The relationship between average annual, peak concentrations, and exceedences of PM_{10}

A discussion document and draft paper

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NB December 2006. This analysis has been extended and updated and will be submitted for publication early in 2007. This report is provided for reference only and should not be referenced until the peer review process has been completed

Introduction

Given the recent introduction of air quality standards and the now ample epidemiological evidence to show that elevated air pollution levels can lead to tangible and serious health consequences for the community (Fisher, 2002; MfE 2003) Councils require a better understanding of the elevated and peak PM_{10} concentrations that occur in their regions. Effective air quality management focuses on minimizing peak pollution concentrations in order to safeguard the health of the community. This study examines the relationships between a site's annual average PM_{10} concentration and:

1. The peak annual PM_{10} concentration.

2. The number of times per year that the 24-hour mean concentration exceeds the air quality standard of 50 µg/m^3.

3. The number of times per year that the 24-hour mean concentration exceeds a nominal 30 µg/m^3 (as an additional indicator).

An understanding of these relationships will give Councils additional tools to implement effective air quality management plans. Thus, minimize the health risks to communities and ensuring national standards are met. Also briefly examined are the relationships between a site's latitude and its peak PM_{10} concentration and number of exceedences over 50 µg/m^3. In general, the average annual PM_{10} concentration is determined by a number of factors, including topography, climatic conditions and emissions from industrial, vehicular, domestic, and natural sources in the same air shed. Thus, while controlling or limiting emissions will have an affect on average PM_{10} levels, local and even national weather patterns may accentuate peak or elevated PM_{10} levels either through direct mechanisms such as an inversion or indirect mechanisms such as the increased domestic heating levels on cold days. In general, peak and elevated pollutant levels occur on calm days.

This study covers five regions: Auckland, Canterbury, Wellington, Waikato, and Nelson. These regions were chosen for a number of reasons: firstly, the first four regions represent areas with major population centres; secondly, the sites contained a sufficient number of valid PM_{10} measurements; and thirdly, the data were made available to the authors for the study. PM_{10} monitoring is relatively new to New Zealand with many Regional Councils beginning to conduct some degree of monitoring in the late 1990s (Although Canterbury and Auckland have records going back further). Data exists for these regions in varying degrees. Auckland and Canterbury have multiple monitoring sites with data dating back to the mid-1990s. Nelson, on the other hand, is comprised of only one monitoring site and only began monitoring in 2001. However, Nelson's sizeable domestic wood heating regime in winter makes it an interesting study. While this study produced some interesting results, it is perhaps slightly premature due to the relatively short period of data. It is recommended that a similar study be conducted in the near future when more complete datasets are available. A future study which takes into account more data points would elicit a higher degree of confidence of any correlations that might exist.

Methodology

24-hour PM_{10} data were obtained from the respective Regional Councils. This data was then analysed to determine the peak 24-hour PM_{10} values and the number of times per year that the mean 24-hour concentration exceeded 50 µg/m^3 and 30 µg/m^3. Most of the sites analysed conducted daily PM_{10} sampling, however some sites, particularly in Auckland, conduct sampling at given intervals usually once every three or six days. To account for the intermittent sampling, calculations on the number of exceedences needed to be adjusted. Thus, if sampling was conducted once every three days the total number of exceedences over 50 µg/m^3 and 30 µg/m^3 was multiplied by three. This added significant degree of uncertainty, especially to the calculations on the number of exceedences over 50 µg/m^3 due to the sometimes scare nature of the data points. For example, Takapuna experienced only one monitored exceedence of 50 µg/m^3 in 1997 and none for the following four years. However, since sampling occurred once every six days, one exceedence was normalized to six, while exceedences in the following four years remained at zero.

All data used is from quality controlled Council-supplied data, and comes from standard monitors (Hi Vols, Partisols, Beta Gauges, and temperature corrected TEOMs).

Discussion on Confidence Limits: All of the data are plotted with the 95% confidence limits, based on normal double tailed t-tests. In some cases these are relatively wide due to the few number of data points. However the nature of the relationships shown in the plots is relatively clear. It is hypothesised that as more years' of data become available these relationships will show less statistical variability.

The relatively few numbers of data points was the reason for selecting 30 µg/m^3 as well as 50 µg/m^3 for the frequency of exceedence analysis (10 µg/m^3 and 20 µg/m^3 were also examined but are not shown). There are significantly more data points for days over 30 µg/m^3, allowing the nature of the relationship to be explored. The patterns were similar for other exceedence levels.

Results

Peak Concentration: Figure 1 through Figure 5 examine the relationship between annual average PM_{10} and the peak annual PM_{10} concentration. All of the figures present the 95% confidence interval, all valid data points for the region, and the best fit line to those data points. In varying degrees all the graphs exhibit a relationship between the peak and average concentrations. This relationship is perhaps most strongly seen in Auckland and the Waikato Regions. Nelson also exhibited a high correlation though with fewer data points. In general, the confidence intervals plotted in each graph show there is still a high degree of uncertainty – even when the data seems to correlate well as with Nelson. This is due in large part to the fact that there exists a general scarcity of data points.

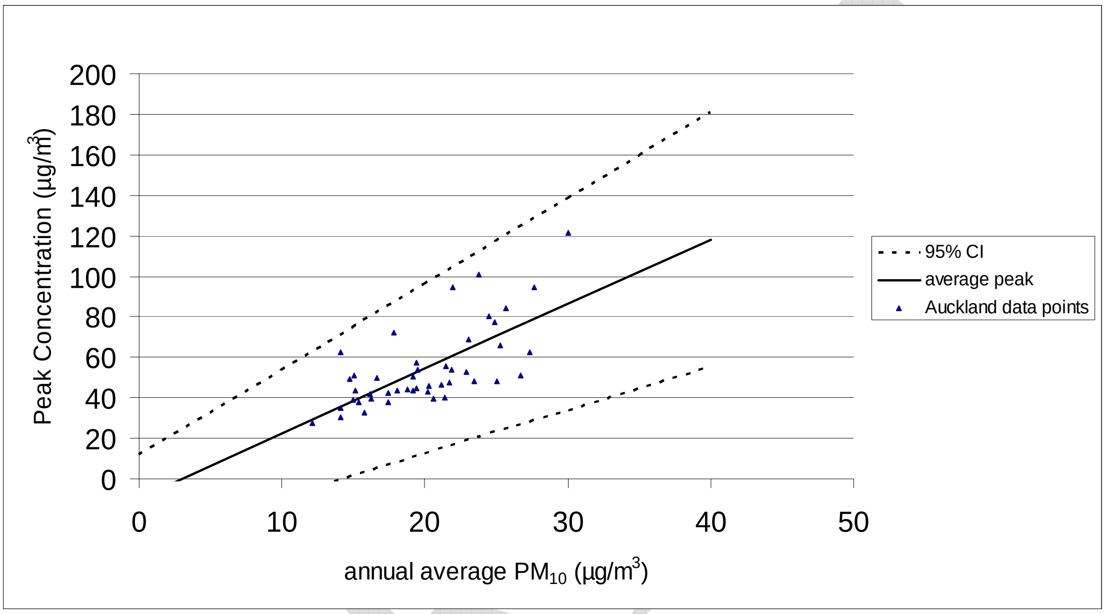

Figure 1. Peak PM_{10} concentration and confidence interval for the Auckland Region.

