	39.2	Collingwood	HiVol
	1999	3 Feb	38.1	52.4	33.2	Collingwood	HiVol
		11 Mar	31.9	66.1	38.7	RMIT	HiVol
		4 May	40.1	64.4	46.1	Collingwood	HiVol
	2000	4 Feb	53.4	-	49.8	Dandenong	TEOM
		4 Feb	46.8	52.3	50.7	Paisley	HiVol
		9 Mar	79.9	-	32.8	Box Hill	TEOM
		12 Apr*	75.3	-	74.5	Dandenong	TEOM
17 Jul		54.5	-	40.5	Brighton	TEOM	
1 Aug		55.3	-	36.6	Brighton	TEOM	
28 Nov		52.4	-	39.7	Footscray	TEOM	
Domain Tunnel Open	21 Dec	52.0	44.1	33.7	Alphington	TEOM	
	2001	11 Jan**	55.0	61.3	44.7	Brighton	TEOM
Both Tunnels Open	12 Jan**	75.2	77.3	72.6	Alphington	TEOM	

* Fuel reduction burning on 12 April 2000

** King Island Bushfire on 11 and 12 January 2001

Table 5: PM₁₀ Exceedences (shaded cells)

It is important to note, that exceedences of the PM₁₀ objective occurred at both Madden Grove and Grant Street prior to the opening of the CityLink tunnels (although readings during this time may have been elevated due to construction work around the Grant Street station). In 2001, which represents the first full year of operation of both tunnels, there were two exceedences of the PM₁₀ objective (hence the SEPP goal was met). However, both these exceedences occurred as a result of the King Island bushfire elevating particle levels across Melbourne. In 2000, there were seven exceedences, of which three occurred prior

to the opening of the tunnels, and four occurred while only the Domain tunnel was open. In general, elevated particle levels are seen across the EPA network on the days that exceedences occurred at Madden Grove or Grant Street. The data tends to indicate that CityLink emissions are not the primary cause of the PM₁₀ exceedences observed.

2.2.2 Airborne Particles – PM_{2.5}

Time Series Plots (Figures 11–14)

PM_{2.5} levels (both median and maximum) appear to be elevated at Grant Street and Madden Grove, in comparison with the EPA network¹⁴. As with PM₁₀, the same situation was apparent even before any of the CityLink tunnels opened, suggesting that inner city sources of particles by themselves are likely to have caused the elevation in levels.

Median levels of the order of 10 µg/m³ are observed, well below the target applied for modelling purposes. The CityLink stations also track the general levels observed in the EPA network. These results tend to indicate that CityLink is not the dominant factor influencing air quality at Madden Grove and Grant Street. Note, that peaks in PM_{2.5} were observed in April 2000 (fuel reduction burning in outer Melbourne, prior to the opening of the Domain Tunnel on 16 April 2000) and in January 2001 (the King Island Bushfire).

Statistical Analysis

For PM_{2.5}, the fine particles most frequently associated with motor vehicle exhaust, median levels do not appear to have changed significantly since opening of the tunnels. Comparisons of median and maximum PM_{2.5} levels (both TEOM and HiVol) between Madden Grove and Grant Street and the EPA network are shown in Tables 6 and 7. For PM_{2.5}, the air quality at both CityLink sites is similar to the EPA network median. PM_{2.5} levels at the two CityLink sites post-opening of the tunnels are only slightly elevated above EPA network median levels (~2 µg/m³ higher). This elevation is a continuation of the trend observed prior to the tunnels opening. Median levels also have not increased since the opening of the tunnels. Results of t-tests performed (see Appendix 1) indicate that there has not been a statistically significant change in the difference between the CityLink and EPA stations since the opening of both tunnels.

¹⁴ Alphington and Brighton were used as the EPA comparative stations.

