greater WELLINGTON
REGIONAL COUNCIL
Te Pane Matua Taiao

Carterton winter air quality

2010 to 2016

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Contents

1. Introduction

Carterton, located in the Wairarapa Valley, has a population of 4,686 and 1,968 households (Statistics New Zealand, 2013). In 2013, 70.6% of homes, which equates to about 1,390 dwellings, reported using wood as a heating fuel. When wood is burnt it releases fine particles into the air which are measured as PM_{10} (particles less than 10 µm in diameter) and as $PM_{2.5}$ (particles less than 2.5 µm in diameter). Generally, the smaller $PM_{2.5}$ particles are produced by combustion, such as wood burning or from car exhausts. PM_{10} includes larger particles that arise from natural sources, such as sea salt and wind-blown soil, as well as the smaller $PM_{2.5}$ particles derived from combustion sources.

A range of adverse health effects are associated with both short-term and long-term exposure to PM_{10} and $PM_{2.5}$, particularly in children, the elderly and those with underlying health conditions. These health effects impact the respiratory and cardiovascular systems with consequences ranging from restricted activity days to increases in hospital emergency visits and general admissions. The most severe effect is reduced life expectancy of the average population linked to long-term exposure (Pope & Dockery, 2006).

There is no evidence of a threshold below which there are no adverse health effects from exposure to particles (World Health Organization (WHO), 2016). The National Environmental Standard for Air Quality (NES-AQ) sets a regulatory framework that provides a set level of health protection for all New Zealander's from elevated levels of daily PM_{10} (Ministry for the Environment, 2011).

The first air quality monitoring undertaken in Carterton consisted of a two-week pilot study in winter 2009 which showed potential for high PM_{10} concentrations due to home fires (Davy, 2009). Following this study, PM_{10} was monitored in Carterton during winter 2010 and then again in winter 2013. During 2010 and 2013 only one exceedance of the NES-AQ was recorded (on 21 July 2010). Carterton was found to have a similar pattern of PM_{10} concentrations during the day as Masterton, that is, a small morning peak and a larger evening peak coinciding with people lighting their fires. However, the evening PM_{10} levels in Carterton were lower than that measured in Masterton during winter 2010 and 2013.

Modelling work commissioned by GWRC, as part of the review of the extent of the Wairarapa airshed boundary, found that it was unlikely that Carterton and any other areas outside of the township of Masterton would breach the NES-AQ[1] (Golder Associates, 2014). The Wairarapa airshed was therefore disestablished and a smaller airshed, confined to the Masterton urban area, was gazetted in 2014. Although Carterton is not a formally gazetted airshed, it is still classified as a general airshed under the NES-AQ and therefore needs to be monitored if it is likely that the PM_{10} standard will be breached.

[1] A breach occurs when there is more than one exceedance of the PM_{10} standard in a 12 month period.

Based on past monitoring results and air quality modelling work, it was decided not to install a permanent monitoring station in Carterton, but instead undertake winter air quality monitoring every three years, commencing in 2016. This report summarises the results of monitoring undertaken in winter 2016, compares them to that of past years and to Masterton, and provides new information on $PM_{2.5}$ levels in Carterton.

2. Method

2.1 Monitoring objectives

- To measure concentrations of PM_{10} and $PM_{2.5}$ in Carterton during winter 2016 and compare results to relevant air quality guidelines and regulatory standards.

- To compare levels of PM_{10} measured in Carterton in 2016 to previous monitoring in 2013 and 2010 and detect any trend present.

- To compare levels of PM_{10} measured in Carterton in 2010, 2013 and 2016 to levels measured in Masterton and detect any trend present.

2.2 Air quality guidelines and standards

The NES-AQ for PM_{10} allows only one day per year to be above the threshold of 50 $\mu g/m^3$ (24-hour average).

There are no national standards currently available for daily $PM_{2.5.}$ In the absence of New Zealand standards for $PM_{2.5}$, the WHO guideline of 25 $\mu g/m^3$ (24-hour average) has been used (WHO, 2006).

2.3 Monitoring location and instrumentation

GWRC's mobile air quality monitoring station (Figure 2.1) was installed in the Carterton public swimming pool grounds (Figure 2.2.) from May to August 2016. Both PM_{10} and $PM_{2.5}$ were measured using a beta attenuation monitor (Thermo Scientific FH62-C14). This method is a NES-AQ compliant monitoring method for PM_{10}. The locations of the two Masterton monitoring stations are shown in Figure 2.3.

