Environment Canterbury Regional Council
Kaunihera Taiao ki Waitaha

TECHNICAL REPORT Science Group

Air quality monitoring in Lyttelton 2016

Report No. R17/10
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Environment Canterbury Regional Council
Kaunihera Taiao ki Waitaha

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Summary

Background

Environment Canterbury carried out an air quality investigation during 2016, in response to concerns raised by the Lyttelton/Mt Herbert Community Board about air quality in the vicinity of Norwich Quay.

What we did

We measured particles and gases at a roadside monitoring station on the corner of Norwich Quay and Canterbury Street from January 2016 to January 2017. We measured concentrations of two particle sizes, those less than 10 micrometres (µm) in diameter (PM_{10}) and those less than 2.5 µm in diameter ($PM_{2.5}$), a subset referred to as fine particles. The particles with sizes between 2.5 and 10 µm are referred to as coarse particles. The gases measured were sulphur dioxide (SO_2), nitrogen dioxide (NO_2) and carbon monoxide (CO).

Vehicle movements on Norwich Quay were measured by the New Zealand Transport Agency for six weeks during March and April.

What we found

PM_{10} and $PM_{2.5}$ concentrations exceeded daily guidelines six times during June. On these days, wind speeds were very low and fine and coarse particles contributed roughly similar amounts to the average concentration of PM_{10}. There were a further 11 days when coarse particle concentrations were high and the wind was from a southerly direction.

The potential sources of fine and coarse particles are different. Burning wood or coal for home heating is likely to be the main source of fine particles in Lyttelton, while vehicle movements generating dust on Norwich Quay, along with Port activities, is the most likely source of the coarse particles.

Sulphur dioxide concentrations were well below national guidelines, but were above the updated World Health Organisation daily guidelines 16 times between January and September. The concentrations on these 16 days occurred when the wind was generally from a southwest direction. These days were spread throughout the year and the concentrations were high at any time of day. Probable sources of SO_2 are shipping vessels that use fuels with high sulphur content, like fuel oils.

NO_2 and CO concentrations were below guidelines and less than concentrations measured at the roadside monitoring site in Riccarton Road.

Guidelines for particles and gases are based on exposure over a particular time period. In some cases there are no guidelines for the time periods that people on Norwich Quay are typically exposed to (in its current usage). Therefore it should be noted that while guidelines may have been exceeded during a 24 hour period, people are unlikely to have been breathing that quality of air for that length of time at this roadside location.

This report will be presented to the Community Board (now the Banks Peninsula Community Board) and options discussed. The report will also be made available to LPC, who manage the Port, and NZ Transport Authority who manage State Highway 74, which Norwich Quay is part of.

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Figure 1-1: Location of Lyttelton showing air monitoring site on Norwich Quay (red spot)

1 Background

Environment Canterbury carried out an air quality investigation during 2016 in response to concerns raised by the Lyttelton/Mt Herbert Community Board about air quality in the vicinity of Norwich Quay. A monitoring station was installed on the corner of Norwich Quay and Canterbury Street (Figure 1-1), to monitor particles and gases during 2016. The gases measured were sulphur dioxide (SO_2), nitrogen dioxide (NO_2) and carbon monoxide (CO). The particles measured included two sizes, those less than 10 micrometres (µm) in diameter (PM_{10}) and a subset, those less than 2.5 µm ($PM_{2.5}$).

This report presents the results of the monitoring programme and summarises the main findings for each pollutant. Comparison is made to air quality guidelines. These guidelines are for outdoor air and cover various time periods, for example for PM_{10} the guideline is an average over a 24 hour period. The guidelines don't necessarily apply to a roadside site, such as Norwich Quay, because people are likely to be exposed for much shorter periods.

2 Particles

Particulate matter (PM) refers to a mixture of tiny particles and liquid droplets present in air. This is typically classified by particle size, as size influences the potential impact for health effects and provides some information about likely source of origin. Particles with an equivalent diameter of less than 10 µm are referred to as PM_{10} and are small enough to be inhaled into the human lung. PM_{10} is further split into "fine" ($PM_{2.5}$) and "coarse" (PM_c) particle categories. Coarse particles are usually generated by non-combustion processes (e.g. grinding, crushing, evaporation) and include airborne dust and sea salt. These are not inhaled far into the lung and typically only impact the upper respiratory tract. Fine particles are mostly produced by combustion processes (burning of coal, wood, gas etc.) and travel deep into the lung causing both respiratory and cardiovascular effects.

The hourly average concentrations measured at the Norwich Quay air monitoring site are summarised in Figure 2-1 by month of year and time of the day for fine and coarse particles. The darkest colours show the highest concentrations. Figure 2-1(a) shows that the highest fine particle concentrations occurred during June, July and August, particularly during June and evenings. The highest coarse particle concentrations occurred during the daytime, particularly during June afternoons, as shown in Figure 2-1(b). This suggests that the sources are different for the fine and coarse particles.

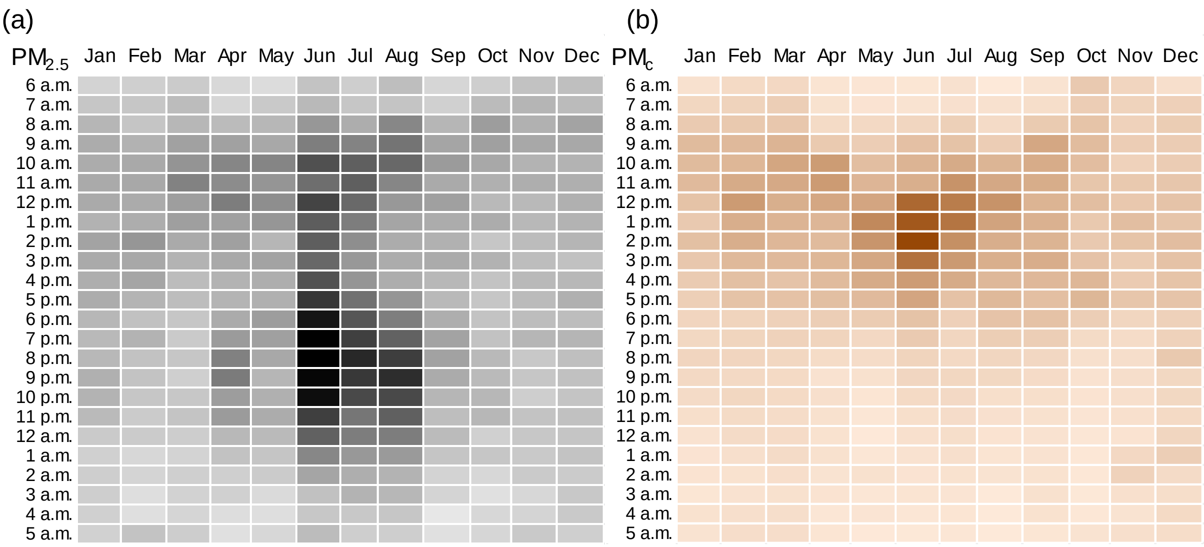


Figure 2-1: Hourly average concentrations of (a) fine ($PM_{2.5}$) and (b) coarse (PM_c) particles by month of year and time of the day. Darkest colours are the highest concentrations, and the maximum concentrations are shown in Table 2-1

When added together, the coarse and fine particles make PM_{10}. The National Environmental Standards for Air Quality (NESAQ) allow only one daily average PM_{10} concentration to be greater than 50 µg/m^3 per year. At the Norwich Quay site, six days exceeded the standard and these all occurred during June, as shown in Figure 2-2. On those days, fine and coarse particles contributed roughly similar amounts (40% to 60%) to the daily concentration of PM_{10}. Currently there is no NESAQ for fine or coarse particles separately, although one for fine particles is being considered. $PM_{2.5}$ concentrations were greater than 25 µg/m^3 (World Health Organisation (WHO) guideline), on those same six days in June, as shown in Figure 2-3. There were 15 days PM_c concentrations were greater than 25 µg/m^3, including four of the days when PM_{10} was high in June. The other 11 days were spread throughout the months from March to December as shown in Figure 2-4. Monthly average concentrations of PM_c are also shown in Figure 2-4.