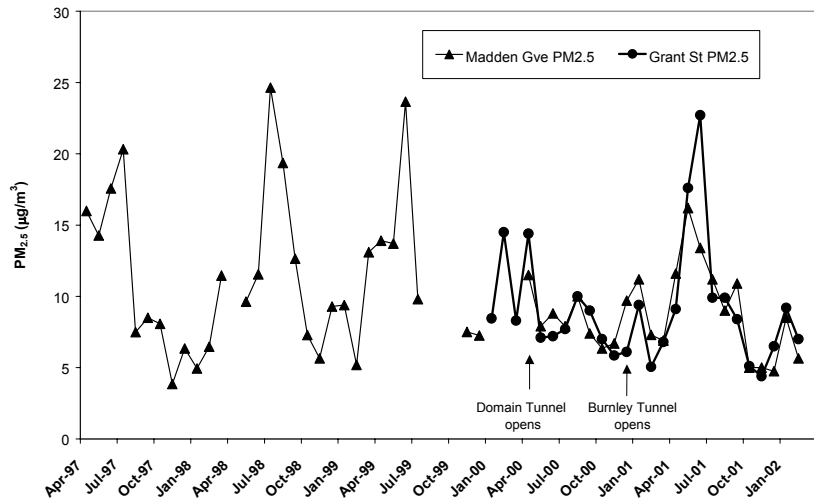


Figure 11: Monthly Median of 24-hr PM_{2.5} (HiVol)

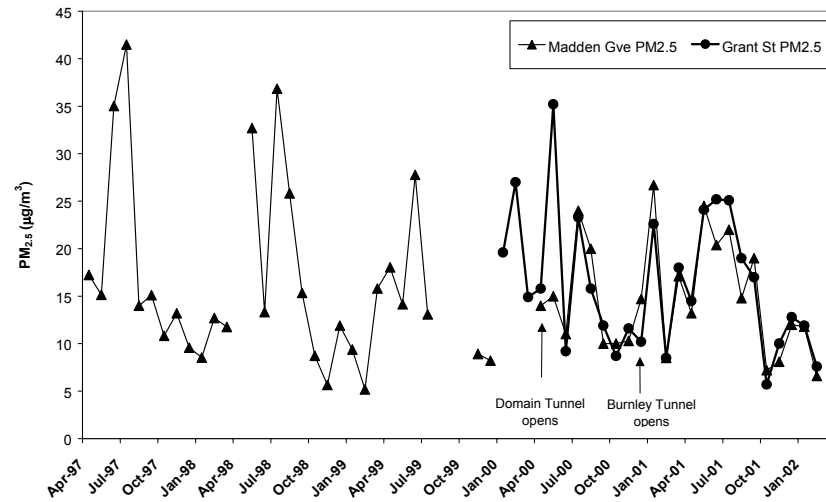


Figure 12: Monthly Maxima of 24-hr PM_{2.5} (HiVol)

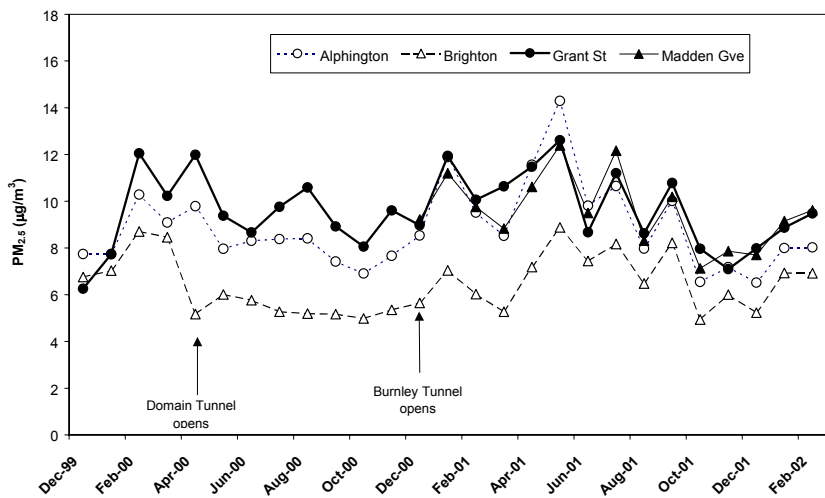


Figure 13: Monthly Median of 24-hr PM_{2.5} (TEOM)

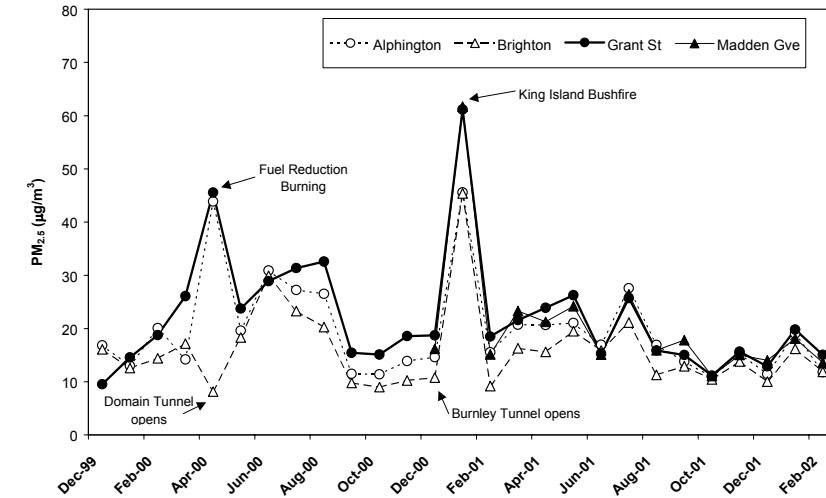


Figure 14: Monthly Maxima of 24-hr PM_{2.5} (TEOM)