Figure 2.1: Mobile air quality monitoring station located at Carterton public swimming pool (May to August 2016)

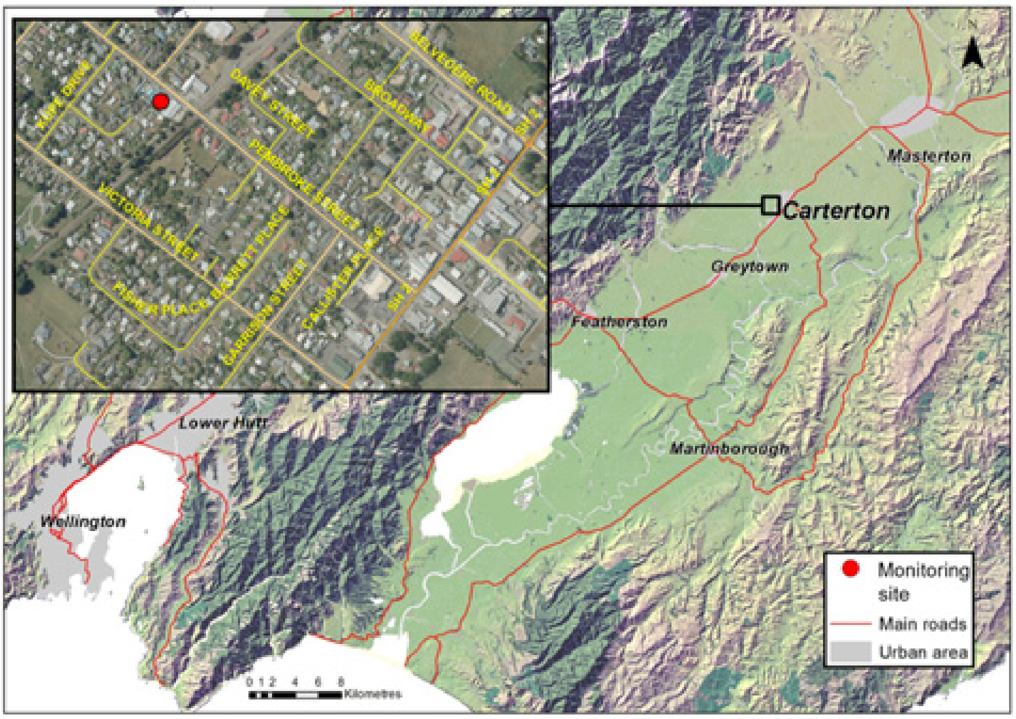

Figure 2.2: Location of Carterton monitoring site (Pembroke Street)