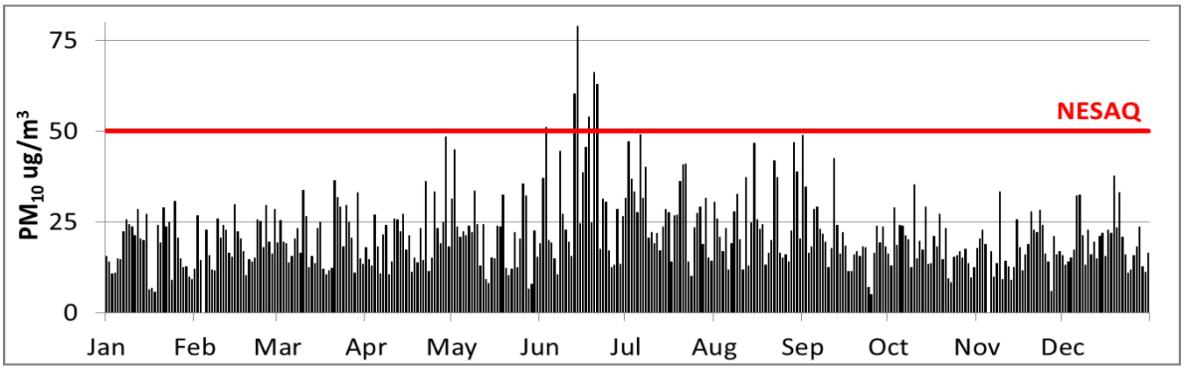


Figure 2-2: Daily average PM_{10} concentrations (fine and coarse) measured at the Lyttelton Norwich Quay air monitoring site in 2016

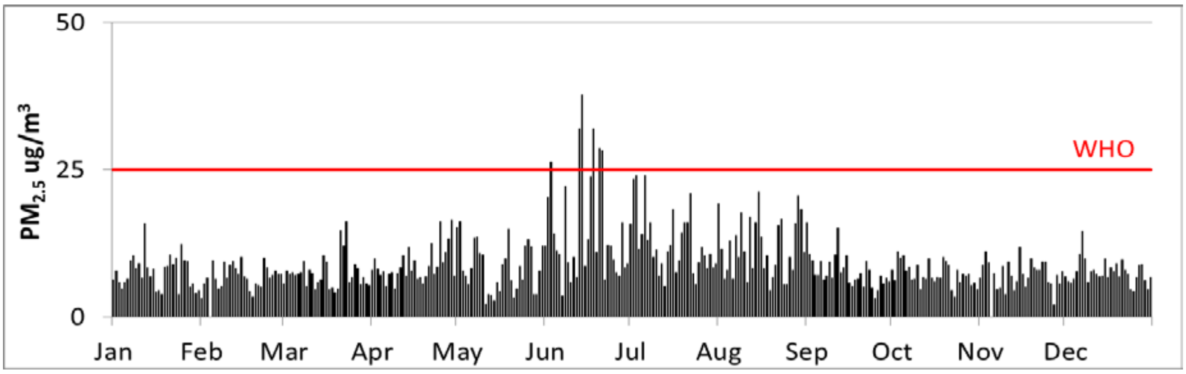


Figure 2-3: Daily average fine particle concentrations ($PM_{2.5}$) measured at the Lyttelton Norwich Quay air monitoring site in 2016

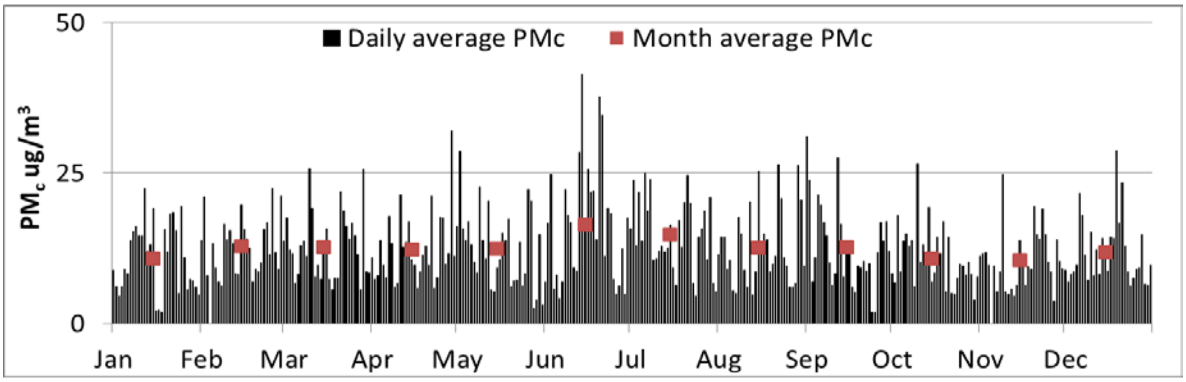


Figure 2-4: Daily average coarse particle concentrations (PM_c) measured at the Lyttelton Norwich Quay air monitoring site in 2016

Table 2-1 puts the concentrations measured at the Norwich Quay site into perspective with other monitoring sites in Canterbury, though the purpose of monitoring does differ. Most of these sites are in residential areas, while industrial sources are dominant at the monitoring sites in Woolston and Washdyke. Norwich Quay is the only roadside monitoring site that measured particle concentrations during 2016. It should be noted that while guidelines may have been exceeded, people on Norwich Quay are unlikely to have been breathing that quality of air for 24 hours or longer.

The number of high PM_{10} days and maximum concentration was similar to those measured at other monitoring sites, but the annual average was higher on Norwich Quay. The NESAQ focuses on daily average PM_{10}, but monitoring of fine and coarse particles separately allows better understanding of the likely sources and how they might be managed to reduce PM_{10} concentrations.

The number of high $PM_{2.5}$ days on Norwich Quay was less than the number measured at most other monitoring sites, while the number of high PM_c days was more. Unlike some other sites, none of the daily average $PM_{2.5}$ or PM_c concentrations on Norwich Quay were high enough to exceed the PM_{10} guideline alone. The annual average PM_c concentration was similar to those measured at the Woolston and Washdyke monitoring sites, while the $PM_{2.5}$ annual average was similar to those at the Christchurch and Rangiora monitoring sites.