PM _{2.5} by TEOM (µg/m ³)							
Period	Value	Grant St	EPA Network	Difference	Madden Gv	EPA Network	Difference
Prior to Opening of Tunnels	Median	9.9	7.9	+2.0	-	-	-
	Max	45.6	43.9	-			
Domain Tunnel Open	Median	9.2	6.8	+2.4	10.2	8.4	+1.8
	Max	32.6	30.9	-	16.2	30.9	-
Both Tunnels Open	Median	9.5	7.6	+1.9	9.2	7.6	+1.6
	Max	61.2	45.6	-	61.7	45.6	-

NB. EPA Network = Alphington and Brighton

Table 6: Median and Maximum Particles (PM_{2.5}) as measured by TEOM

PM _{2.5} by HiVol (µg/m ³)			
Period	Value	Grant St	Madden Gv
Prior to Opening of Tunnels	Median	-	-
	Max	27.0	41.5
Domain Tunnel Open	Median	7.3	8.3
	Max	35.2	24.0
Both Tunnels Open	Median	8.4	8.2
	Max	25.2	26.7

NB. EPA does not monitor PM_{2.5} by HiVol

Table 7: Median and Maximum Particles (PM_{2.5}) as measured by HiVol

Exceedences of the PM_{2.5} Target

The ambient air quality SEPP sets the health-based environmental quality objectives to be met in Victoria. The SEPP mirrors objectives set in the NEPM. Whilst a PM_{2.5} objective is yet to be set, a target of 25 µg/m³ (24-hour objective) was set as the design criterion in CityLink modelling. Table 8 shows exceedences of the PM_{2.5} target set as part of the CityLink design criteria. A comparison to the maximum EPA network¹⁵ value is also given in this table. The EPA network does not monitor PM_{2.5} by HiVol.

Again, it is important to note that exceedences of the PM_{2.5} target occurred at both Madden Grove and Grant Street prior to the opening of the CityLink tunnels (although readings during this time may have been elevated due to construction work near the Grant Street station). In 2001, which represents the first full year of operation of both tunnels, there were seven exceedences of the PM_{2.5} target adopted for the CityLink project. However, two of these exceedences occurred as a result of the King Island bushfire elevating particle levels across Melbourne. In general, elevated particle levels are seen across the EPA network on the days that exceedences occurred at Madden Grove or Grant Street.

¹⁵ All stations in the EPA network are considered in the comparison shown in Table 8.

Tunnels Opened	Year	Date	Grant St	Madden Gv	EPA Network Maximum		Comments	
					Max	Station		
Prior to Opening of the Tunnels	1997	1 Jun	-	35.0	-	-	HiVol	
		19 Jun	-	32.0	-	-	HiVol	
		1 Jul	-	41.5	-	-	HiVol	
	1998	3 May	-	32.7	-	-	HiVol	
		14 Jul	-	36.8	-	-	HiVol	
		26 Jul	-	36.8	-	-	HiVol	
		19 Aug	-	25.8	-	-	HiVol	
	1999	27 Jun	-	27.8	-	-	HiVol	
	Domain Tunnel Open	2000	10 Feb	27.0	-	-	-	HiVol
			9 Mar	26.1	-	10.9	Footscray	TEOM
12 Apr*			45.6	-	43.9	Alphington	TEOM	
10 May			35.2	-	-	-	HiVol	
12 Jun			28.9	-	30.9	Alphington	TEOM	
13 Jun			28.3	-	29.9	Brighton	TEOM	
17 Jul			31.4	-	27.2	Alphington	TEOM	
1 Aug			32.6	-	26.5	Alphington	TEOM	
Both Tunnels Open	2001	11 Jan**	27.5	28.5	26.6	Alphington	TEOM	
		11 Jan**	22.6	26.7	-	-	HiVol	
		12 Jan**	61.2	61.7	49.7	Richmond	TEOM	
		4 May	26.3	24.2	21.1	Alphington	TEOM	
		4 Jun	25.2	20.4	-	-	HiVol	
		2 Jul	25.7	23.6	25.7	Alphington	TEOM	
		4 Jul	25.1	21.7	-	-	HiVol	
		24 Jul	21.9	26.4	27.6	Alphington	TEOM	

* Fuel reduction burning on 12 April 2000
 ** King Island Bushfire on 11 and 12 January 2001

Table 8: PM_{2.5} Exceedences based on CityLink targets (shaded cells)

In 2000, there were eight exceedences of the PM_{2.5} target, of which three occurred prior to the opening of the tunnels, and five occurred while only the Domain tunnel was open.