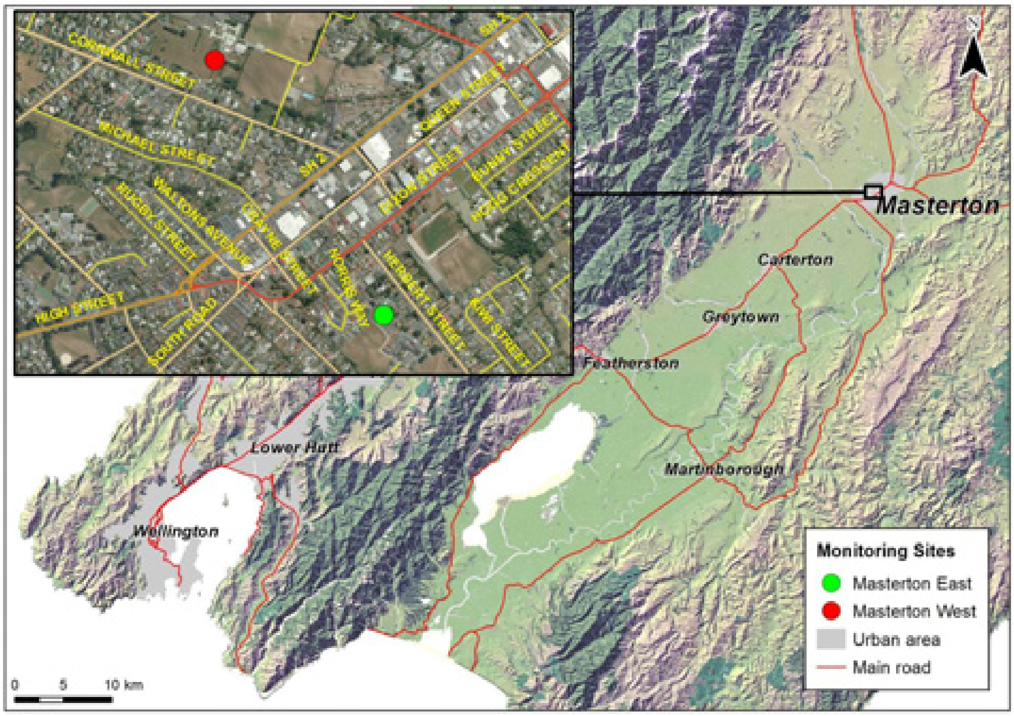

Figure 2.3: Location of Masterton West and Masterton East monitoring sites

2.4 Data analysis

PM_{10} and $PM_{2.5}$ levels recorded at different sites and over time are not always comparable because the results obtained depend on the measurement method or instrument.

Certain instrument types may be phased out and replaced by newer technologies that use different principles of measurement. For example, the FH62 instrument is no longer manufactured and when these instruments reach the end of their working lives they are replaced by the newer 5014i model. When operated side by side in a wood smoke environment, the 5014i measures higher levels of particulate matter (PM) than the FH62. This is because the 5014i adjusts and lowers the sample inlet temperature based on relative humidity so that more volatile particles from wood smoke are measured instead of being evaporated by heating of the air sample.

Such instrument changes confound trend analysis because the higher levels of PM measured may be due to the instrument's principle of measurement rather than an actual increase in wood smoke. For this reason, different instrument types are co-located for a period of time at the same monitoring site to evaluate their relationship, in order to calibrate data from the new instrument.

In this report, the Masterton West 2016 data has been adjusted to compensate for the change in instrument type. Appendix 1 presents the equation used to adjust these data. Data have not been adjusted where they are used for compliance reporting, such as number of PM_{10} NES-AQ exceedances and number of days where $PM_{2.5}$ was above the WHO guideline. A table of the different instruments used at the three monitoring sites between 2010 and 2016 is also presented in Appendix 1.

All statistical analysis was carried out using R statistical software (R Core Team, 2015). The time series plots and data averaging were carried out using the *openair* package (Carslaw & Ropkins, 2015). A pairwise t-test using matched 24-hour periods of concurrent measurements at Carterton, Masterton West and Masterton East with correction for multiple comparisons[2] was used to test for differences between the sites and monitoring periods at the 95% confidence level. Matched pairs were used (ie, 24-hour measurements taken on the same day) because of inter-correlation between the three sites.

[2] Bonferroni correction used in which the p-values are multiplied by the number of comparisons to control for the family-wise error rate.

3. Results and discussion

3.1 Winter 2016

PM_{10} monitoring results for Carterton and Masterton are summarized in Table 3.1. During winter 2016 there were two exceedances measured at Carterton, one at Masterton West and 10 at Masterton East. The PM_{10} exceedances at Carterton were close to the threshold limit (52 µg/m^3 on 4 June and 54 µg/m^3 on 5 June).

There were 17 days in Carterton when daily $PM_{2.5}$ levels failed to meet the WHO guideline threshold compared to 19 days at Masterton West and 33 days at Masterton East.

A time series of the PM_{10} 24-hour values measured at Carterton, Masterton West and Masterton East are shown in Figure 3.1 and $PM_{2.5}$ values are shown in Figure 3.2.

The distribution of 24-hour average PM_{10} and $PM_{2.5}$ levels recorded at Carterton and the two Masterton sites are shown in Figure 3.3. There was no statistically significant difference in average PM_{10} levels recorded at Carterton and Masterton West during winter 2016, both with and without the adjustment for instrument change at Masterton West. However, average levels of PM_{10} recorded at Masterton East were higher than those recorded at Carterton and Masterton West.

Likewise for $PM_{2.5}$, average levels recorded at Carterton and Masterton West were not significantly different. Also, average levels of $PM_{2.5}$ recorded at Masterton East were higher than those recorded at Carterton and Masterton West.

The reasons for higher concentrations of PM_{10} and $PM_{2.5}$ at Masterton East (compared to Masterton West) probably relate to local night time patterns of cold air drainage, which causes emissions from home fires to accumulate towards the south east of Masterton, where the Masterton East station is located (Mitchell, 2013).

Table 3.1: Summary statistics PM_{10} and $PM_{2.5}$ for Carterton and Masterton, winter 2016

PM metric	Carterton	Masterton West	Masterton East
PM_{10} winter average	18.3	20.9 [19.0][3]	25.0
PM_{10} maximum 24-hr average	54	57	66
Number of NES-AQ exceedances	2	1	10
$PM_{2.5}$ winter average	15.0	15.7	19.8
$PM_{2.5}$ maximum 24-hr average	54	49	58
Number of WHO exceedances	17	19	33

[3] Masterton West PM_{10} data adjusted for instrument change in 2016.

