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PREPARED FOR
West Coast Regional Council

PREPARED BY
Emily Wilton, Environet Ltd
www.environet.co.nz

Air Quality in Reefton – monitoring and trends assessment

EXECUTIVE SUMMARY

Reefton has historically experienced poor air quality with breaches of the National Environmental Standards (NES) for PM_{10} during the winter months. The NES specifies a limit of 50 µgm^{-3} (24-hour average) with one allowable exceedance per year.

Air quality monitoring for daily PM_{10} has been carried out in Reefton since 2006. In September 2016 the monitoring site was shifted to an alternative location. The new site records lower PM_{10} concentrations with 2020 being the only year to record a breach of the NES between 2017 and 2021.

Assessing trends in PM_{10} in Reefton is complicated by the relocation of the air quality monitoring site. Additionally the impact of meteorological conditions, which varies from year to year, complicate trend analysis. An evaluation of trends in PM_{10} concentrations, accounting for the impact of meteorological conditions for the old monitoring site was carried out in 2013 which covered the period from 2006 to 2012. This suggested no downward trend in daily concentrations nor in the frequency of exceedance of the 24-hour average NES for PM_{10} of 50 µg/m^3 (one allowable exceedance per year). This analysis was updated to include data from 2014 to 2016.

There is some indication based on the assessment that concentrations in Reefton have improved between the years 2014 and 2016 or potentially 2017. However, it is unlikely that improvements in PM_{10} concentrations account for all the differences between the old and new monitoring sites.

The meteorological conditions which result in the highest PM_{10} concentrations at the new site were 24-hour average wind speeds. The highest pollution potential days occurred when the average (24-hour average) wind speed was less than 0.74 µg/m^3. A further analysis of high pollution potential days identified additional wind speed and temperature variables to further quantify pollution potential.

An evaluation of trends in high pollution potential days from 2017 to 2021 indicates no improvement in PM_{10} in Reefton over this period. Data from 2006 to 2014 are also indicative of no trend in PM_{10} concentrations. It is possible that some reduction in PM_{10} concentrations occurred from 2015 to 2016 and a reduction between 2016 and 2017 is also possible but unquantified owing to the relocation of the monitoring site. Characterisation of the relationship between the old and new air quality monitoring sites would assist with understanding any change in PM_{10} in Reefton from 2015 to 2017.

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1 INTRODUCTION

Concentrations of PM_{10} in Reefton historically have breached the National Environmental Standards (NES) for PM_{10} during the winter months. The NES specifies a limit of 50 µgm^{-3} (24-hour average) with one allowable exceedance per year.

Air quality monitoring for daily PM_{10} has been carried out in Reefton since 2006. Assessing trends in PM_{10} concentrations based on monitoring data alone is difficult because the impact of meteorological conditions varies from year to year. An evaluation of trends in PM_{10} concentrations, accounting for the impact of meteorological conditions for the old monitoring site was carried out in 2013 which covered the period from 2006 to 2012. This suggested no downward trend in daily concentrations nor in the frequency of exceedance of the 24-hour average NES for PM_{10} of 50 µg/m^3 (one allowable exceedance per year).

In September 2016 the air quality monitoring site was shifted. Characterisation of relationship between elevated particulate concentrations and meteorological conditions for the new site provides the ability to be able to adjust for the impact of meteorology and better understand trends in particulate. Previous relationships established may identify the same meteorological conditions resulting in elevated pollution but the relationship between those variables and the associated PM_{10} concentrations will differ owing to the lower PM_{10} measured at the new site.

This study assesses the relationship between particulate concentrations and meteorology and identifies meteorological conditions most conducive to elevated concentrations.

The objectives of this study are to:

- characterise meteorological conditions in terms of impact on PM_{10} concentrations
- assess trends in PM_{10} concentrations when the impact of meteorological conditions is minimised, including daily and annual trends and the proportion of high pollution days that have resulted in exceedances of the NES
- evaluate the likelihood of changes in emissions having occurred from 2017 to 2021.