2.2.3 Carbon Monoxide (CO)

Time Series Plots (Figures 15–16)

Maximum CO levels recorded at the CityLink stations and at Alphington are similar and all within the SEPP objective of 9 ppm (8-hour average). Median levels recorded at all stations are similar and

typically less than 0.6 ppm. Strong seasonal variation in CO is evident in both Figures 15 and 16. This is believed to be related to the seasonal variation in meteorology across the Melbourne region.

Statistical Analysis

Comparisons of median and maximum 8-hour CO levels between Madden Grove and Grant Street and the EPA station at Alphington are shown in Table 9. For CO, the air quality at both CityLink sites is

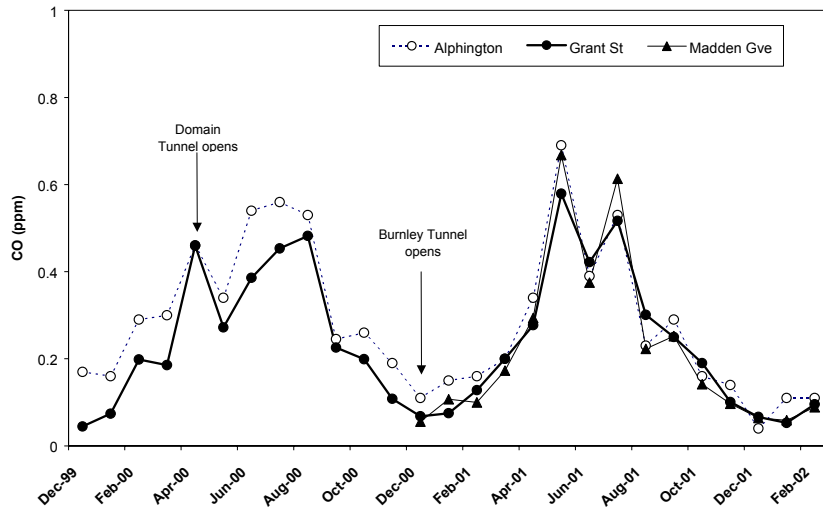


Figure 15: Monthly Median of 8-hr CO

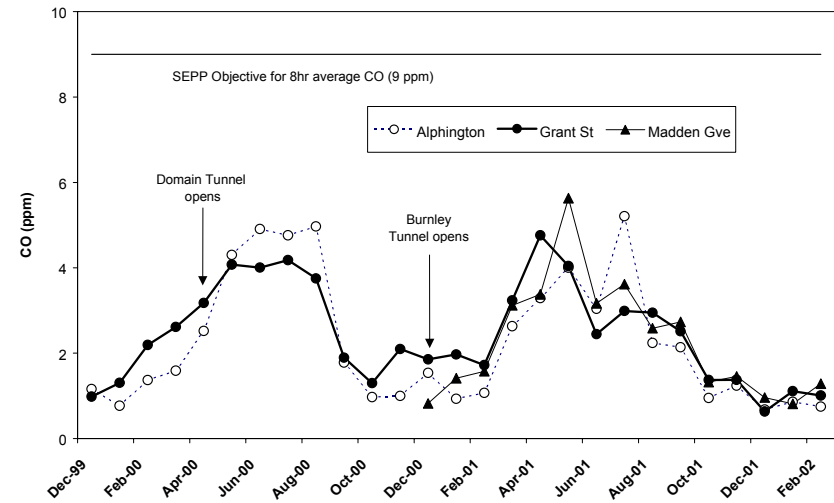


Figure 16: Monthly Maxima of 8-hr CO

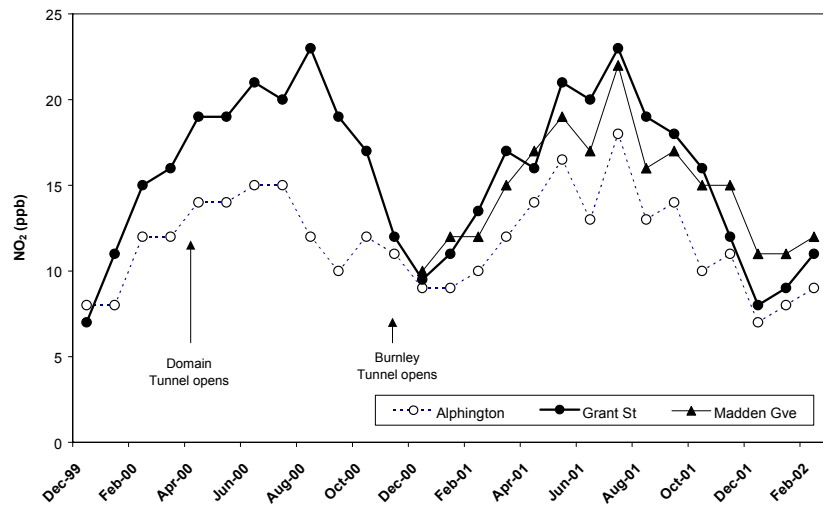


Figure 17: Monthly Median of 1-hr NO₂

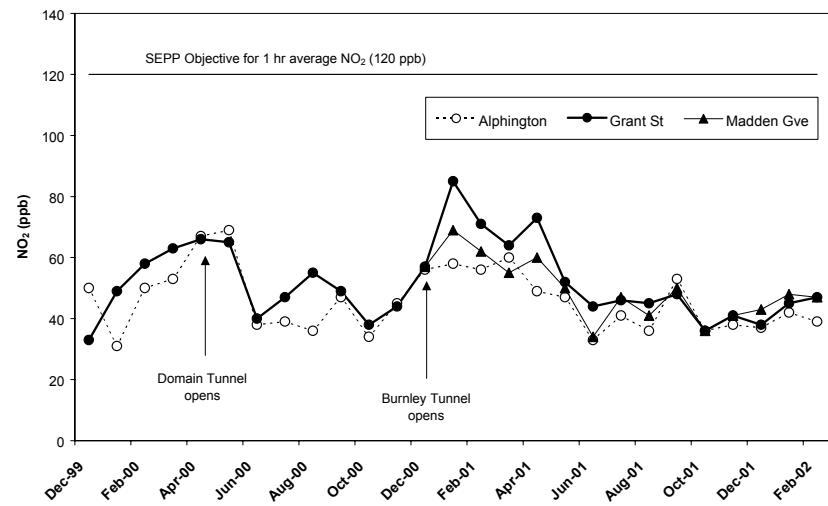


Figure 18: Monthly Maxima of 1-hr NO₂

8-hr Carbon Monoxide (ppm)				Policy Objective = 9.0 ppm			
Period	Value	Grant St	EPA Network	Difference	Madden Gv	EPA Network	Difference
Prior to Opening of Tunnels	Median ¹⁶	0.66	0.49	+0.18	-	-	-
	Max	2.61	1.69	-			
Domain Tunnel Open	Median	0.73	0.68	+0.05	0.21	0.34	-0.13
	Max	4.19	4.97	-	0.82	4.97	-
Both Tunnels Open	Median	0.53	0.47	+0.06	0.48	0.46	+0.03
	Max	4.76	5.21	-	5.63	5.21	-

NB. EPA Network = Alphington

Table 9: Median and Maximum 8-hr Carbon Monoxide Levels

similar to the Alphington median. CO levels at the two CityLink sites post-opening of both the tunnels appear slightly elevated relative to the median levels at Alphington (<0.1 ppm higher). However, the elevation is not statistically significant. This elevation is a continuation of the trend observed prior to the tunnels opening (when the elevation may have been even higher). Median levels also have not increased since the opening of the tunnels. Results of t-tests performed (see Appendix 1) indicate that there has been no statistically significant change in the difference between the CityLink stations and Alphington since the opening of the tunnels.

Exceedences

There have been no exceedences of the 8-hour CO objective at either the Grant Street or Madden Grove air monitoring stations. The maximum levels of CO recorded have

been 5.6 ppm at Madden Grove and 4.8 ppm at Grant Street. In comparison, the maximum level recorded at Alphington over this period was 5.2 ppm.