Table 2-1: Summary of the maximum and annual concentrations measured in 2016 and number of PM exceedances

Guideline			50 µg/m³	20 µg/m³		25 µg/m³	10 µg/m³			
		Days PM_{10} >50	Max 24-hr PM_{10} µg/m³	Annual PM_{10} µg/m³	Days $PM_{2.5}$ >25	Max 24-hr $PM_{2.5}$ µg/m³	Annual $PM_{2.5}$ µg/m³	Days PM_c >25	Max 24-hr PM_c µg/m³	Annual PM_c µg/m³
Lyttelton Norwich Quay		6	79	22	6	38	9	15	41	13
Rangiora		7	67	17	17	56	8	0	21	9
Kaiapoi		7	74	18	-	-	-	-	-	-
Christ-church	St Albans	3	75	19	15	68	9	0	22	9
Christ-church	Woolston	4	95	19	5	62	8	10	63	11
Ashburton		2	58	18	23	44	10	4	52	8
Geraldine		1	56	17	20	48	11	0	23	7
Timaru	Anzac Square	27	88	23	48	71	13	4	46	9
Timaru	Washdyke	1	89	17	0	19	6	11	82	11
Waimate		0	47	16	19	41	10	1	34	6

Colours indicate how maxima relate to regional ambient air quality targets:

- Not measured

Action	Alert	Acceptable	Good
>100%	66% - 100%	33% - 66%	< 33%

3 Gases

The gases monitored on Norwich Quay during 2016 were sulphur dioxide (SO_2), nitrogen dioxide (NO_2), nitric oxide (NO) and carbon monoxide (CO). These were all well below the NESAQ for the relevant pollutant.

3.1 Sulphur dioxide

The hourly average SO_2 concentrations measured at the Lyttelton air monitoring site are summarised in Figure 3-1 by month of year and time of day, except for 2am when an instrument check occurred. Data from October to December have been left out of this analysis due to instrument faults. The darkest colours in Figure 3-1 show the highest concentrations, which occurred throughout this monitoring period, mainly around the middle part of the day. Sulphur dioxide is formed by the combustion of sulphur-containing fuels including coal, petrol and diesel, as well as from fertiliser works, geothermal processes and biological activities.

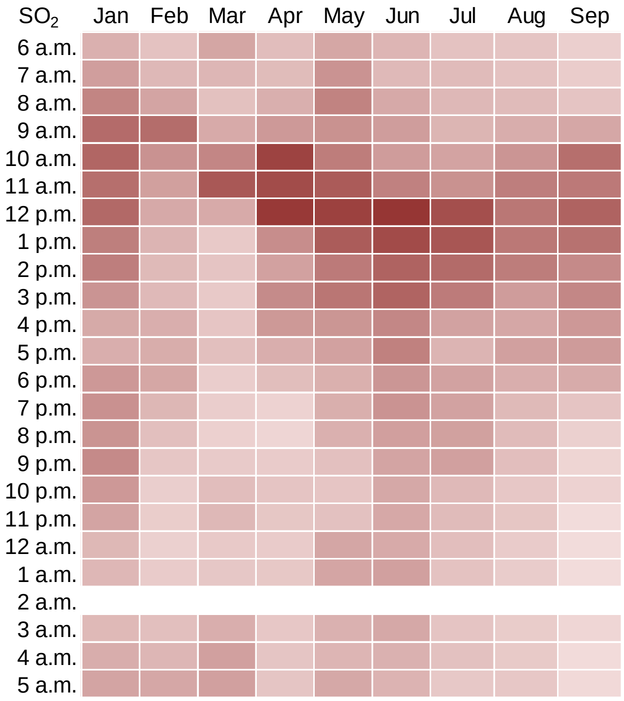


Figure 3-1: Hourly average concentrations of SO_2 by month of year and time of the day, with daily check at 2am. Darkest colours are the highest concentrations, and the maximum concentrations are shown in Table 3-1

The highest hourly average SO_2 concentrations were about half the NESAQ, and daily averages were well below New Zealand's guideline, as shown in Figure 3-2. Also shown in Figure 3-2 is the World Health Organisation (WHO) daily average guideline, which was revised in 2005,[1] and there were 16 days when this was exceeded throughout the year.

[1] http://www.euro.who.int/__data/assets/pdf_file/0005/78638/E90038.pdf?ua=1

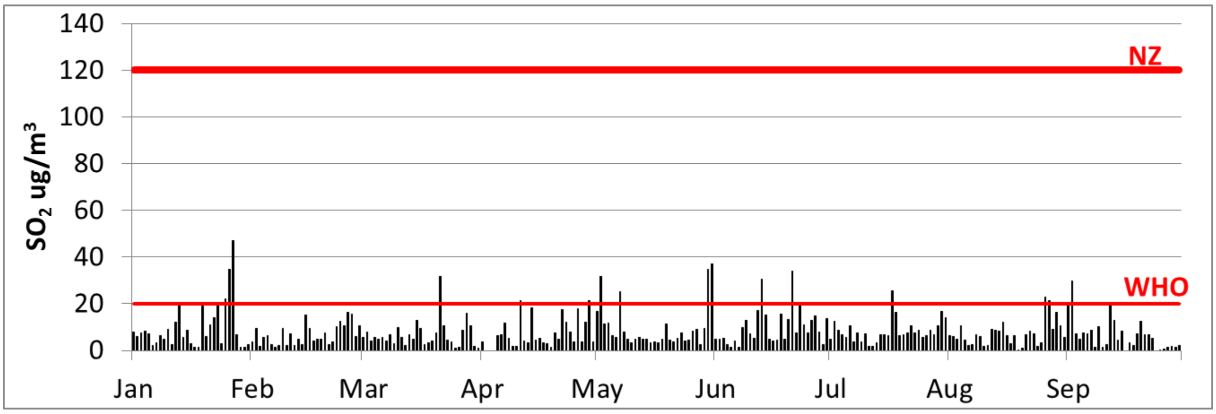


Figure 3-2: Daily average SO_2 concentrations measured at the Lyttelton Norwich Quay air monitoring site during 2016

The Ministry for the Environment is aware of the lowered WHO guideline, but at the time of writing the Ministry have not changed the national guidelines. The WHO also have a guideline for ten minute averages (500 μg/m^3) and concentrations measured on Norwich Quay during 2016 were less than half of this guideline.

Sulphur dioxide is measured at four other air quality monitoring sites in Canterbury and the concentrations measured on Norwich Quay were most similar to those measured at the industrial sites in Woolston and Washdyke.

Table 3-1: Summary of the maximum SO_2 concentrations and January to September averages measured in 2016

Colours indicate how maxima relate to guidelines.

Guideline		500 μg/m^3	350 μg/m^3	120 μg/m^3		
January to September 2016		Max 10-min SO_2 μg/m^3	Max 1-hr SO_2 μg/m^3	Max 24-hr SO_2 μg/m^3	Days SO_2 >20	Average SO_2 μg/m^3
Lyttelton		240	182	47	16	8
Christ-church	St Albans	10	6	2	0	0.5
	Woolston	1427	353	66	20	8
Timaru	Anzac Square	219	89	15	0	5
	Washdyke	279	119	22	1	4

Action	>100%
Alert	66% - 100%
Acceptable	33% - 66%
Good	10% - 33%
Excellent	< 10%

3.2 Nitrogen dioxide

The hourly average NO_2 concentrations measured on Norwich Quay are summarised in Figure 3-3(a) by month of year and time of day. The darkest colours show the highest concentrations, which occurred in June during the day. It is interesting to compare NO_2 concentrations with other contaminants, for example coarse particles in Figure 3-3(b). If the patterns were similar, this could suggest a single source. For example, motor vehicle's exhaust emissions result in NO_2, and the vehicle's movement can create dust in the air, especially during dry conditions if there are coarse particles on the road.