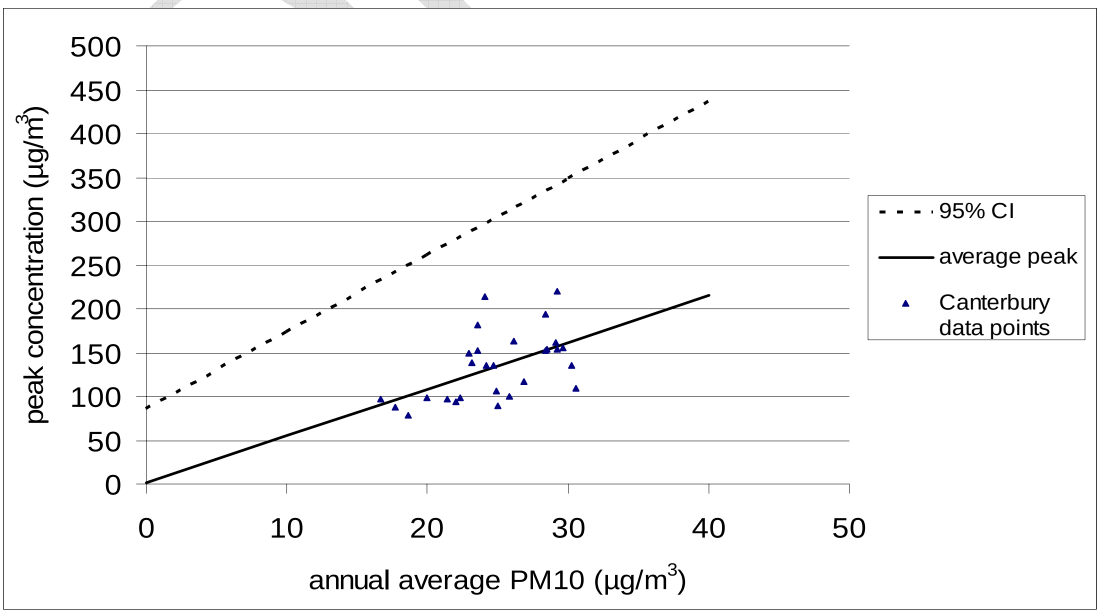

Figure 2. Peak PM_{10} concentration and confidence interval for the Canterbury Region.

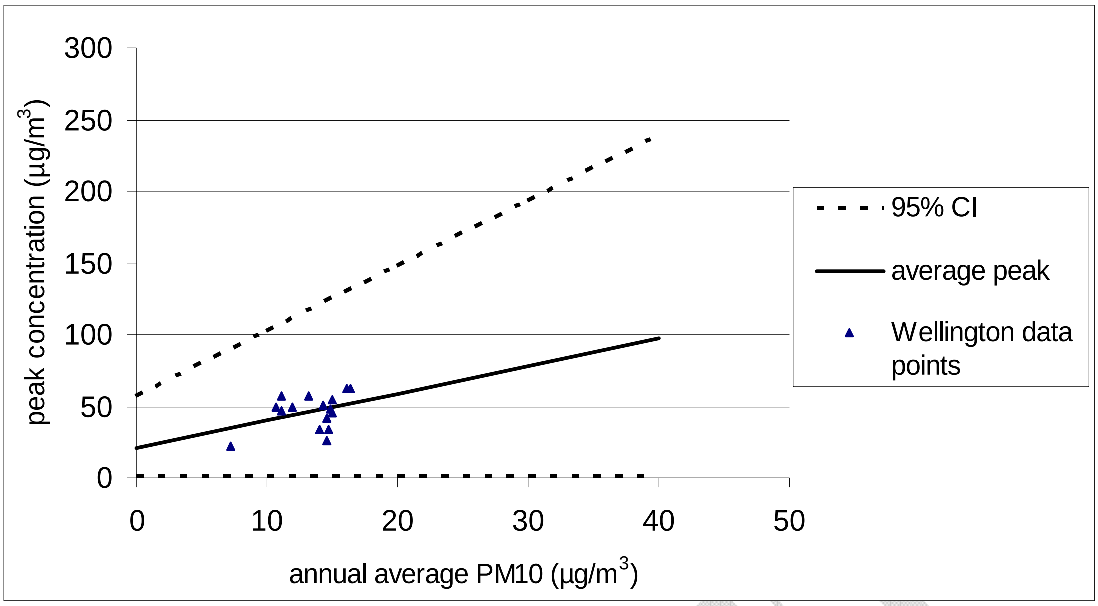

Figure 3. Peak PM_{10} concentration and confidence interval for the Wellington Region.

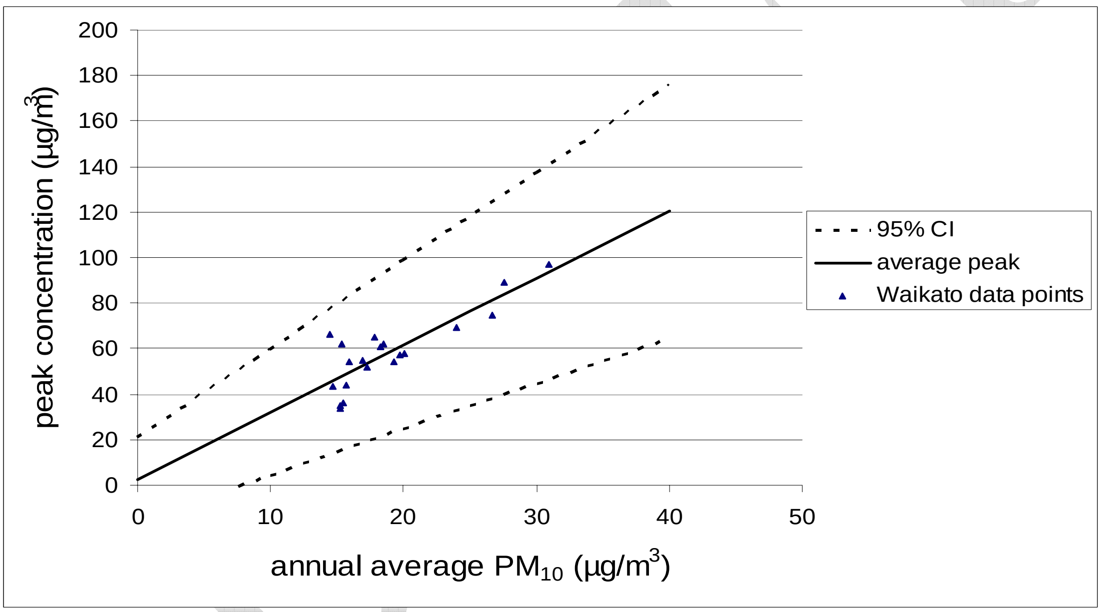

Figure 4. Peak PM_{10} concentration and confidence interval for the Waikato Region.