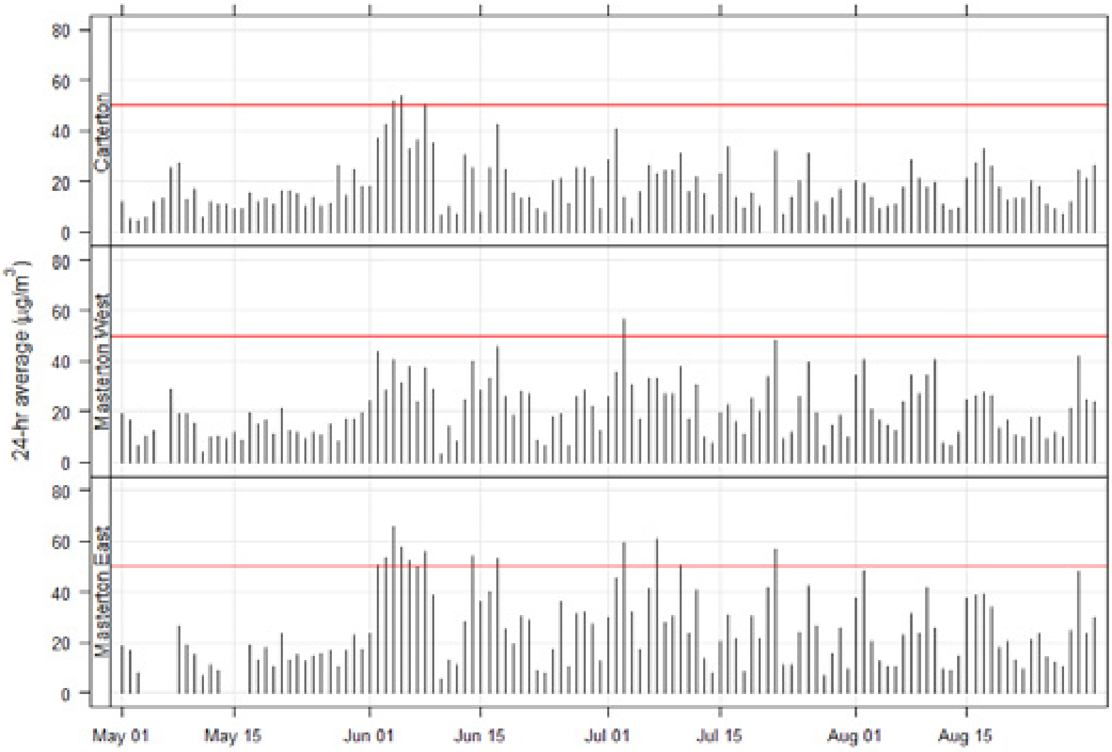

Figure 3.1: Time series of PM_{10} in winter 2016 for Carterton, Masterton West and Masterton East (red line shows NES-AQ threshold)