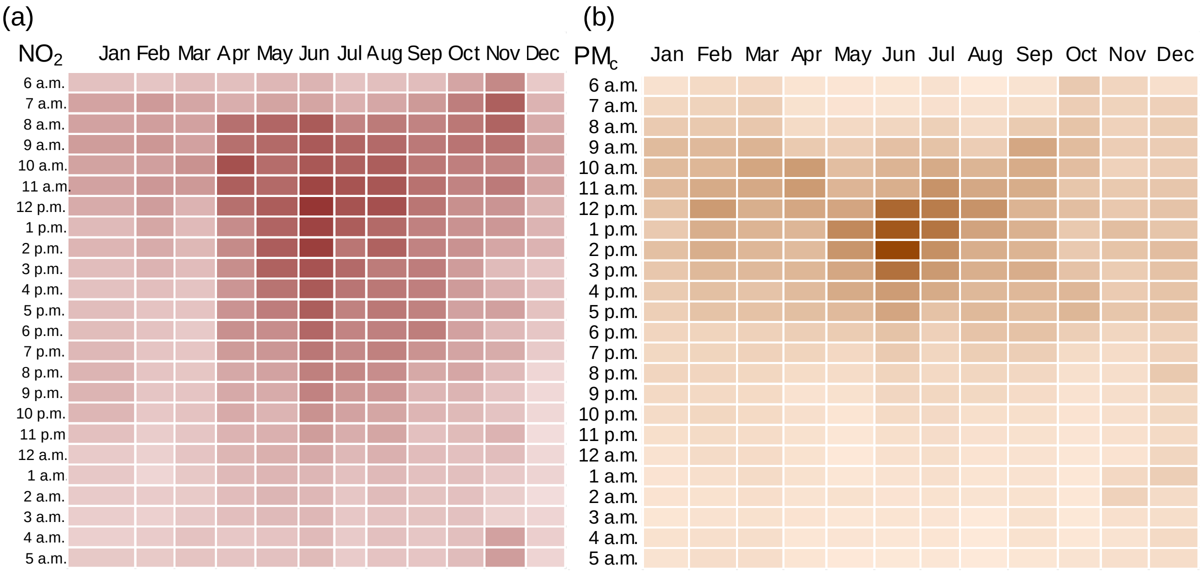


Figure 3-3: Hourly average concentrations of (a) nitrogen dioxide and (b) coarse particles by month of year and time of the day. Darkest colours are the highest concentrations, and the maximum concentrations are shown in Table 3-2

Table 3-2 shows that the maximum hourly concentration measured on Norwich Quay was similar to that measured at the roadside site in Riccarton Road, but all concentrations were well below guidelines.

Table 3-2: Summary of the maximum NO_2 concentrations and annual averages measured in 2016

Colours indicate how maxima relate to guidelines.

	Guideline	200 µg/m³	100 µg/m³	40 µg/m³
		Max 1- hr NO_2 µg/m³	Max 24- hr NO_2 µg/m³	Annual NO_2 µg/m³
Lyttelton		120	44	17
Christ-church	St Albans	94	44	11
	Riccarton Rd	121	77	34

Action	>100%
Alert	66% - 100%
Acceptable	33% - 66%
Good	10% - 33%
Excellent	< 10%

3.3 Carbon monoxide

The hourly average CO concentrations measured at the Lyttelton air monitoring site are summarised in Figure 3-4(a) by month of year and time of the day. The darkest colours show the highest concentrations which occurred in June, July and August, peaking in June during the morning and evening. This pattern is similar to the one for fine particles which may be expected as both result from combustion.

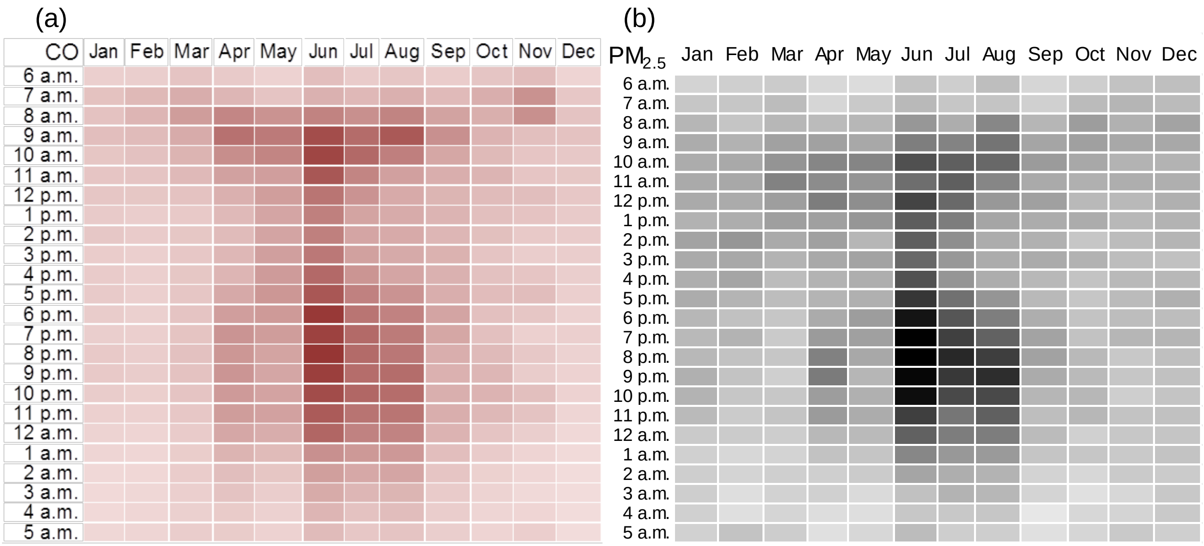


Figure 3-4: Hourly average concentrations of (a) carbon monoxide and (b) fine particles by month of year and time of the day. Darkest colours are the highest concentrations, and the maximum concentrations are shown in Table 3-3

In comparison with other air quality monitoring sites in Canterbury, CO concentrations measured on Norwich Quay were lower than those measured at the roadside in site in Riccarton Road (Table 3-3), and similar to concentrations measured at residential sites in Geraldine and Waimate.

Table 3-3: Summary of the maximum CO concentrations and annual averages in 2016

Colours indicate how maxima relate to guidelines.