2 METHODOLOGY

2.1 Monitoring data

Monitoring or PM_{10} has been carried out at the old school site in Reefton since 2016. Daily PM_{10} concentrations were provided by West Coast Regional Council for the period 2017-2021 (July) for inclusion in the trends evaluation.

The data to be included in the study was limited to include the months May to August. This assists in the characterisation of meteorological conditions most conducive to elevated wintertime PM_{10} concentrations and is more relevant in terms of breaches of the NES. A total of 482 days were included in the study. Data for 2016 were unable to be included because the site was not established until September.

2.2 Meteorological data

Meteorological data for the period 2017 to 31 August 2021 were collated from the Reefton Air quality monitoring site for the variables shown in Table 3.1. The range of averaging periods were included to determine which variables most significantly explained variations in 24-hour average PM_{10} concentrations and which were the greatest indicators of elevated PM_{10}.

Table 2.1: Meteorological classifications used for the analysis

	Period	PM_{10}	Wind speed (ms^{-1})	Temperature (ºC)	Wind direction (ºN)
24-hour average	Midnight to midnight	✓	✓	✓	
7-hour average	5 pm to midnight		✓	✓	
4-hour average	8 pm to midnight		✓	✓	
6-hour average	6am to midday		✓		
6-hour average preceding day	6pm to midnight		✓		
Minimum 1-hour	Midnight to midnight		✓	✓	
Minimum following day 1-hour	Midnight to midnight			✓	
Minimum sample day less minimum day following 1-hour	Midnight to midnight			✓	
Maximum 1-hour	Midnight to midnight		✓	✓	
Hourly average	5 pm		✓	✓	✓
	5 pm to midnight		<1ms-1	<1 ºC	
Number of hours	Midnight to midnight		<2 ms-1	<5 ºC	
				<10 ºC	

2.3 Statistical Analysis

Regression tree analysis was used to investigate the meteorological conditions with the greatest potential to produce elevated concentrations of PM_{10} in Reefton. Classification and Regression Trees (CART) describe a statistical procedure that was introduced by Breiman et al. (1984). Classification and Regression Trees have been applied to a wide variety of environmental studies including air quality problems (e.g., Zheng et al. 2009, Hendrikx et. al., 2005).

Based on a set of predictor variables, this statistical approach repeatedly splits the response into a set of classes (or nodes) with maximum possible class purity at each split stage and arranges the final splits into a decision tree diagram. Analysis was undertaken using the Classification and Regression Tree (CART) analysis in Systat which is based on the algorithms of Breiman et al. (1984).

3 TRENDS IN PM_{10} CONCENTRATIONS

3.1 Trends in all PM_{10} data

Figure 3.1 shows trends in PM_{10} concentrations from 2006 to 2021 unadjusted for variability in meteorological impacts. Data illustrated includes the average and median (dash and cross within box) as well as the lower and upper quarter concentrations (box) for Reefton. Data can be compared from 2006 to 2016 (old site) and from 2017 – 2021 (new site). The 2016 upper quarter concentrations were lower than the median 2006 concentrations indicating a reduction in concentrations over this period was possible at the old site.

Data suggest no significant changes in any of the indicators of PM_{10} concentrations from 2017 to 2021 since the relocation of the monitoring site. However, the analysis does not account for year-to-year variability in meteorological conditions.