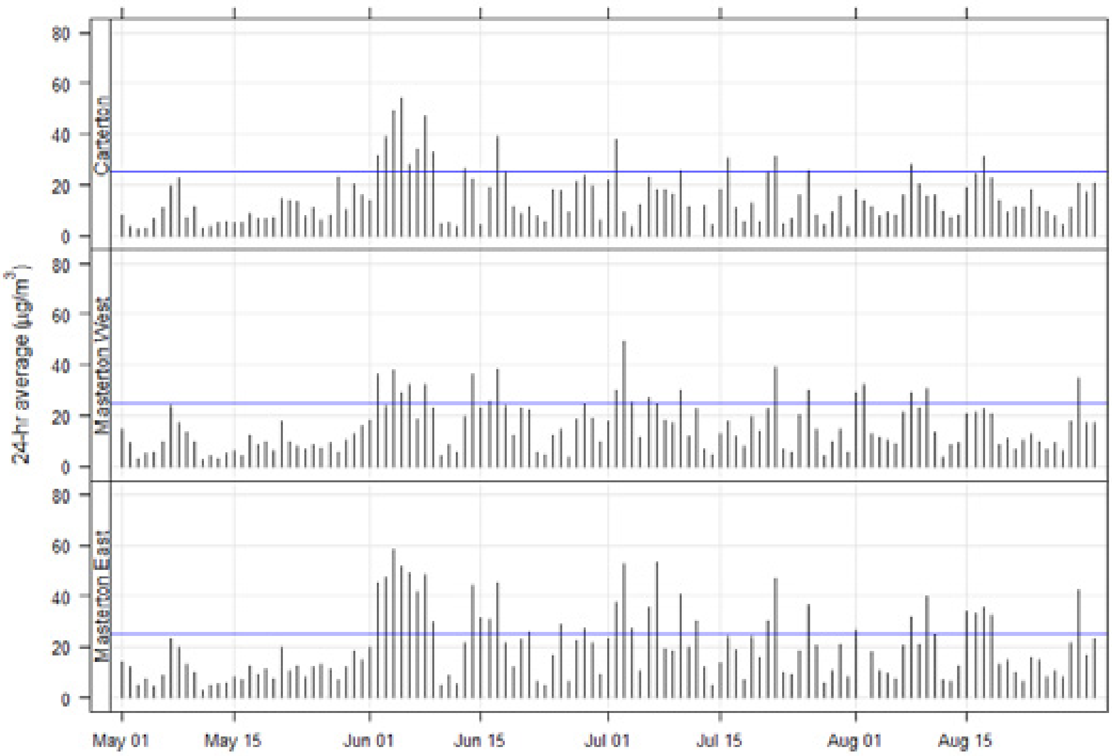

Figure 3.2: Time series of $PM_{2.5}$ in winter 2016 for Carterton, Masterton West and Masterton East (blue line shows WHO threshold)

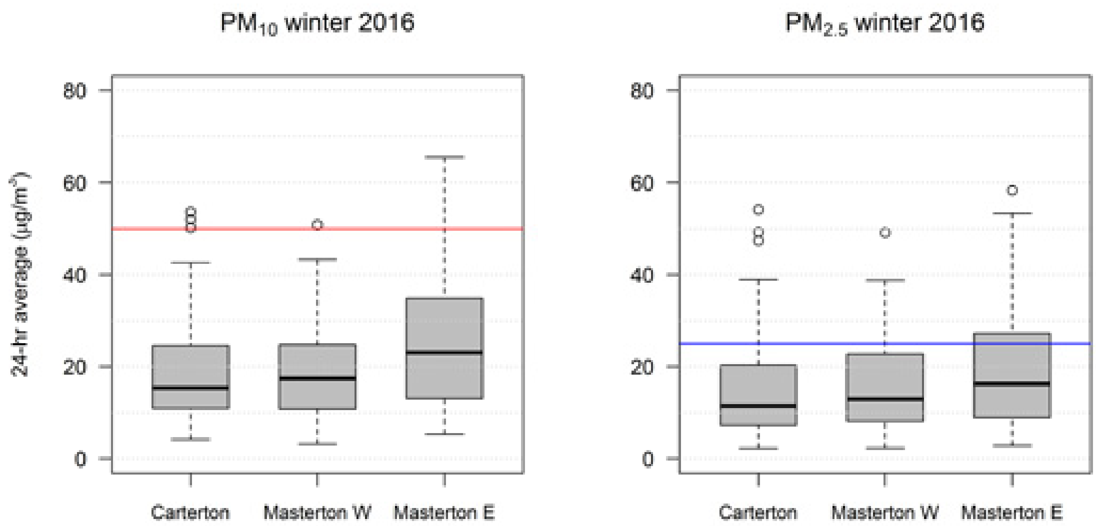

Figure 3.3: Boxplots showing distribution of 24-hour average PM_{10} (left) and $PM_{2.5}$ (right) at the Carterton and Masterton monitoring sites during winter 2016. The red line shows NES-AQ threshold for PM_{10} and the blue line shows WHO guideline for $PM_{2.5}$ (Masterton West PM_{10} data adjusted for instrument change in 2016).

3.2 Winter PM_{10} levels in 2016 compared to 2010 and 2013

The distribution of 24-hour average PM_{10} levels recorded at the Carterton and Masterton West monitoring sites during winter 2010, 2013 and 2016 are shown in Figure 3.4.

At both sites the average winter PM_{10} levels were similar across the three monitoring periods, with no statistically significant difference found at the 95% confidence level. This is despite a likely long-term downward trend in average winter PM_{10} concentrations at Masterton West observed between 2003 and 2016 (Pezza & Mitchell, 2016).