Guideline		10 mg/m³	30 mg/m³	
		Max 8-hr CO mg/m³	Max 1-hr CO mg/m³	Annual CO mg/m³
Lyttelton		1	2	0.2
Rangiora		3	4	0.2
Kaiapoi		3	5	0.3
Christ-church	St Albans	3	5	0.3
	Woolston	3	5	0.2
	Riccarton Rd	3	5	0.6
Ashburton		3	5	0.2
Geraldine		1	2	0.2
Timaru	Anzac Square	3	4	0.3
	Washdyke	1	1	0.1
Waimate Kennedy		2	2	0.2

Action	>100%
Alert	66% - 100%
Acceptable	33% - 66%
Good	10% - 33%
Excellent	< 10%

4 Meteorology

Meteorology, especially wind, has a big impact on concentrations of pollutants. Under calm conditions pollutants can accumulate and concentrations are often highest. Strong winds generally blow pollutants away, although they can stir up dust from unpaved areas resulting in high coarse particle concentrations. Figure 4-1(a) shows hourly average wind speed by month of year and time of day. The darkest colours show the lightest winds. During 2016 winds on Norwich Quay were lighter in the evenings in general, and all day during June. When there is little air movement, a temperature inversion can occur, further restricting dispersion of any pollutants. The strongest temperature inversions occurred during June and July (darkest colours in figure 4-1(b)).

Figure 4-1(c) shows that May was a wet month, as well as being windy. There were many warm norwesters during the first part of May 2016, and the weather was unsettled for the second part with colder temperatures and rain on many days. Rain or dew can keep dust moist, keeping coarse particle concentrations low. The coldest month was August (darkest colours in figure 4-1(d)).

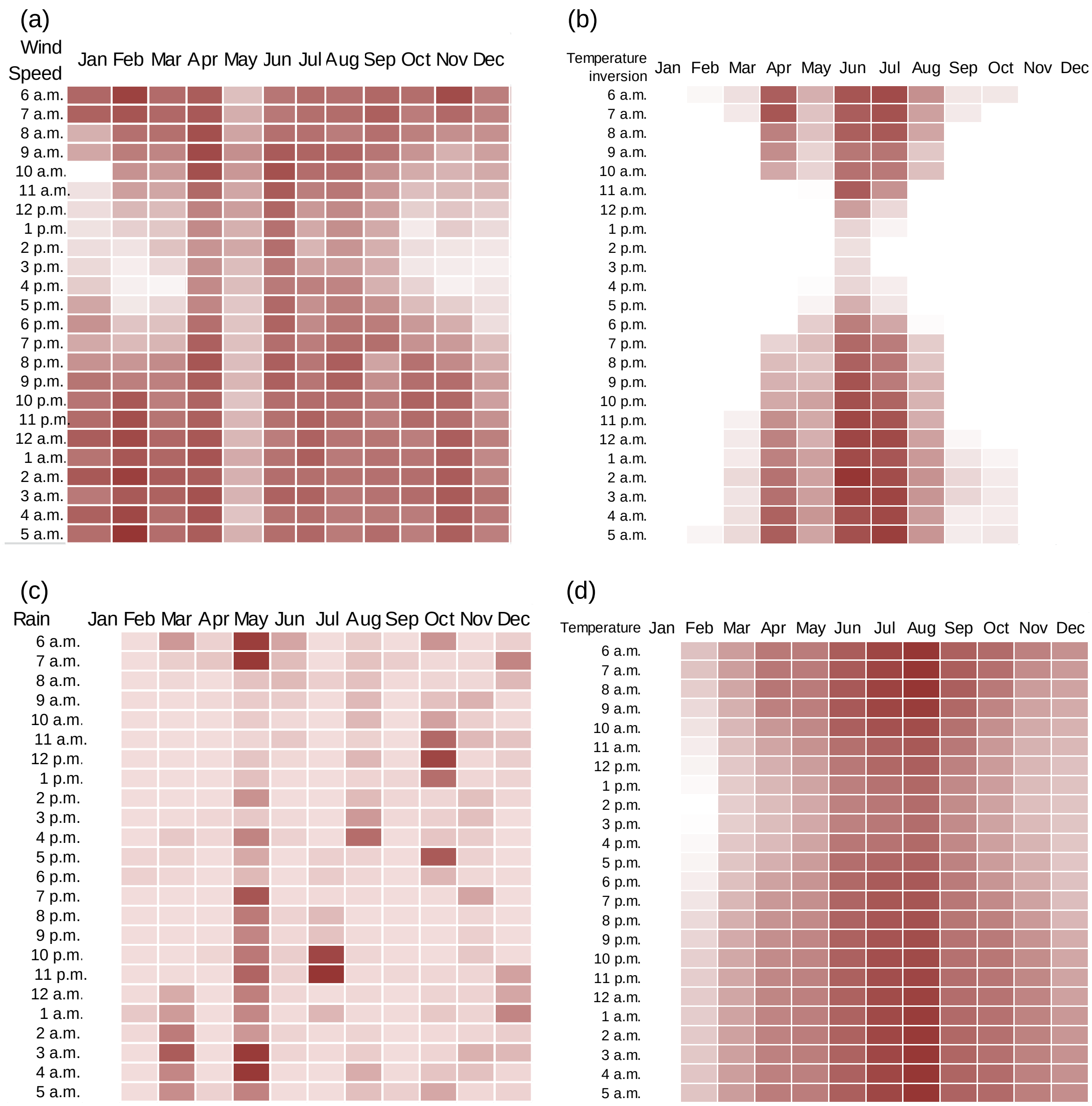


Figure 4-1: Hourly averages of (a) wind speed, (b) temperature inversion, (c) rain and (d) temperature by month of year and time of the day. Darkest colours are the lowest wind speeds, strongest inversions, highest rainfall and coldest temperatures

4.1 Comparison to past weather

A long record of climate is not available for Lyttelton, so a comparison has been made to Christchurch locations in 2016 as well as for the previous ten years. Figure 4-2 shows monthly rainfall measured in Lyttelton and Christchurch Airport (data from Metservice.com). While rainfall in Lyttelton follows a similar pattern to Christchurch Airport during 2016, there was much less rain in Lyttelton each month. The comparison to the previous ten years shows that January and May were wet months in 2016, while February, April, June and July were drier than average.

Figure 4-3 shows monthly wind speeds measured at Norwich Quay air monitoring site and the St Albans air monitoring site in Christchurch. This show similar average wind speeds from April to July, but lower wind speeds in Lyttelton in other months. This is likely to be because Lyttelton is protected from the easterly that is more predominant during the summer. Compared to the last ten years, May was windier and June was less windy.

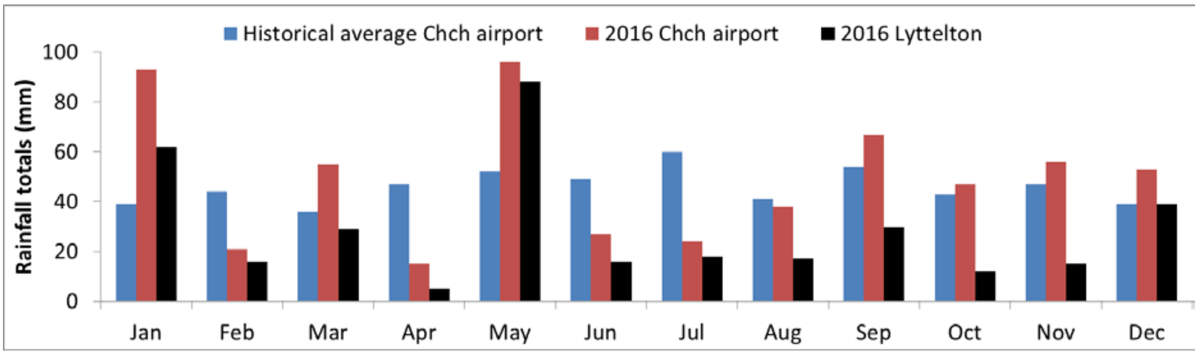


Figure 4-2: Rainfall totals during 2016 and the average during the previous ten years