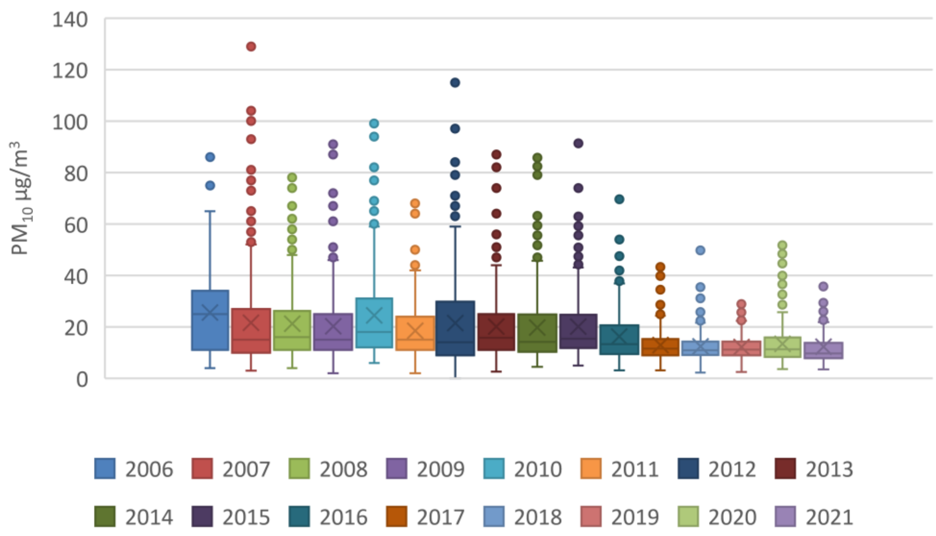

Figure 3.1: Box and whisker PM_{10} concentrations by year for Reefton

An analysis of the relationship between meteorological conditions and PM_{10} concentrations carried out in 2012 provided a method for adjusting PM_{10} concentrations to reduce the impact of year-to-year variability in meteorological conditions. Figure 3.2 shows trends in PM_{10} concentrations from 2006 to 2016 when that method is applied to these data, including the period from 2013 to 2016 which had not previously been assessed. This suggests PM_{10} concentrations in 2016 are lower than previous years with the 75th percentile concentrations for 2016 being equal to or lower than the median concentration for all preceding years. This indicates the potential for a reduction in concentrations. This would typically be confirmed using data for the subsequent years. However, this data is of limited value for this purpose owing to the relocation of the monitoring site.

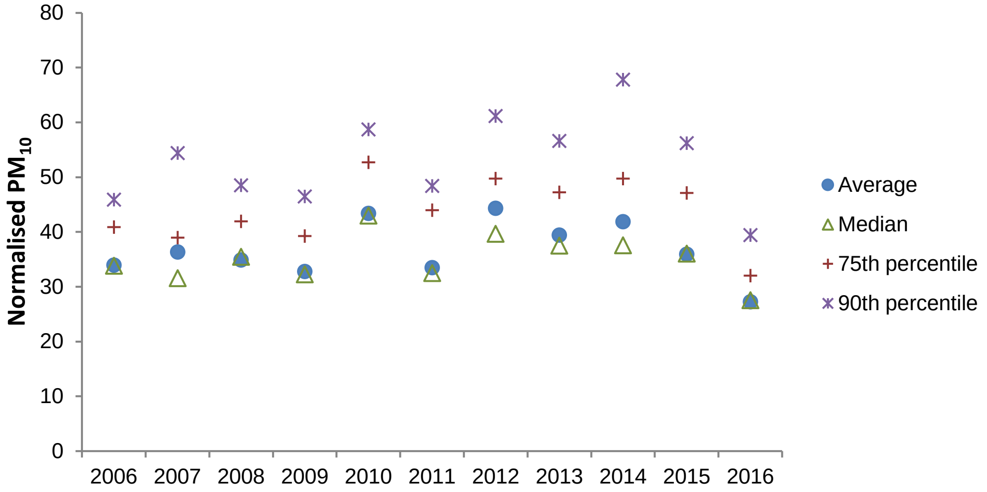

Figure 3.2: Trends in PM_{10} concentrations adjusted for meteorological conditions – 2006 to 2016

To further examine the likelihood of 2016 PM_{10} concentrations representing a reduction in PM_{10} in Reefton, an evaluation was made of the proportion of days when meteorological conditions were conducive to elevated pollution when the NES was breached (Figure 3.3). This shows year to year variability in the frequency of high pollution potential days and the proportion that resulted in an exceedance of the NES. The highest proportion of exceedances occurred in 2012 (53%) and the lowest in 2016 (12%). This supports the potential for a reduction in PM_{10} in 2016. It is noted that 2011 also experiences a low proportion of high pollution potential days that resulted in breaches (16%), however and it is noted that higher concentrations were observed in the years 2012 to 2014.