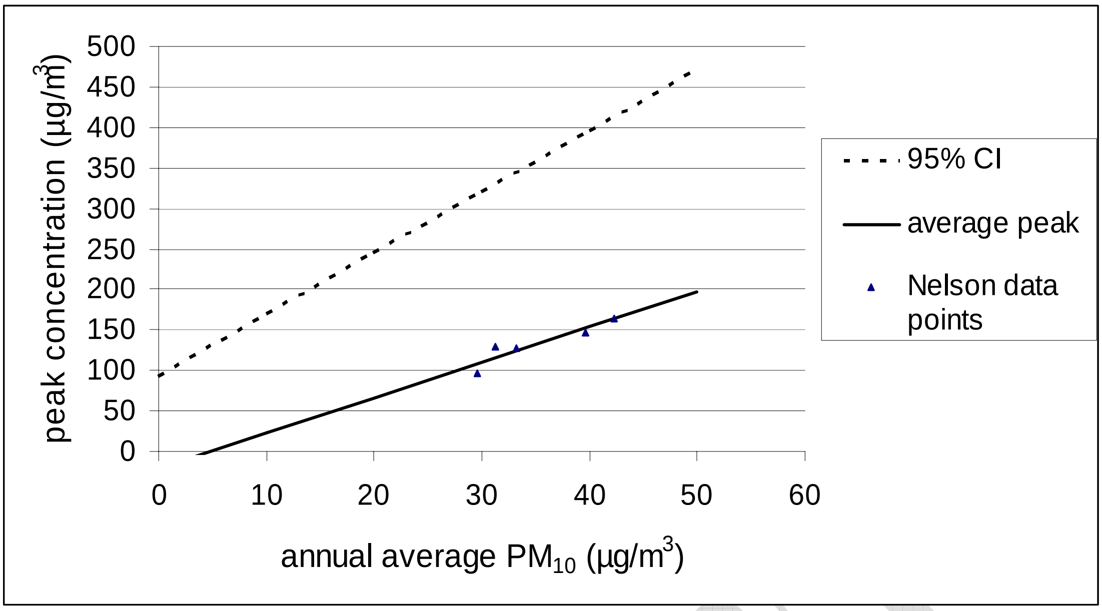

Figure 5. Peak PM_{10} concentration and confidence interval for the Nelson Region.

Exceedences:

Exceedences of 24-hour mean of 30 µg/m^3: Figures 6 through 10 show the relationship between average annual PM_{10} and the number of times per year that the 24-hour mean exceeds 30 µg/m^3 for each region analysed. The figures show a strong relationship, though less so with Wellington and Nelson.

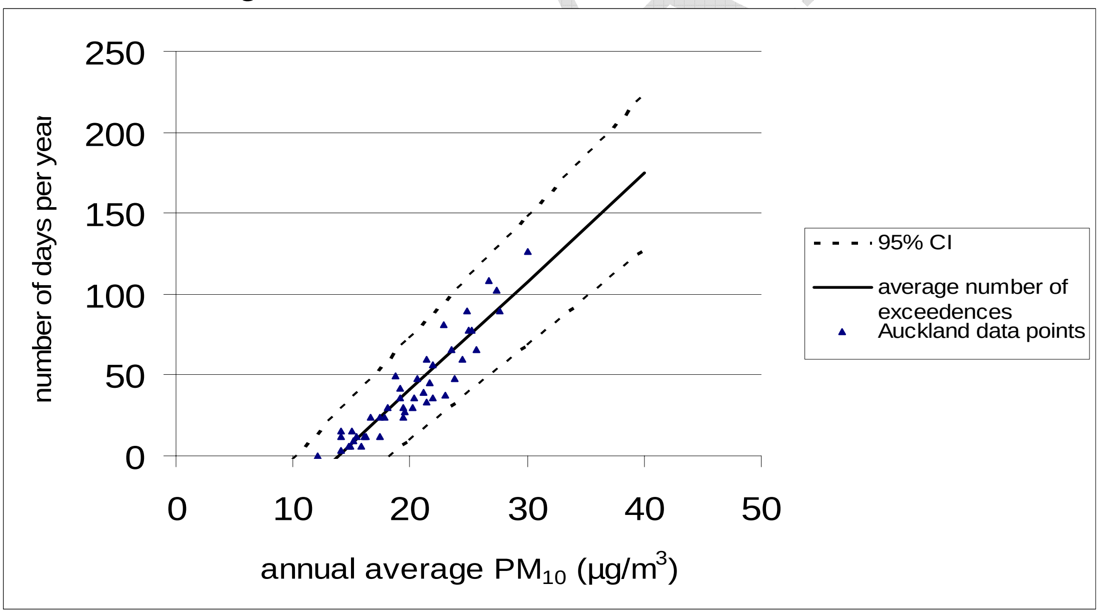

Figure 6. Number of days per year that PM_{10} concentration exceeds 30 µg/m^3 in the Auckland Region.

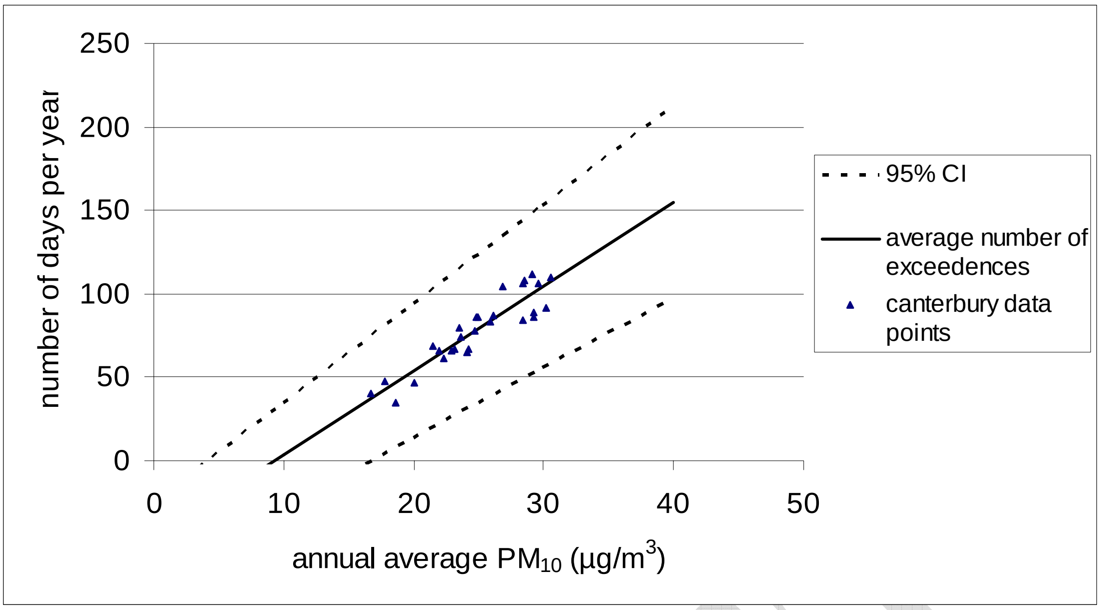

Figure 7. Number of days per year that PM_{10} concentration exceeds 30 µg/m^3 in the Canterbury region.