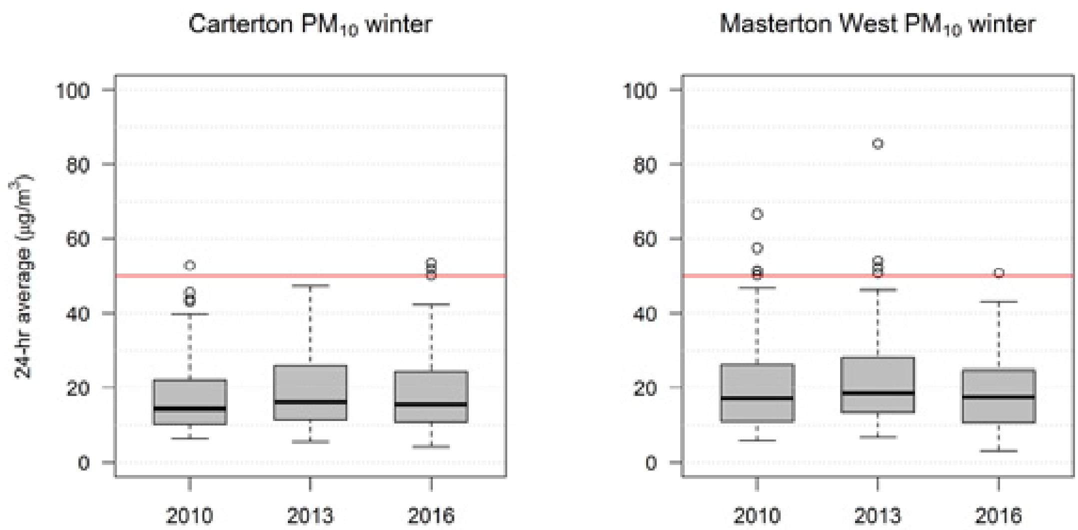

Figure 3.4: Boxplots showing distribution of 24-hour average PM_{10} at Carterton (left) and Masterton West (right) during winter 2010, 2013 and 2016. The red line shows NES-AQ threshold for PM_{10} (Masterton West PM_{10} data adjusted for instrument change in 2016).

The difference in PM_{10} levels (ie, 24-hour averages measured on the same day) between Masterton West and Carterton for each of the winter periods is shown in Figure 3.5. Over the three monitoring periods PM_{10} values were higher at Masterton West than Carterton, with an average overall difference of 2.3 µg/m³ [1.5, 3.1][4]. However, in 2016 the relative difference between the two sites was much closer, with no statistically significant difference found at the 95% confidence level.

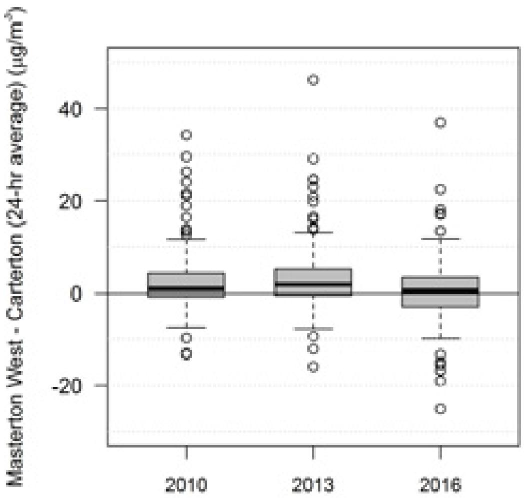

Figure 3.5: Boxplots showing distribution of the difference (µg/m³) between 24-hour average PM_{10} concentration at Masterton West and Carterton during winter 2010, 2013 and 2016. The horizontal line at zero on the y-axis represents no measurement difference between the two sites (Masterton West PM_{10} data adjusted for instrument change in 2016).

3.3 Impact of weather on dispersion of PM emissions in winter

Daily weather patterns strongly influence the dispersion of air pollutants. Low temperatures and low wind speeds during winter evenings are associated with elevated PM_{10} and $PM_{2.5}$ as smoke from wood burners builds up and is not readily dispersed. Conversely, windy conditions during the day can lead to higher levels of PM_{10}, as particles from sources such as wind-blown soils and road dust become mobilised.

Local wind conditions are influenced by the larger-scale or synoptic weather patterns such as highs and lows. The synoptic weather patterns often associated with settled conditions and low wind speeds during winter are high pressure systems or anticylones. During anticyclones a layer of high pressure air descends towards the Earth’s surface. The high pressure air warms as it descends causing evaporation of any moisture in the air leading to clear skies. The high pressure system also suppresses the upward motion of air that leads to clouds forming and rainfall.