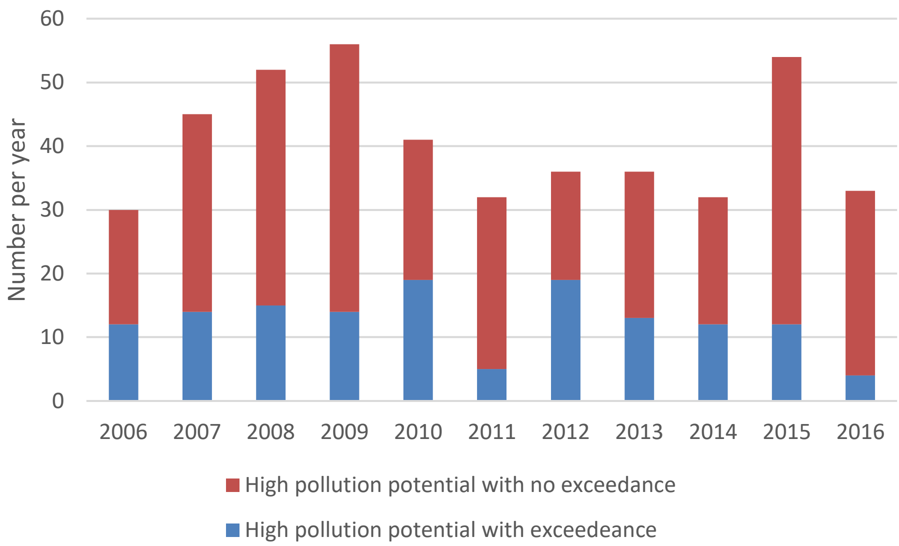

Figure 3.3: High pollution potential days with and without exceedances – 2006 to 2016

In our view, there is some evidence to support a reduction in PM_{10} concentrations in Reefton from 2014 to 2016. In the absence of additional years of monitoring PM_{10} concentrations at the old monitoring site, however, some uncertainty remains as to the validity of this conclusion. We also note the possibility that the reduction continued for 2017 as the trend from 2016 to 2017 is unknown owing to the relocation of the monitoring site.

3.2 Regression tree on PM_{10} data

To evaluate the potential for trends in PM_{10} data from 2017 to 2021 (new site), the relationship between daily average PM_{10} data and meteorological conditions for 2017 to 2021 were analysed using a regression tree (Figure 3.4). The main variable impacting on PM_{10} concentrations at the site was wind speed and the analysis indicated that a daily wind speed average of less than 0.74 ms^{-1} was associated with highest PM_{10} concentrations.