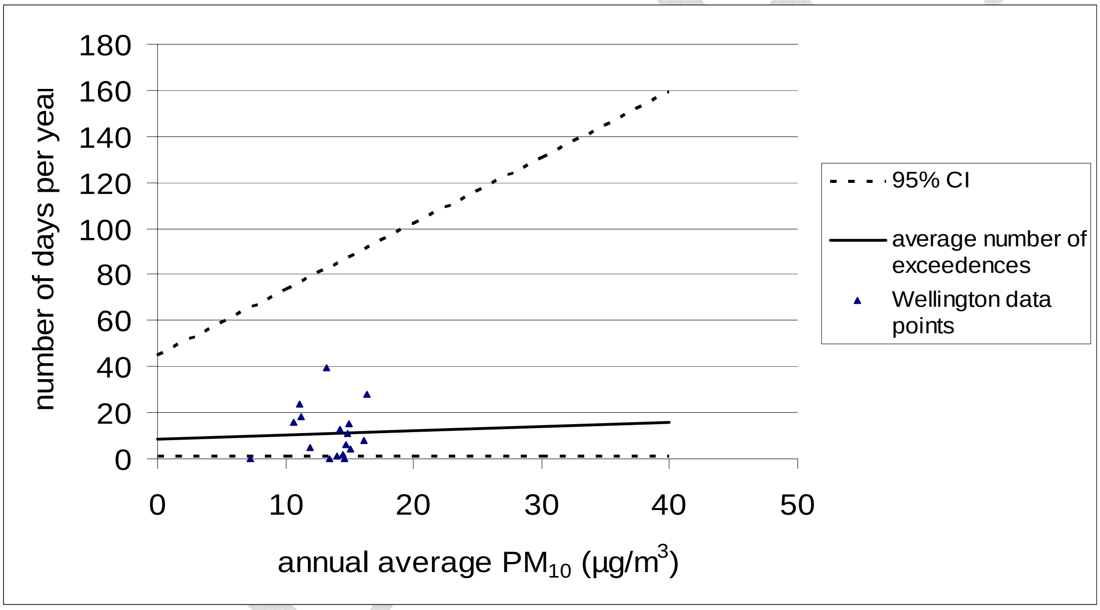

Figure 8. Number of days per year that PM_{10} concentration exceeds 30 µg/m^3 in the Wellington Region.

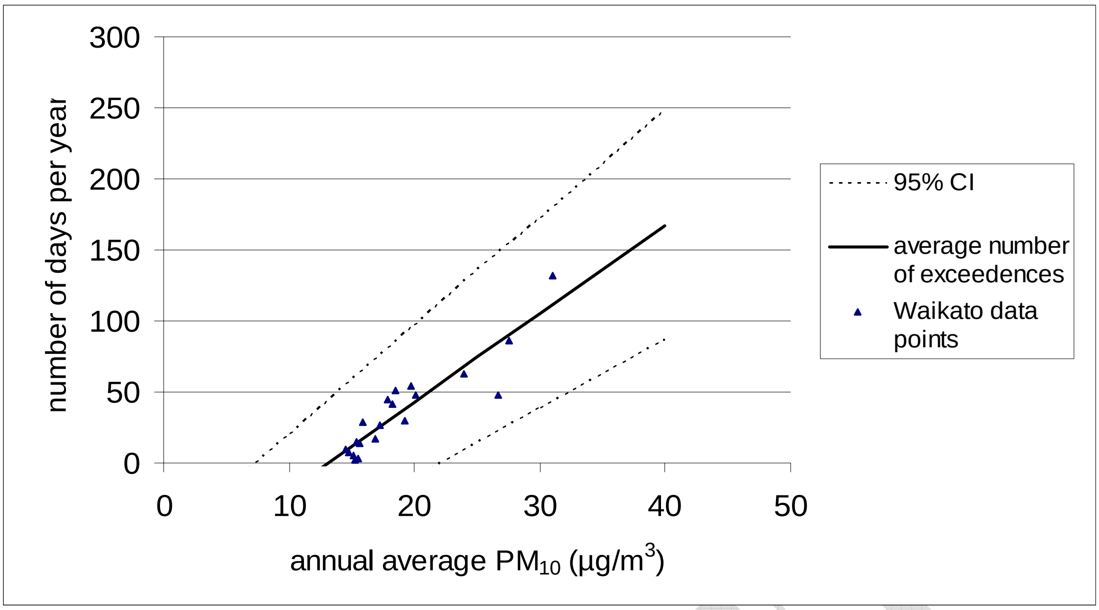

Figure 9. Number of days per year that PM_{10} concentration exceeds 30 µg/m^3 in the Waikato Region.

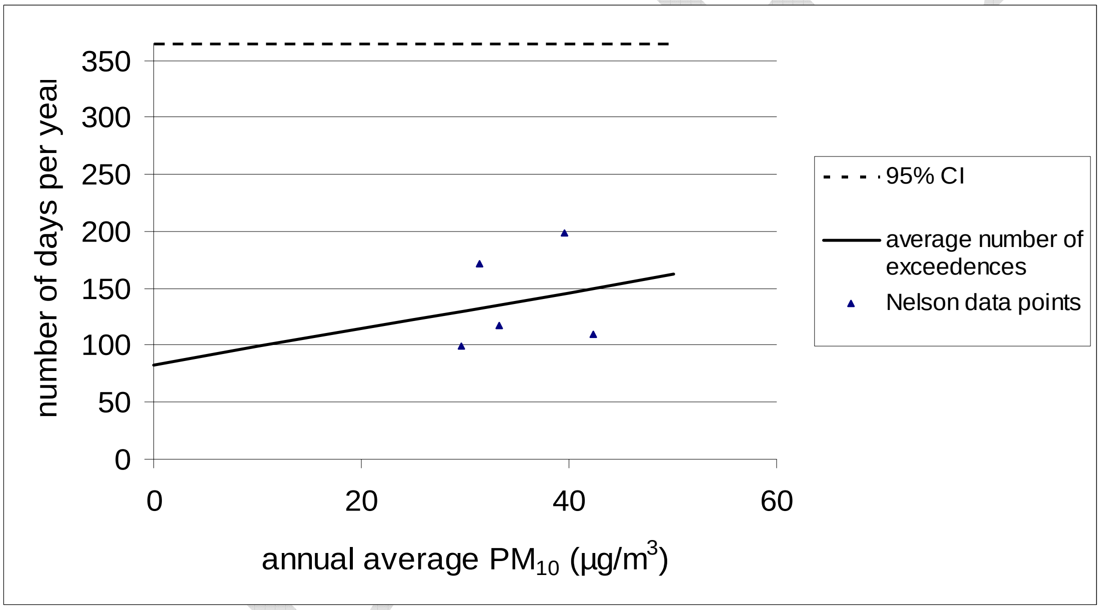

Figure 10. Number of days per year that PM_{10} concentration exceeds 30 µg/m^3 in the Nelson Region.