2.2.4 Nitrogen Dioxide (NO₂)

Time Series Plots (Figures 17–18)

NO₂ levels reported at the CityLink stations were all within the objective of 120 ppb. Both Grant Street and Madden Grove monthly median NO₂ concentrations were, on average, between 25% and 30% higher than those of Alphington, which is most likely due to the relatively higher road traffic densities around the City Link stations compared to Alphington. However, monthly NO₂ maxima were only about 12% higher on average at Grant Street compared with Alphington, and approximately 7% higher at Madden Grove compared with Alphington. Figure 17 shows

¹⁶ Median = Analysis is based on the maximum 8-hr CO level recorded each day

a strong seasonal pattern in median hourly average NO₂. These seasonal variations, like the seasonal variations in CO, are believed to correspond with the regular changes in Melbourne's meteorology throughout the year.

Statistical Analysis

Comparisons of median and maximum 1-hour NO₂ levels between Madden Grove and Grant Street and Alphington are shown in Table 10. For NO₂, the air quality at both CityLink sites is similar to the Alphington median. NO₂ levels at the two CityLink sites post-opening of both the tunnels are only slightly elevated above median levels at Alphington (~3-4 ppb higher) This elevation is a continuation of the trend observed prior to the tunnels opening.

Results of t-tests performed (see Appendix 1) indicate that there has been no statistically significant change in the difference between the median NO₂ levels at the CityLink stations and Alphington since the opening of the tunnels.

Exceedences

There have been no exceedences of the 1-hour NO₂ objective at either the Grant St or Madden Grove air monitoring stations. The maximum levels of NO₂ recorded have been 84.8 ppb at Grant Street and 69.3 ppb at Madden Grove (4 January 2001). In comparison, the maximum level recorded at Alphington over this period was 69.0 ppb.

1-hr Nitrogen Dioxide (ppb)			Policy Objective = 120 ppb				
Period	Value	Grant St	EPA Network	Difference	Madden Gv	EPA Network	Difference
Prior to Opening of Tunnels	Median ¹⁷	24.5	22.5	+2.0	-	-	-
	Max	66.0	67.0	-	-	-	-
Domain Tunnel Open	Median	29.0	25.0	+4.0	19.4	19.5	-0.1
	Max	65.0	69.0	-	57.4	69.0	-
Both Tunnels Open	Median	27.0	23.0	+4.0	25.6	23.0	+2.6
	Max	84.8	60.0	-	69.3	60.0	-

NB. EPA Network = Alphington

Table10: Median and Maximum Nitrogen Dioxide Levels

¹⁷ Analysis based on the maximum 1-hr NO₂ level recorded each day

3. CONCLUSION

The combination of in-tunnel, ventilation stack, local and stack wake monitoring provides EPA with a comprehensive system to identify and proactively manage ambient air quality issues that may arise from the CityLink project. The range of targeted monitoring and research has detected no impact associated with CityLink on local air quality in the vicinity of the project. EPA, however, has an on-going role ensuring that CityLink is operated within its licence conditions controlling ventilation stack discharges and portal emissions. In this role, EPA has a commitment to:

- investigate any exceedences of ambient air quality objectives – this is essential for addressing the impacts on human health and well-being; and
- assess trends in air quality through comparison of TLO data with the EPA network over the longer term – by assessing trends, EPA will be in a position to proactively identify and address the potential impacts of CityLink on ambient air quality.

APPENDIX 1: STATISTICAL METHODS AND RESULTS

Data used in statistical comparisons

Objectives for air quality are listed in the State Environment Protection Policy (Ambient Air Quality) – the SEPP. These objectives are based on environmental and health-related studies undertaken by EPA and elsewhere. Care was therefore taken to ensure that the particular form of data used in statistical comparisons were those that best reflected attainment of SEPP objectives. Variables derived for statistical comparisons were:

- Daily maxima of 8-hour average CO (ppm)
- Daily maxima of 1-hour average NO₂ (ppb)
- 24-hour average TEOM PM₁₀ (µg/m³)
- 24-hour average TEOM PM_{2.5} (µg/m³)
- 24-hour average HiVol PM₁₀ (µg/m³)

Data transformations

Air pollutants tend to show a variety of distribution types, some of which are not consistent with the normal distributions required in statistical analyses such as regression analysis, t-test and analysis of variance. The underlying theoretical assumptions upon which statistical tests are based must be satisfied in order for the resulting tests to be interpretable. For this reason monotonic data transformations were applied to change the scales of the indicators so that parametric statistical tests could be applied. These transformations do not affect the truth of fundamental assertions about the data, ie. if the medians of transformed data from two stations are found to be different then the corresponding untransformed medians will also be different.