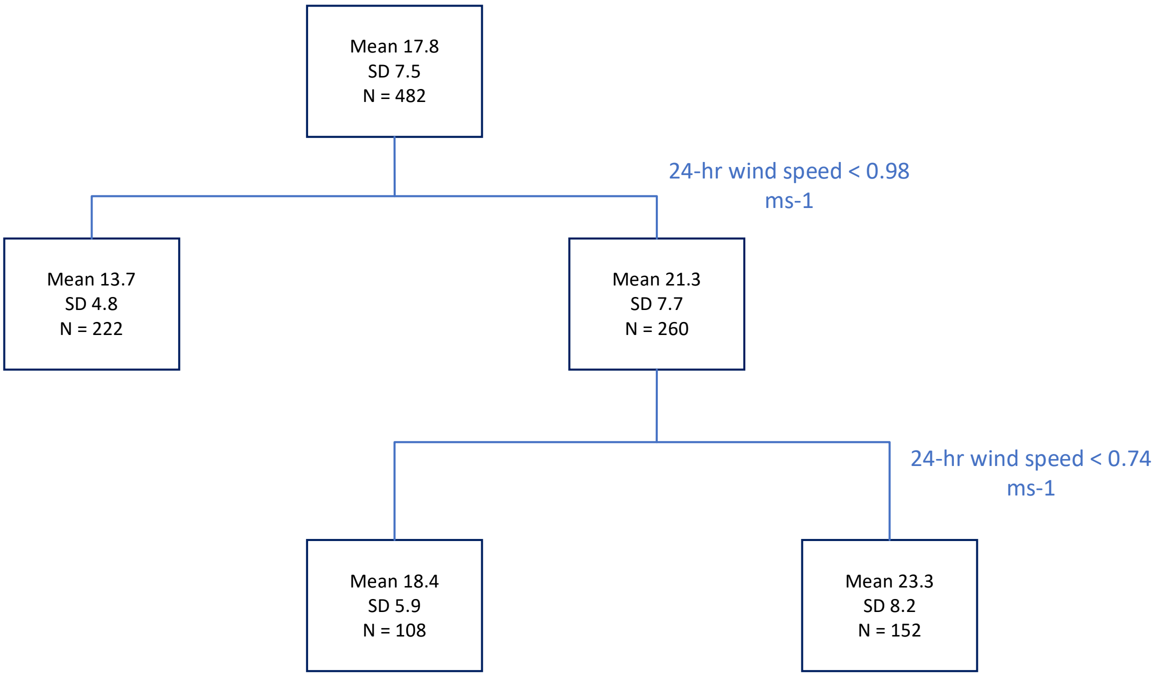

Figure 3.4: Regression tree on PM_{10} data.

The meteorological variables found to have the greatest impact on PM_{10} concentrations were:

- 24 hour average wind speed less than 0.98 ms^{-1}
- 24 hour average wind speed less than 0.74 ms^{-1}

The highest pollution dataset was characterised wind speed (24-hour average) less than 0.74 ms^{-1}. This split contained 152 days and included both high pollution days during the monitoring period.

3.3 Trend analysis of days with high pollution potential

An evaluation of PM_{10} concentrations by year for days when meteorological conditions met the elevated pollution criteria can be used as a first indication of potential trends in PM_{10} when some of the impact of meteorological conditions is accounted for.

The high pollution potential dataset from the analysis contains 172 days when the 24-hour average wind speed was less than 0.74 ms^{-1}. These data were separated by year and the resulting data are shown in Figure 3.5.

Figure 3.5: Average, 75th percentile and median PM_{10} concentrations for days when the wind speed was less than 0.74 ms^{-1} (24-hour average).

Results suggest PM_{10} emissions are unlikely to have decreased from 2017 to 2021. Improved understanding of meteorological conditions conducive to elevated PM_{10} and trends in PM_{10} concentrations can be made by conducting a further regression tree on the 172 days when the 24-hour average wind speed was less than 0.74 ms^{-1}.

3.4 Regression tree on high pollution potential days

Figure 3.6 shows a regression tree on the 172 days when the 24-hour average wind speed was less than 0.74 ms^{-1}. This shows two classifications of meteorological conditions that result in average PM_{10} concentrations greater than 30 µg/m^3 (nodes 3 and 5). These occur under two conditions:

- 24-hour average wind speed less than 0.29 ms^{-1} and average wind speed between 5pm and midnight of less than 0.37 ms^{-1}.
- 24-hour average wind speed greater than 0.29 ms^{-1}, average temperature less than 3.3 degrees and a minimum wind speed between 5pm and midnight of less than 0.27 ms^{-1}.