Exceedences of 24-hour mean of 50 µg/m^3: Figures 11 through 15 show the relationship between average annual PM_{10} and the number of times per year that the 24-hour mean exceeds the national standard of 50 µg/m^3 for each region analysed. While a strong relationship can be seen in Canterbury and Nelson, the other plots are more scattered and display a less strong correlation. In Figure 11 and 13 a large number of data points remain fixed on the x-axis, i.e. there were no exceedences over 50 µg/m^3 these years. However, as mentioned above the intermittent sampling of some sites increased the uncertainty.

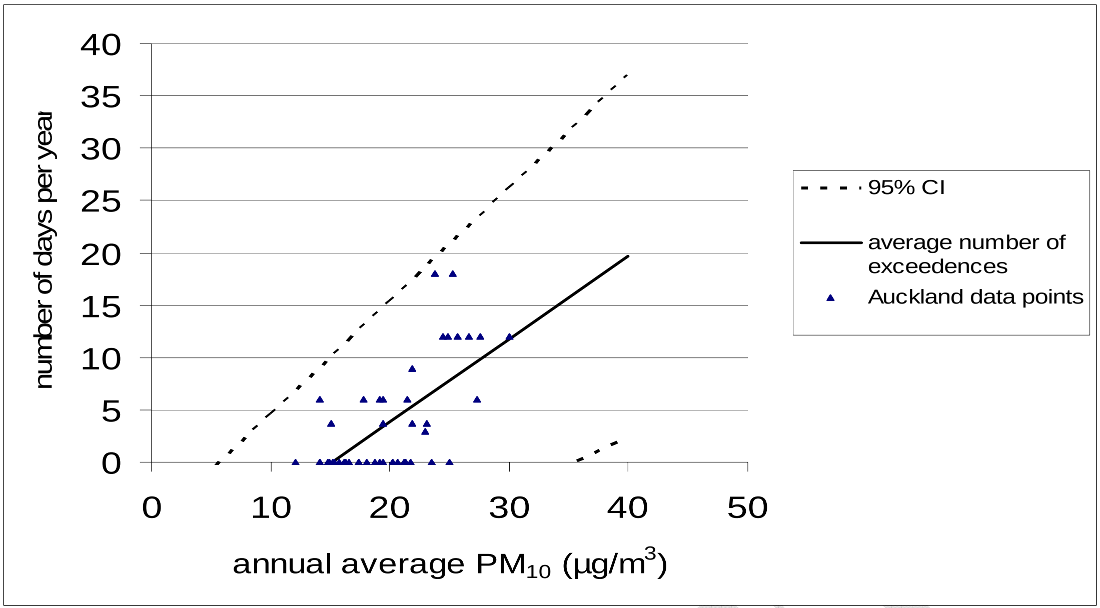

Figure 11. Number of days per year that PM_{10} concentration exceeds 50 µg/m^3 in the Auckland Region.

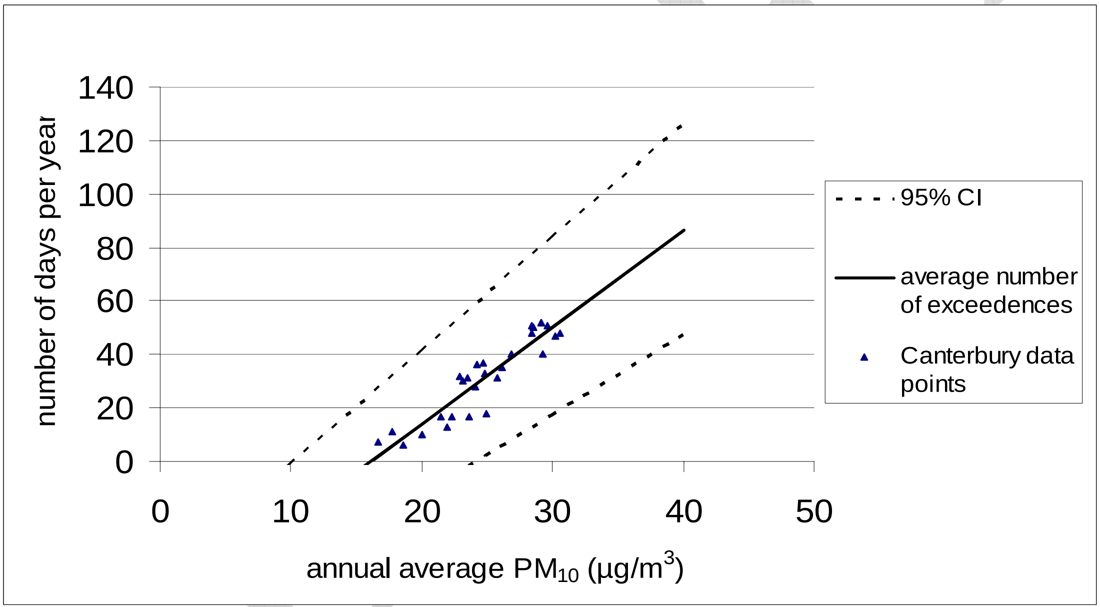

Figure 12. Number of days per year that PM_{10} concentration exceeds 50 µg/m^3 in the Canterbury region.

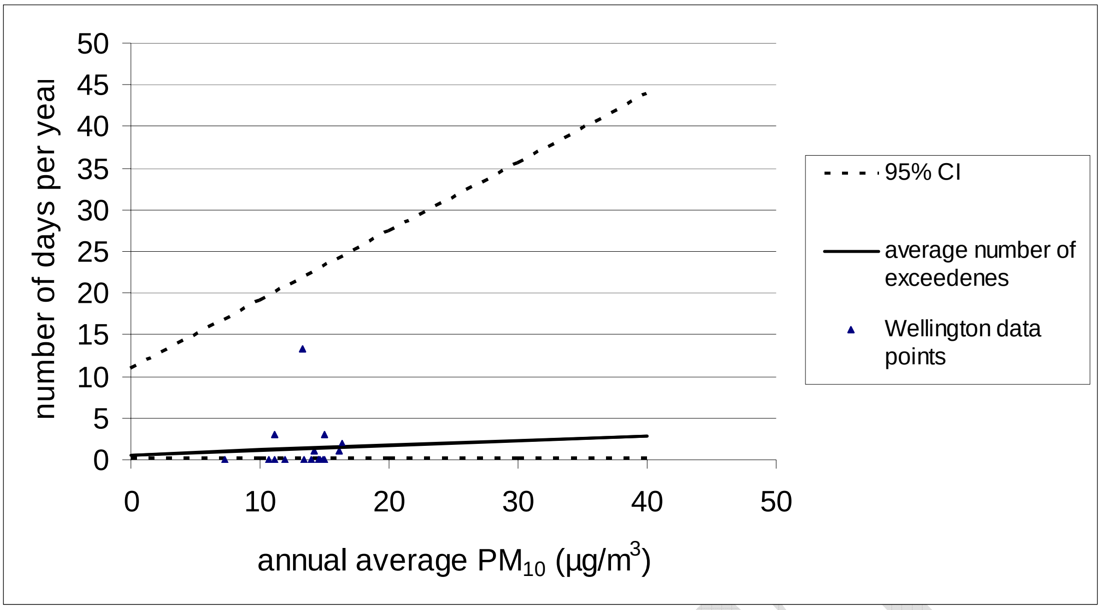

Figure 13. Number of days per year that PM_{10} concentration exceeds 50 µg/m^3 in the Wellington Region.