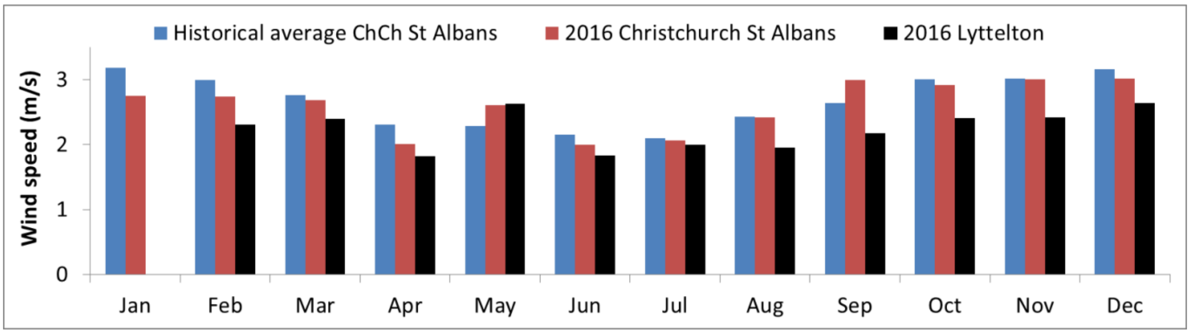


Figure 4-3: Average wind speeds during 2016 and the average during the previous ten years

4.2 Wind speed and direction during high pollution

On the six exceedance days in June when PM_{10}, $PM_{2.5}$ and CO were highest, there was very little wind (dates detailed in the Appendix). Figure 4-4 shows that on those six days, the highest hourly average PM_{10} concentrations occurred when the wind speed was low. Figure 4-5(a) shows the fine particle concentrations, with wind direction and time of day. The larger dots represent the highest hourly average concentrations. This shows that the highest fine particle concentrations occurred during the evening when the wind was from a northerly direction, as well as during the daytime when the wind was from the south. Figure 4-5(b) shows that the highest coarse particle concentrations occurred during the late morning and afternoon period when winds were from a southerly direction.

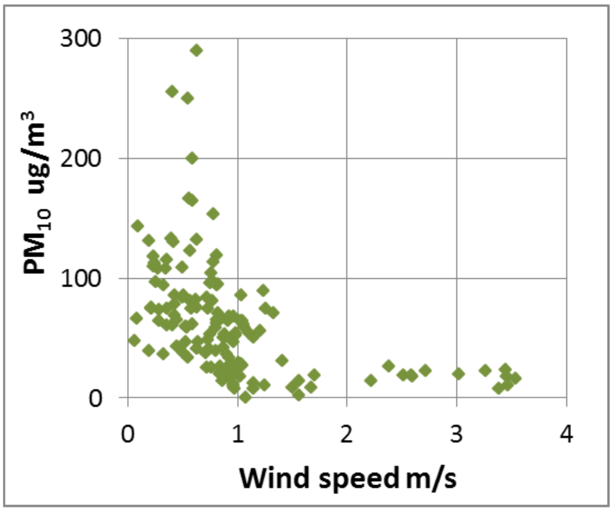
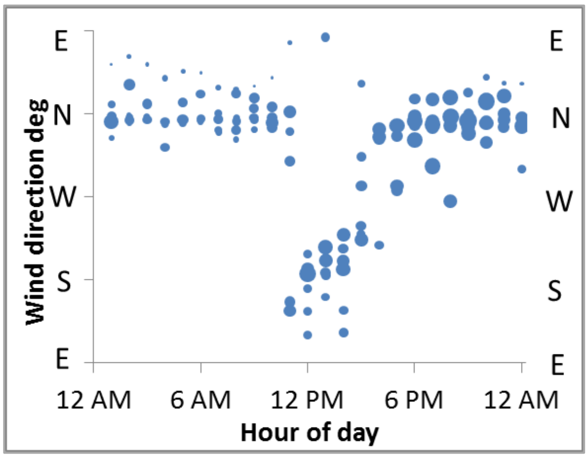


Figure 4-4: Hourly average PM_{10} concentrations against wind speed on six high PM_{10} days

(a)



(b)

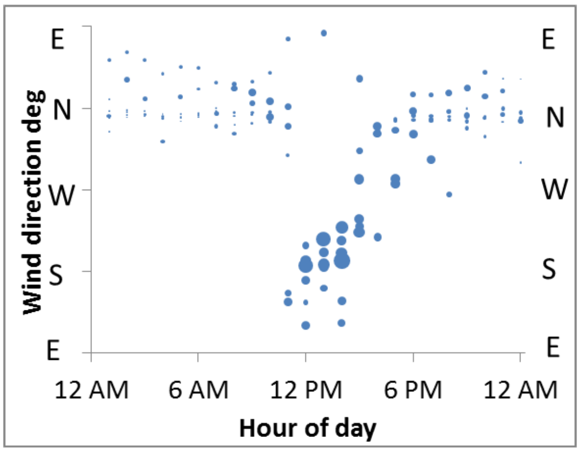


Figure 4-5: Hourly average (a) fine particle and (b) coarse particle concentrations shown by dot size with time of day and wind direction on six high PM_{10} days

There were another 11 days when coarse particle concentrations were high. Those days were spread across the year from March to December (dates detailed in the Appendix). During those days, the hourly average wind speed was sometimes low, but often it was much windier, as shown in Figure 4-6(a). Figure 4-6(b) shows the coarse particle concentrations, with wind direction and time of day. The highest hourly average concentrations, those with the biggest dots, occurred during the late morning and afternoon period when the wind was from a southerly direction. This is similar to Figure 4-5(b), but the southerly winds extended later into the evening and were from a wider direction range, south of east and west, on the 11 days.

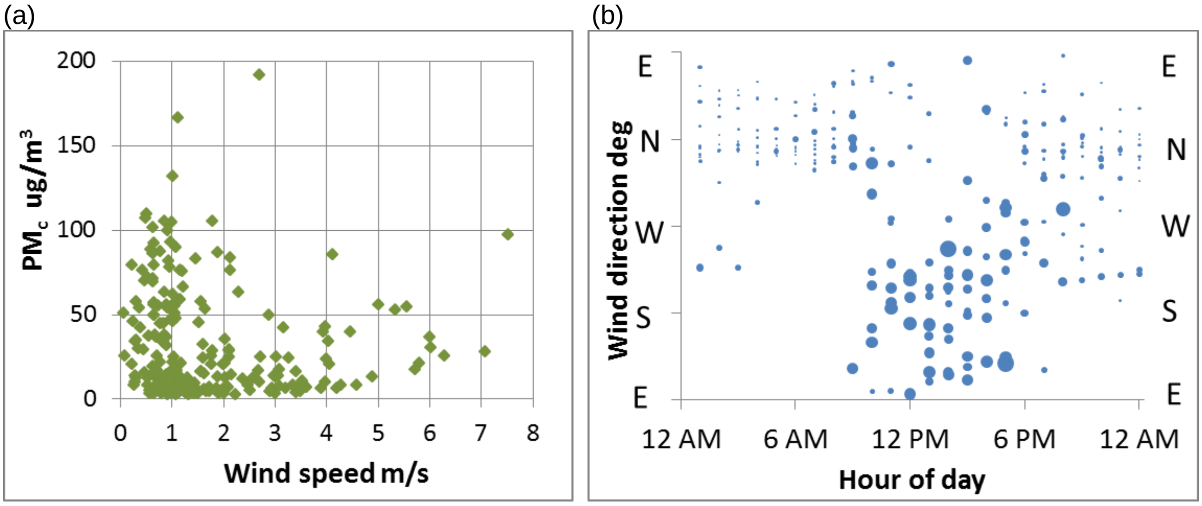


Figure 4-6: (a) Hourly average coarse particle concentrations against wind speed on 11 high PM_c days (b) Hourly average coarse particle concentrations shown by dot size, with time of day and wind direction on 11 high PM_c days