During winter, under clear skies and low wind speeds, a night-time surface temperature inversion can occur when the ground cools releasing heat absorbed

[4] 95% confidence interval

during the daytime back into space. The air immediately above the ground becomes colder than the layer above creating a temperature inversion which is a reverse of the normal situation in which temperature decreases with height above ground level. Consequently emissions from wood burners become trapped in the layer of cooler air and cannot disperse upwards due to the cap of warmer air on top.

The upper Wairarapa Valley is more prone to night time surface temperature inversions because of the effect of topography. At night colder air from the surrounding ranges and hills flows downhill (due to gravity) and can pool in low lying areas further cooling the ground layer and creating a stronger temperature inversion (Griffiths 2011).

During winter 2016 two exceedances of the PM_{10} NES-AQ were recorded in Carterton on 4 and 5 June (Queen's Birthday weekend) with a further close to exceedance day on 8 June. During this period (between 3 and 6 June) wind speeds measured at the monitoring site were low (less than 1 m/s), daily average temperatures were below 6°C and overnight temperature minima were below zero degrees.

From 1 to 8 June there was a strong high pressure system (anticyclone) situated over central New Zealand (Figure 3.6). This anticyclone was slow moving and persisted for eight consecutive days. A strong anticyclone lasting for this length of time is unusual and may be a one in ten year event (Alex Pezza, pers. comm. 22/8/2016). It is most likely that the persistent anticyclone resulted in very stable atmospheric conditions so that emissions from wood burning were not able to be dispersed and reached higher than average concentrations leading to PM_{10} exceedances.

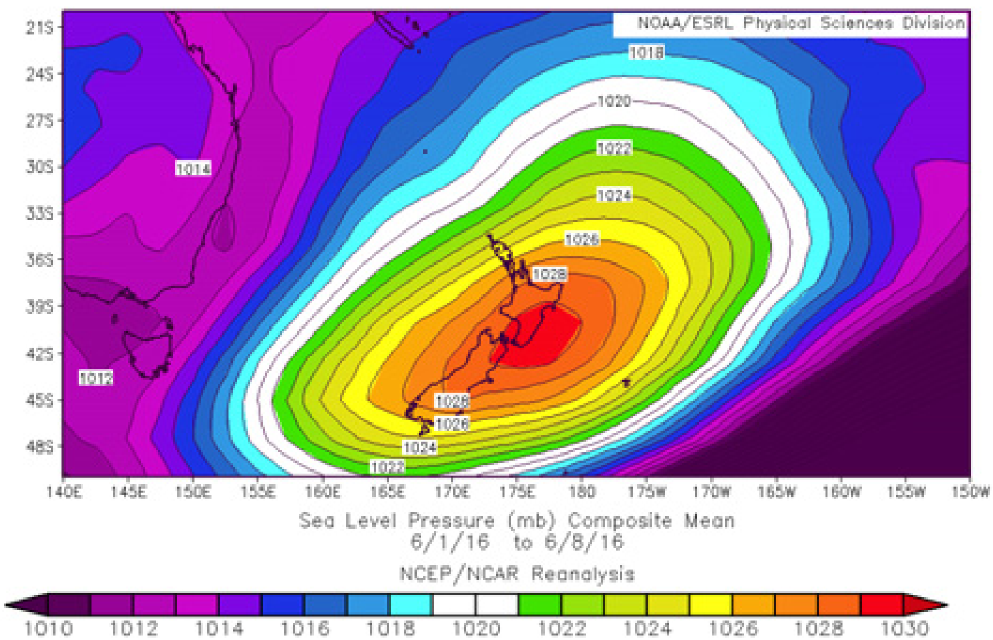

Figure 3.6: Composite mean sea level pressure (hPa) contours from 1 to 8 June 2016

4. Conclusion

Average winter PM_{10} levels in Carterton have remained fairly static over the 2010, 2013 and 2016 winters. PM_{10} and $PM_{2.5}$ levels measured in Carterton are similar to those recorded at Masterton West. Previously, Masterton West measured higher concentrations of PM_{10} than Carterton, but due to the small but steady reduction in PM_{10} concentrations measured at Masterton West since 2003, the two monitoring sites now record similar average concentrations.

Two PM_{10} NES-AQ exceedances were recorded in Carterton in June 2016 which equates to a breach of the NES-AQ as only one exceedance per 12-month period is permitted. The PM_{10} exceedances were associated with the strong and unusually persistent anticyclone situated over central New Zealand in the first week of June 2016. This type of synoptic condition is atypical and would be expected to occur about once every 10 years.