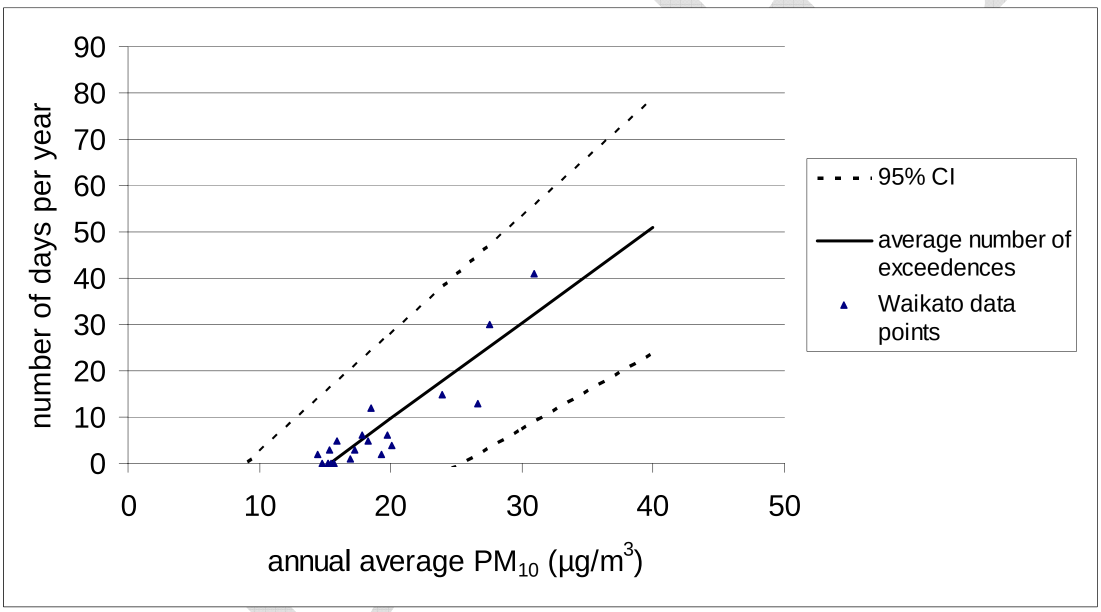

Figure 14. Number of days per year that PM_{10} concentration exceeds 50 µg/m^3 in the Waikato Region.

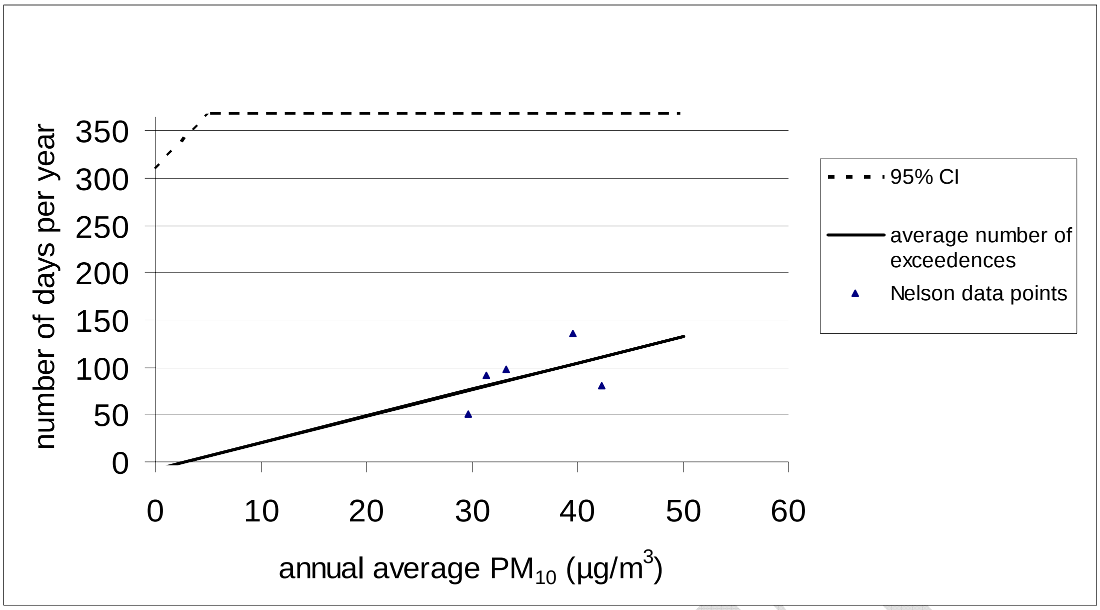

Figure 15. Number of days per year that PM_{10} concentration exceeds 50 µg/m^3 in the Nelson Region.

Latitude: Figure 16 examines latitude the relationship between a site's latitude and the measured peak 24-hour PM_{10} concentration. Figure 17 examines the relationship between a site's latitude and the number of days per year that the 24-hour mean PM_{10} concentration exceeds 50 µg/m^3. The plots show that both higher peaks and a greater number of exceedences can be expected as the latitude increases or the further south one goes.

The data are summarised in Figure 18.

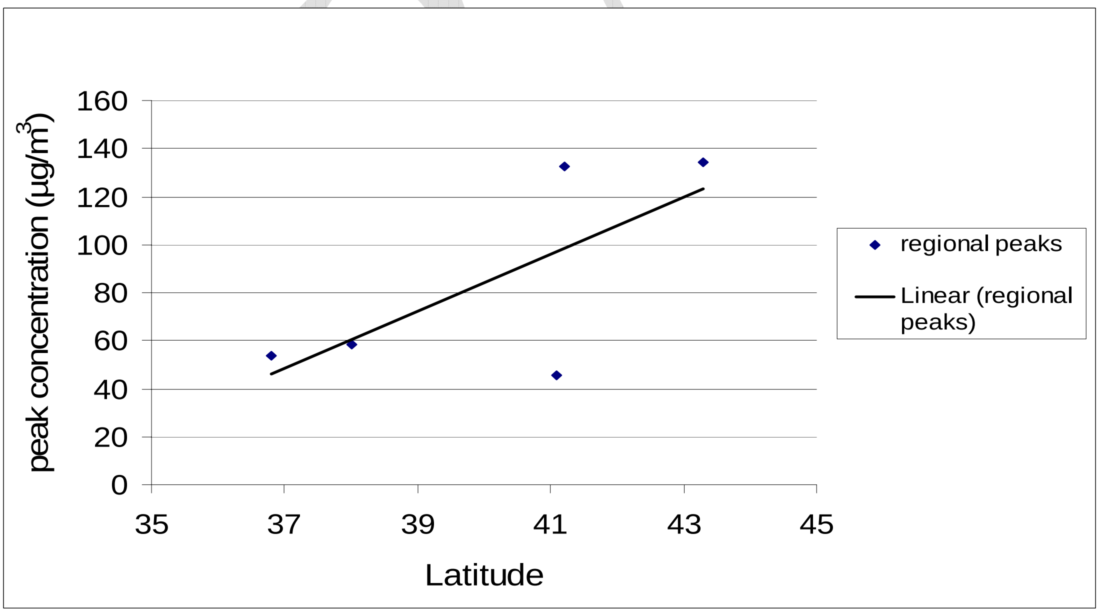

Figure 16. Average regional peak PM_{10} concentration vs. approximate latitude.