Melbourne 'background' concentrations

Stations selected to represent Melbourne background levels were Alphington and Brighton. CO, NO₂ and HiVol PM₁₀ data were only available at Alphington. TEOM PM₁₀ and PM_{2.5} were available at both Alphington and Brighton. Comparative HiVol PM_{2.5} data is not available in the EPA network of stations.

Comparison with background levels

Gas and particle concentrations measured at Madden Grove and Grant Street were compared to concentrations measured at the EPA 'background' stations, over the period between completion of CityLink and the end of February 2002. Statistical comparisons were based on the paired differences between transformed data from each CityLink station and the means of transformed data from the 'background' stations. The effects of pairing were to:

- ensure that the comparison is only made using days when data were available at all stations; and
- remove large-scale seasonal effects or trends tending to occur across the entire airshed.

It should be noted that differences between variables that have been log-transformed are equivalent to logarithms of ratios of the original variables. Comparisons based on variables that have been log-transformed are therefore more appropriately expressed in terms of ratios rather than differences.

Results of these comparisons are presented in the summary tables (Tables A1.2–A1.4).

Adjustments for background levels

It can sometimes be difficult to discern local variations in air quality from those acting over a more widespread area, and analysis of the local ambient data by itself may erroneously attribute changes in air quality to local sources. For this reason, the local ambient data were adjusted for 'background' air quality variation, where 'background' consisted of average pollution levels measured by the EPA ambient air quality monitoring network. Adjusted data were derived for each air pollutant at each CityLink monitoring station by performing a regression analysis of the (transformed) CityLink ambient concentrations on EPA network average concentrations, and then saving the regression residuals. The residuals can be interpreted as being the variation remaining after the 'background' variation has been removed.

Tests for change in adjusted data

These analyses were concerned with changes in air quality in the suburban area local to each exhaust stack following the openings of the Domain and Burnley Tunnels.

Three periods of interest for comparisons were:

- the period prior to opening of the Domain Tunnel (i.e. no tunnels are open);

- the period after opening of the Domain Tunnel but before opening of the Burnley Tunnel and
- the period after opening of the Burnley Tunnel (ie. both tunnels are open).

Date ranges for the various comparisons used are shown in Table A1.1.

		Prior to Tunnels Opening	Domain Tunnel Open	Both Tunnels Open
CO	Madden Gv	1 Dec 00–15 Apr 00	16 Apr 00–21 Dec 00	22 Dec 00–28 Feb 02
	Grant Street	23 Dec 99–15 Apr 00	16 Apr 00–21 Dec 00	22 Dec 00–28 Feb 02
NO₂	Madden Gv	1 Dec 00–15 Apr 00	16 Apr 00–21 Dec 00	22 Dec 00–28 Feb 02
	Grant Street	23 Dec 99–15 Apr 00	16 Apr 00–21 Dec 00	22 Dec 00–28 Feb 02
TEOM particles	Madden Gv	1 Dec 00–15 Apr 00	16 Apr 00–21 Dec 00	22 Dec 00–28 Feb 02
	Grant Street	23 Dec 99–15 Apr 00	16 Apr 00–21 Dec 00	22 Dec 00–28 Feb 02
HiVol particles	Madden Gv	20 Apr 97–15 Apr 00	16 Apr 00–21 Dec 00	22 Dec 00–28 Feb 02
	Grant Street	2 Jun 98–15 Apr 00	16 Apr 00–21 Dec 00	22 Dec 00–28 Feb 02

Table A1.1: Periods of data available from CityLink stations:

Statistically significant differences in adjusted indicator values between these three periods can be interpreted as changes relative to the background air quality. Two types of statistical analysis were performed using the adjusted data, depending on the availability of data from the first of the above periods. If insufficient data were available from the first period, then mean adjusted indicator values for the latter two periods were compared using a Two-sample t-test. If sufficient data were available from all three periods, then the mean adjusted indicator values for the three periods were compared using One-way Analysis of Variance. If the Analysis of Variance detected a significant variation between means, then a Multiple Range Test was undertaken to independently compare the means of each period against the means of the other two periods.