Short term (ie, daily) $PM_{2.5}$ levels in Carterton, like those measured in Masterton, fail to meet the WHO guideline. Therefore, it is recommended that monitoring of $PM_{2.5}$ continues in Carterton. Where possible non-regulatory methods adopted for reducing emissions from domestic fires so as to improve air quality in the Masterton urban area should also be considered for Carterton.

Acknowledgements

We are grateful to Carterton District Council for allowing us to use their public swimming pool site for the mobile air quality monitoring station. Thank you to Darren Li for undertaking the monitoring and to James Bell for logistical support. Thanks to Alex Pezza for synoptic reanalysis.

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Appendix 1

Table A.1: Monitoring instruments used at Carterton and Masterton (2010, 2013 and 2016)

Site	2010	2013	2016
Carterton	FH62 (PM_{10})	FH62 (PM_{10})	FH62 (PM_{10}) FH62 ($PM_{2.5}$)
Masterton West	FH62 (PM_{10}) 5030 ($PM_{2.5}$)	FH62 (PM_{10}) 5014i (PM_{10}) 5030 ($PM_{2.5}$)	5014i (PM_{10}) 5014i ($PM_{2.5}$)
Masterton East	5014i (PM_{10})	5014i (PM_{10}) 5014i ($PM_{2.5}$)	5014i (PM_{10}) 5014i ($PM_{2.5}$)

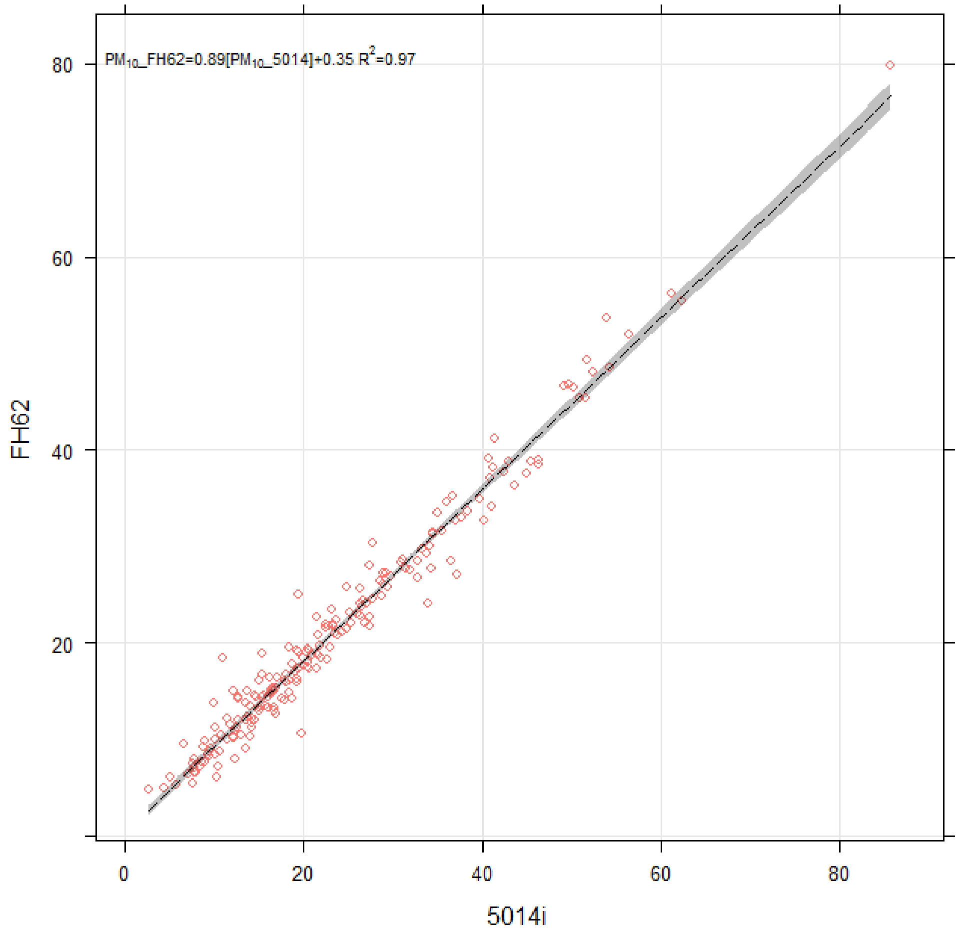

Figure A.1: Linear relationship between co-located FH62 and 5014i instruments for 24-hour PM_{10} measurements at Masterton West from 2012 to 2013 for May, June, July and August. Equation used to adjust data: E[FH62] = 0.89[5014i] + 0.35 R^2=0.97