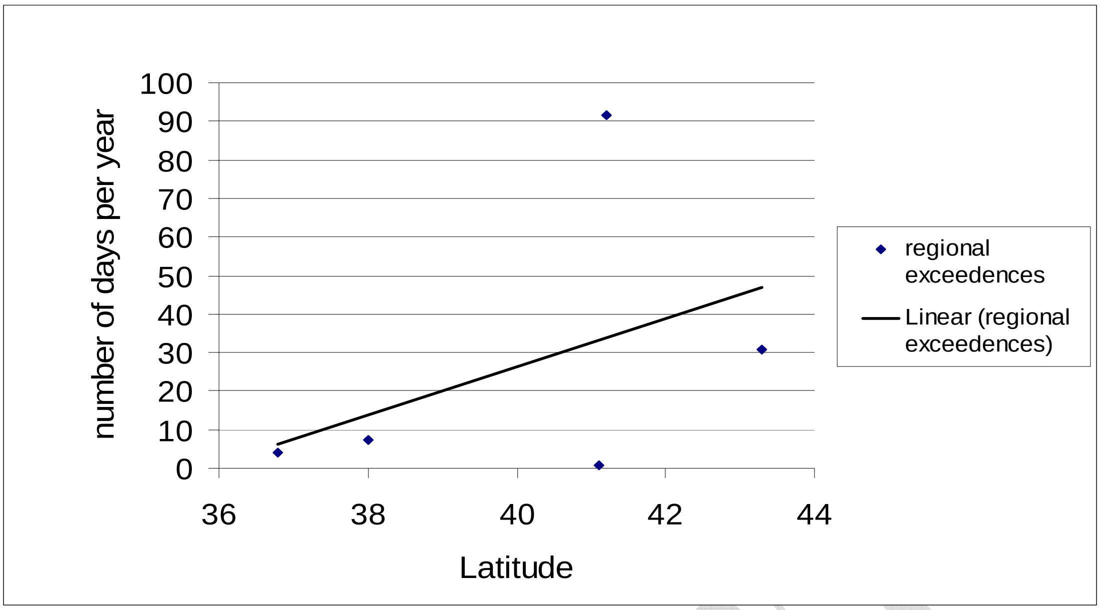

Figure 17. Average number of days per year per region that 24-hour mean PM_{10} concentration exceeds 50 µg/m^3 vs. approximate latitude.

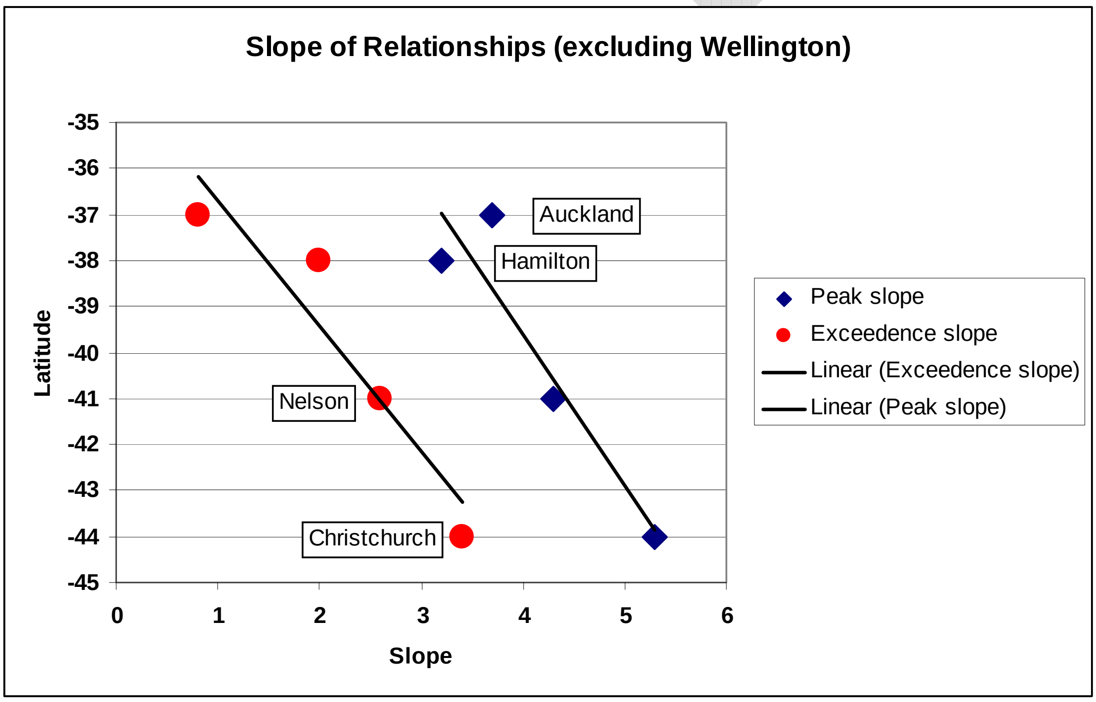

Figure 18. Summary of peak and exceedence data vs. approximate latitude. (Wellington is omitted due to its particularly high exposure regime).

Conclusion

The results show a general correlation between the peak annual and average annual PM_{10} concentrations. A correlation also seems to exist between the number days that the mean 24-hour PM_{10} concentration exceeds 30 µg/m^3 and the average annual concentration. These relationships are stronger at some sites than others. Less strongly correlated is the relationship between exceedences of 50 µg/m^3 and annual average. This could be due in large part to the fact that there are very few data points. It is also due to intermittent data sampling which requires a normalization of data. Relationships could elicit a higher degree of confidence as more data points are collected. As it stands the data presented above does provide reasonable estimates on the peak and exceedence number for the regions analysed. Thus, they provide an additional tool to Councils in managing their air quality.

The correlations with latitude (as a broad indicator of climate factors) are interesting, although not strong. The latitude plots, though showing less correlation, are provided for estimates of peak and exceedences in regions where there is currently little or no PM_{10} monitoring being conducted. The trend shows higher peaks and a greater number of exceedences with greater latitudes – i.e. further south. This is most likely due to the colder climate and increased incidence of home heating. Other climate related factors may be important (such as frequency of inversions) but these have not yet been investigated.