The particular comparison of interest relates to whether concentrations post-opening of both tunnels differ significantly from levels prior to the tunnels opening after adjustment for Melbourne ambient levels. Results of these comparisons are presented in the summary tables (Tables A1.2–A1.4)

24-hour TEOM PM ₁₀ (µg/m ³) at Grant Street (December 1999 to February 2002)			
Median concentration for each CityLink stage			
Period	Prior to Tunnels Opening	Domain Tunnel Open	Both Tunnels Open
Date Range	23 Dec 99–15 Apr 00	16 April 00–21 Dec 00	22 Dec 00–28 Feb 02
Number of Samples (n)	107	218	395
Grant Street median	25.9	20.50	20.46
EPA network median	17.3	13.12	15.12
Ratio of Grant St median to EPA network median	1.50	1.56	1.35
Result of statistical test against Pre-Opening levels	-	not significant at α = 0.05	decrease significant at α = 0.05
Estimated % change in ratio of Grant St to EPA network medians	-	none detected	approx. - 10%

24-hour TEOM PM _{2.5} (µg/m ³) at Grant Street (December 1999 to February 2002)			
Median concentration for each CityLink stage			
Period	Prior to Tunnels Opening	Domain Tunnel Open	Both Tunnels Open
Date Range	23 Dec 99–15 Apr 00	16 April 00–21 Dec 00	22 Dec 00–28 Feb 02
Number of Samples (n)	98	241	388
Grant Street median	9.87	9.19	9.48
EPA network median	7.86	6.79	7.62
Ratio of Grant St median to EPA network median	1.26	1.35	1.24
Result of statistical test against Pre-Opening levels	-	increase significant at α = 0.05	not significant at α = 0.05
Estimated % change in ratio of Grant St to EPA network medians	-	approx 7%	none detected

24-hour HiVol PM ₁₀ (µg/m ³) at Grant Street (June 1998 to February 2002)			
Median concentration for each CityLink stage			
Period	Prior to Tunnels Opening	Domain Tunnel Open	Both Tunnels Open
Date Range	2 Jun 98–15 Apr 00	16 April 00–21 Dec 00	22 Dec 00–28 Feb 02
Number of Samples (n)	86	40	68
Grant Street median	26.65	17.40	20.80
Alphington median	17.50	13.94	16.75
Ratio of Grant St median to Alphington median	1.52	1.25	1.24
Result of statistical test against Pre-Opening levels	-	decrease significant at α = 0.05	decrease significant at α = 0.05
Estimated % change in ratio of Grant St to Alphington medians	-	approx -18%	approx -18%

24-hour HiVol PM ₁₀ (µg/m ³) at Madden Grove (April 1997 to February 2002)			
Median concentration for each CityLink stage			
Period	Prior to Tunnels Opening	Domain Tunnel Open	Both Tunnels Open
Date Range	20 Apr 97–15 Apr 00	16 April 00–21 Dec 00	22 Dec 00–28 Feb 02
Number of Samples (n)	112	39	68
Madden Grove median	29.28	18.00	21.15
Alphington median	18.19	13.28	16.75
Ratio of Madden Gv median to Alphington median	1.61	1.36	1.26
Result of statistical test against Pre-Opening levels	-	decrease significant at α = 0.05	decrease significant at α = 0.05
Estimated % change in ratio of Grant St to Alphington medians	-	approx -16%	approx -22%

Table A1.2: Particles statistical analyses.

8-hour Carbon Monoxide (ppm) at Grant Street (December 1999 to February 2002)			
Median concentration for each CityLink stage			
Period	Prior to Tunnels Opening	Domain Tunnel Open	Both Tunnels Open
Date Range	23 Dec 99–15 Apr 00	16 April 00–21 Dec 00	22 Dec 00–28 Feb 02
Number of Samples (n)	115	250	425
Grant Street median	0.661	0.726	0.527
EPA network median	0.486	0.681	0.467
Ratio of Grant St median to EPA network median	1.36	1.07	1.13
Result of statistical test against Pre-Opening levels	-	not significant at $\alpha = 0.05$	not significant at $\alpha = 0.05$
Estimated % change in ratio of Grant St to EPA network medians	-	none detected	none detected

Table A1.3: CO statistical analyses

1-hr Nitrogen Dioxide (ppb) at Grant Street (December 1999 to February 2002)			
Median concentration for each CityLink stage			
Period	Prior to Tunnels Opening	Domain Tunnel Open	Both Tunnels Open
Date Range	23 Dec 99–15 Apr 00	16 April 00–21 Dec 00	22 Dec 00–28 Feb 02
Number of Samples (n)	114	228	415
Grant Street median	24.5	29.0	27.0
EPA network median	22.5	25.0	23.0
Ratio of Grant St median to EPA network median	1.09	1.16	1.17
Result of statistical test against Pre-Opening levels	-	not significant at $\alpha = 0.05$	not significant at $\alpha = 0.05$
Estimated % change in ratio of Grant St to EPA network medians	-	none detected	none detected

Table A1.4: NO₂ statistical analyses