On the 16 days when SO_2 concentrations were elevated, the wind speed was sometimes low, but often it was much windier, as shown in Figure 4-7(a). These days were spread across the monitoring period (dates detailed in the Appendix). The highest hourly average SO_2 concentrations, shown by the bigger dot size in Figure 4-7(b), occurred from early morning to late at night, mainly with winds from the south west direction. Some also occurred during the day when the wind was from the south east direction.

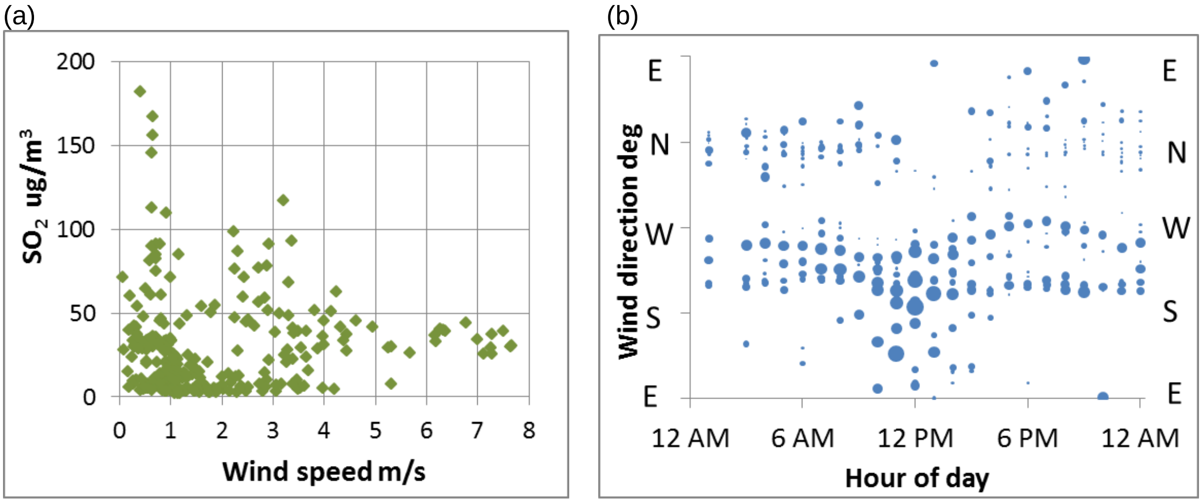


Figure 4-7: (a) Hourly average SO_2 concentrations against wind speed on 16 high SO_2 days (b) Hourly average SO_2 concentrations shown by dot size, with time of day and wind direction on 16 high SO_2 days

5 Sources

Figure 1-1 shows a satellite image of Lyttelton and the location of the monitoring site in 2016. Figure 5-1 shows Lyttelton from various aspects looking north, southeast, southwest and east, illustrating potential sources of air pollution in the area.

View north to Canterbury St from Lyttelton Harbour (2016)

View to southwest from cemetery on Canterbury St (2003)

Monitoring unit on Canterbury St and Norwich Quay looking southeast (2016)

Looking east along Norwich Quay and Lyttelton Port (2015)

Figure 5-1: Views of Lyttelton from various aspects

The Norwich Quay site is classified as a peak traffic site, and is also influenced by sources in the Port, as well as in residential areas, depending on the wind direction.

Norwich Quay is part of State Highway 74 and the New Zealand Transport Agency counted the number of vehicles along it during March and April in 2016. The counts were grouped into classes based on axle and length. The total numbers of vehicles per hour on an average day are shown in Figure 5-2, with cars being the largest group for most hours of the day. Counts did not vary much between directions along Norwich Quay for any class of vehicle. The number of trucks was significantly lower on the weekends.

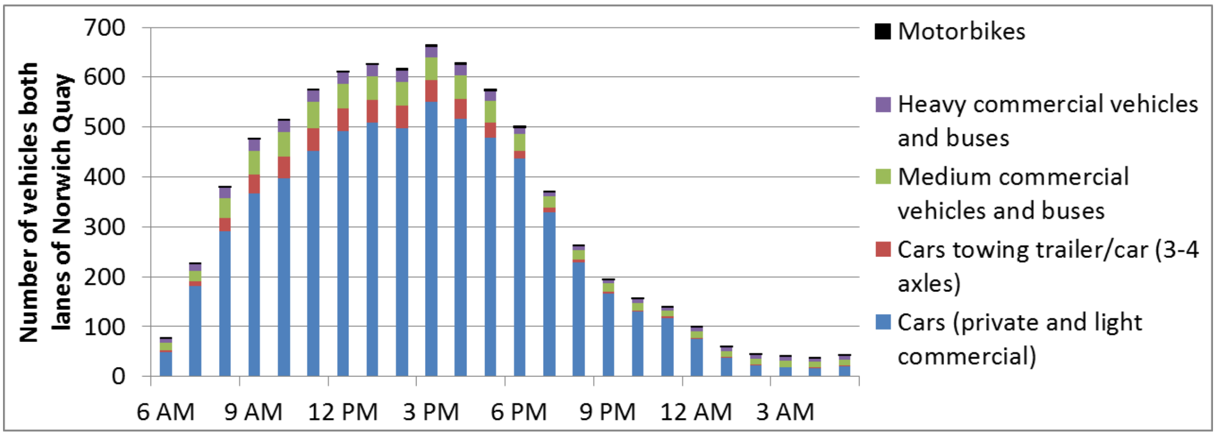


Figure 5-2: Average number of vehicles travelling north or south bound along Norwich Quay, counts taken by NZTA between 1 March and 18 April 2016

5.1 Sources of fine particles

Fine particle concentrations were highest during June, July and August, the winter months. May was wet and windy, which are conditions that reduce fine particle concentrations. On the six days when the daily average was greater than the WHO guideline, the wind was light and from the north through the evening and from the south for a short period in the middle of the day. This is a typical pattern of land and sea breeze triggered by the sun warming the land. The period of daytime sea breeze is short during winter compared to summer when the daylight hours are longer.

A potential source of fine particles from the north is the burning of wood or coal for home heating. There were many potential sources to the south including exhaust emissions from vehicles on Norwich Quay (the majority of vehicles being cars), exhaust emissions from cargo handling equipment, trucks, trains and ships in the Port. Burning diesel produces more fine particles than burning petrol.

While emissions from sources to the south may not change much through the year, emissions from sources to the north will vary. Wood burners are generally only used in winter and those to the north of this site would contribute significantly to high $PM_{2.5}$ concentrations with smoke drifting downhill when wind speeds were low.