References

Health Effects of PM_{10} in New Zealand. Prepared by Environet Limited for the Ministry for the Environment, Air Quality Technical Report No. 39. August 2003

Health Effects Due to Motor Vehicle Air Pollution in New Zealand. Fisher G, Rolfe K, Kjellstrom T, et al. 2002. Report to the Ministry of Transport.

Appendix. Data summary for Auckland. Note: Exceedence numbers have been adjusted to account for intermittent sampling.

AUCKLAND	***Year***	***Average***	***Peak***	***Exceedences***			
				>50	**>40**	**>30**	**>20**
Penrose	1994	23.7	101.1	18	24	48	90
	1995	24.8	77.3	12	36	90	228
	1996	25.0	48.4	0	18	78	246
	1997	25.3	65.8	18	36	78	216
	1998	23.5	48.1	0	18	66	216
	1999	24.5	80.5	12	30	60	216
	2000	19.4	57.4	4	8	30	75
	2001	17.8	72.3	6	9	24	93
	2002	19.4	44.8	0	6	24	153
	2003	19.5	54.0	6	9	27	141
Takapuna	1997	19.2	50.5	6	12	42	108
	1998	15.4	38.1	0	0	12	42
	1999	14.9	39.0	0	0	6	36
	2000	14.1	30.5	0	0	12	54
	2001	14.1	62.3	6	9	15	45
	2002	17.4	42.4	0	6	12	75
	2003	16.6	49.8	0	6	24	78
	2004	19.2	43.3	0	6	36	141
Mt Eden	1997	16.1	42.0	0	6	12	60
	1998	20.6	39.8	0	0	48	174
	1999	20.3	45.8	0	12	36	156
	2000	18.1	43.3	0	6	30	108
	2001	15.1	51.1	4	8	15	68
	2002	14.1	35.1	0	0	3	36
	2003	12.1	27.2	0	0	0	15
	2004	14.7	49.5	0	3	6	54
Khyber Pass	1998	30.0	121.4	12	18	126	264
	1999	27.4	62.2	6	24	102	312
	2000	27.6	94.6	12	48	90	234
	2001	23.0	68.7	4	19	38	191
	2002	21.9	94.5	9	15	36	177
	2003	20.2	42.9	0	3	30	171
	2004	21.7	47.4	0	3	45	240
Henderson	1999	21.4	55.4	6	12	60	150
	2000	17.4	37.7	0	0	24	84
	2001	18.8	43.9	0	5	50	108
	2002	15.8	32.7	0	0	6	81
	2003	15.2	43.7	0	3	9	60
	2004	16.3	39.8	0	0	12	99
Queen St.	1999	26.7	51.1	12	18	108	264
	2000	25.7	84.1	12	30	66	240
	2001	21.9	53.8	4	8	56	184
	2002	21.4	40.1	0	3	33	189
	2003	21.2	46.2	0	9	39	198
	2004	22.9	52.6	3	9	81	210

CANTERBURY	***Year***	***Average***	***Peak***	***Exceedences***		
				>50	**>40**	**>30**
Kaiapoi	2001	29.2	153.5	40	61	86
	2002	23.1	138.5	30	38	67
	2003	26.1	163.0	35	55	87
	2004	22.3	98.5	17	26	61
	2005	23.6	151.8	17	39	74
Rangiora	1999	17.7	87.1	11	23	48
	2000	16.7	97.2	7	13	40
	2004	18.6	77.9	6	16	35
	2005	20.0	98.8	10	20	47
Timaru	1997	30.2	135.1	47	64	92
	1998	25.8	100.7	31	54	83
	1999	28.4	151.6	48	68	106
	2000	29.2	162.0	52	69	112
	2001	28.5	153.9	50	74	108
	2002	24.9	106.8	33	49	86
	2003	29.6	154.7	51	72	106
	2004	26.8	117.1	40	63	104
	2005	30.5	109.4	48	72	110
Ashburton	1999	22.0	93.7	13	32	66
	2000	21.4	96.8	17	35	69
	2005	25.0	89.4	18	42	86
Coles	1999	28.4	193.7	51	63	84
	2000	23.5	181.6	31	44	80
	2001	29.2	220.2	52	65	89
	2002	24.1	214.5	28	40	65
	2003	24.6	136.1	37	54	78
	2004	24.2	134.8	36	48	67
	2005	22.9	149.1	32	42	66

WAIKATO	***Year***	***Average***	***Peak***	***Exceedences***			
				>50	**>40**	**>30**	**>20**
Hamilton	1998	15.3	34.7	0	0	2	33
	1999	15.7	43.9	0	3	14	59
	2000	14.7	43.1	0	1	7	49
	2001	14.5	66.5	2	4	10	30
	2002	15.5	36.2	0	0	3	56
	2003	15.4	62.0	3	6	15	49
	2004	16.9	55.0	1	2	17	90
	2005	15.2	33.5	0	0	5	42
Te Kuiti	2003	20.1	57.7	4	22	48	87
	2004	18.3	61.0	5	19	41	109
	2005	19.3	53.9	2	10	30	73
Tokoroa	2001	26.6	74.6	13	22	48	107
	2002	24.0	69.5	15	26	63	205
	2004	31.0	97.0	41	75	132	262
	2005	27.5	89.3	30	47	86	181
Taupo	2001	19.7	57.0	6	24	54	114
	2002	15.9	54.0	5	14	29	86
	2003	18.5	62.0	12	21	51	126
	2004	17.8	65.0	6	24	45	99
	2005	17.2	52.0	3	15	27	102

WELLINGTON	***Year***	***Average***	***Peak***	***Exceedences***			
				>50	**>40**	**>30**	**>20**
Masterton	2003	16.4	62.2	2	9	28	72
	2004	15.0	54.5	3	7	15	65
	2005	16.1	61.9	1	3	8	31
Upper Hutt	2001	14.2	50.5	1	6	13	23
	2002	14.9	48.6	0	2	11	37
	2003	14.7	34.1	0	0	6	48
	2004	11.9	48.9	0	1	5	36
	2005	7.3	21.5	0	0	0	1
Wainuiomata	2001	13.2	57.4	13	18	40	49
	2002	10.7	49.8	0	8	16	28
	2003	11.2	57.2	3	6	18	24
	2004	11.1	47.2	0	6	24	39
Lower Hutt	2001	13.4	29.5	0	0	0	15
	2002	14.5	41.2	0	1	2	43
	2003	14.0	34.3	0	0	1	31
	2004	15.0	45.2	0	1	4	47
	2005	14.6	26.3	0	0	0	13

NELSON	***Year***	***Average***	***Peak***	***Exceedences***			
				>50	**>40**	**>30**	**>20**
Nelson	2001	42.3	165.0	81	90	109	152
	2002	31.3	129.0	92	120	171	236
	2003	39.6	147.0	136	168	198	286
	2004	33.2	127.0	98	84	117	149
	2005	29.6	96.0	51	77	99	141