5.2 Sources of coarse particles

There were 15 days when coarse particle concentrations were high and these were spread throughout the year, all on weekdays. The three highest concentrations were on the same days in June when fine particle concentrations were high. On the 15 days the wind varied in speed, but was usually from the south. This southerly direction included west through to east. The highest concentrations occurred from mid-morning to around 6 pm.

A potential source of coarse particles is road dust from vehicle movements as vehicle numbers are highest during the day (Figure 5-2). To the south is Norwich Quay and the Port, and there are many potential sources of coarse particles. These include dry particles of dust on the road (soil, brake and tyre wear), bark dust from the logging area or dust from storage, or handling of bulk cargo, like fertiliser, grains or coal. It is possible that all these sources contribute to the concentrations of coarse particles measured at the monitoring site.

The updated Lyttelton Tunnel Bylaw, which came into effect on 1 September 2016, requires vehicles through the tunnel transporting loose material (e.g. sand, soil, fertiliser) to be covered before and after load delivery. From the coarse particle concentrations measured on Norwich Quay (Figure 2-4) it is unclear if this Bylaw has had an impact.

5.3 Sources of sulphur dioxide

Sulphur dioxide concentrations were below national guidelines and the maxima were similar to those measured in industrial areas of Canterbury. There were 16 days spread through the period of monitoring when the daily average was greater than the WHO guideline. On these 16 days the wind varied in speed, but was usually from the south. When the SO_2 concentrations were highest, sources to the southwest would have contributed at any time of the day, with southeast sources impacting around the middle of the day. Potential sources of SO_2 in Lyttelton are shipping vessels or other vehicles that use high sulphur fuels, with light and heavy fuel oil having higher sulphur content than diesel. Coal burning is another potential source of SO_2 in Lyttelton.

5.4 Sources of nitrogen dioxide

Nitrogen dioxide concentrations were below guidelines. The highest concentrations occurred through the daytime. The ten highest daily averages occurred between March and September (dates detailed in the Appendix). NO_2 concentrations are calculated by measuring nitrogen oxides (NO_x) and nitric oxide (NO) and subtracting these two, and these gases are formed during high temperature combustion of fuels. In many towns and cities these gases are primarily generated by motor vehicles. Potential sources of NO_2 in Lyttelton are exhaust emissions from motor vehicles on Norwich Quay and in the Port.

5.5 Sources of carbon monoxide

Carbon monoxide concentrations were well below guidelines and lower than the roadside monitoring site in Riccarton Road. The ten highest daily averages occurred between June and July (dates detailed in the Appendix). CO emissions are produced from combustion processes (burning of wood, coal, petrol, diesel, etc). Potential sources in Lyttelton are the burning of wood or coal for home heating, and exhaust emissions from motor vehicles on Norwich Quay and in the Port.

6 Conclusion

The monitoring carried out during 2016 was able to show that PM_{10} was the only pollutant to exceed the NESAQ. When PM_{10} concentrations were high, fine and coarse particle concentrations were also high. The lack of wind during June resulted in high concentrations on still days, when sources of both fine and coarse particles were around. Coarse particle concentrations were also high at other times of the year, when it was windier, and usually during the working day.

A roadside monitoring site was chosen to address a concern about the increased number of trucks travelling along Norwich Quay. Truck exhaust emissions do not appear to be the source of high fine particle concentrations, but truck movements may have contributed to the high coarse particle concentrations. The Lyttelton Tunnel Bylaw requiring loose loads to be covered may reduce their contribution, but it is unclear if coarse particle concentrations reduced at the monitoring site after the bylaw came into effect on 1 September 2016. Other sources of coarse particles may be more significant like other vehicle movements on Norwich Quay or activities in the Port, e.g. bark dust from the logging area, or dust from the storage or handling of bulk cargo, like fertiliser, grains or coal.

The high fine particle concentrations are more likely to be coming from the burning of wood or coal for home heating. The lack of wind during June was not unusual, as winds are typically lighter during the months from May to August in Canterbury, though May 2016 was windier than normal. If future winters are calmer, there could be more frequent days with high $PM_{2.5}$ concentrations. If further monitoring was carried out, sites should be located closer to where people are living.

Sulphur dioxide concentrations were lower than the NESAQ and national guidelines, but if the daily average guideline was lowered to the WHO guideline, then there would be exceedances on Norwich Quay if sources didn't change.

This investigation was carried out in response to concerns raised by the Lyttelton/Mt Herbert Community Board. This report will be presented to them (now the Banks Peninsula Community Board) and options discussed. The report will also be made available to LPC, who manage the Port, and NZ Transport Authority who manage State Highway 74, which Norwich Quay is part of.

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Appendix

The highest daily average concentrations and when they occurred.

Table 1: Daily average SO_2 > 20 $\mu g/m^3$

Day of week	DATE	SO_2
Mon	25/01/16	22
Tue	26/01/16	35
Wed	27/01/16	47
Mon	21/03/16	32
Mon	11/04/16	21
Fri	29/04/16	21
Mon	2/05/16	32
Sat	7/05/16	25
Mon	30/05/16	35
Tue	31/05/16	37
Mon	13/06/16	30
Tue	21/06/16	34
Sun	17/07/16	25
Fri	26/08/16	23
Sat	27/08/16	21
Fri	2/09/16	30

Table 2: Top ten daily average CO mg/m^3

Day of week	DATE	CO
Thu	2/06/16	0.6
Fri	3/06/16	0.9
Mon	13/06/16	0.7
Tue	14/06/16	0.9
Fri	17/06/16	0.6
Sat	18/06/16	0.9
Tue	21/06/16	0.7
Sat	2/07/16	0.6
Sun	3/07/16	0.7
Wed	6/07/16	0.6

Table 3: Top ten daily average NO_2 $\mu g/m^3$

Day of week	DATE	NO_2
Mon	21/03/16	35
Fri	29/04/16	35
Fri	3/06/16	37
Mon	13/06/16	42
Tue	14/06/16	44
Sat	18/06/16	36
Tue	21/06/16	42
Mon	29/08/16	39
Thu	1/09/16	36
Mon	12/09/16	36

Table 4: Daily average $PM_{2.5}$ > 25 $\mu g/m^3$

Day of week	DATE	PM_{10}	$PM_{2.5}$	PM_c
Fri	3/06/16	51	26	25
Mon	13/06/16	60	32	28
Tue	14/06/16	79	38	41
Sat	18/06/16	54	32	22
Mon	20/06/16	66	29	38
Tue	21/06/16	63	28	35

Table 5: Daily average PM_c > 25 $\mu g/m^3$

Day of week	DATE	PM_{10}	$PM_{2.5}$	PM_c
Thu	10/03/16	34	8	26
Tue	29/03/16	33	7	26
Fri	29/04/16	48	16	32
Mon	2/05/16	45	16	29
Mon	13/06/16	60	32	28
Tue	14/06/16	79	38	41
Thu	16/06/16	39	13	26
Mon	20/06/16	66	29	38
Tue	21/06/16	63	28	35
Mon	22/08/16	42	15	26
Mon	29/08/16	47	20	26
Thu	1/09/16	49	16	31
Mon	12/09/16	42	15	27
Mon	10/10/16	35	9	26
Mon	19/12/16	38	9	29

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