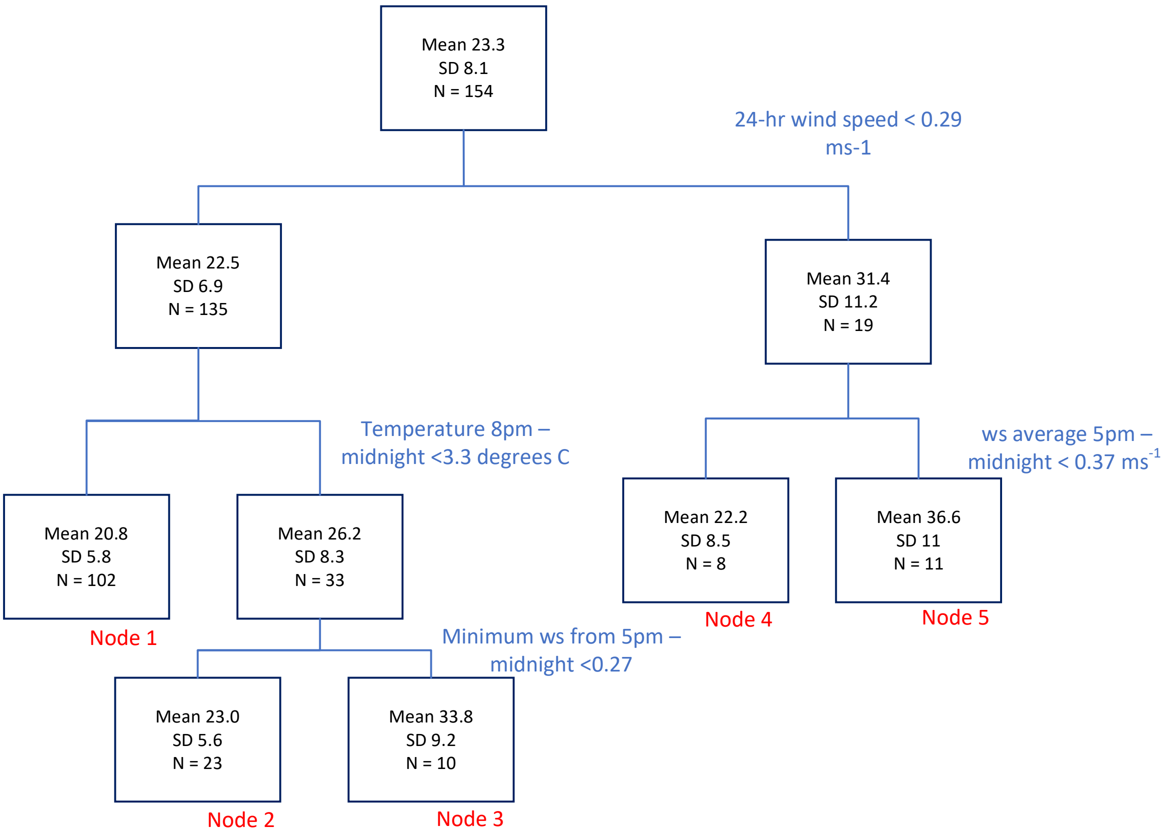

Figure 3.6: Regression tree on 154 days when the average 24-hour wind speed was less than 0.74 ms^{-1}

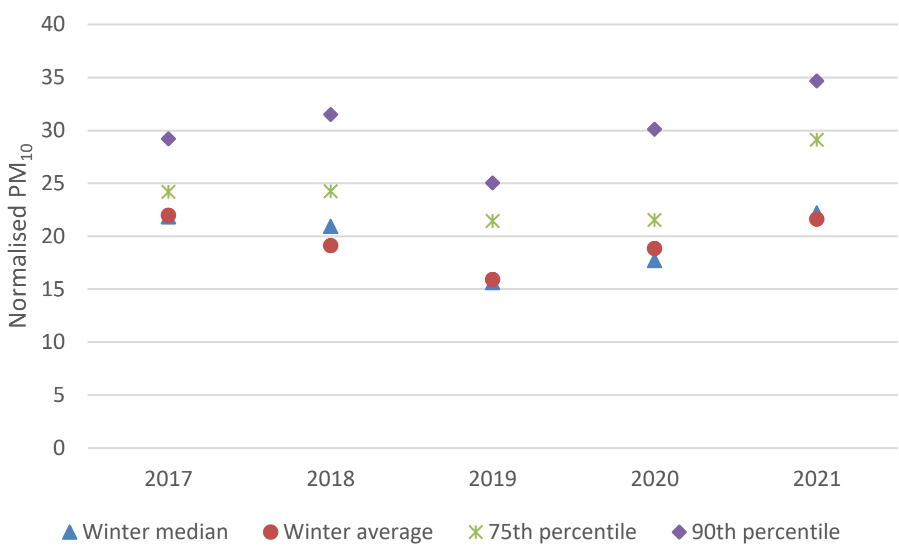

Figure 3.7: Average, 75th and 90th percentiles and median PM_{10} concentrations for days when meteorological conditions were consistent with nodes 3 and 5 of Figure 3.6.

An evaluation of PM_{10} concentrations within the highest two nodes (nodes 3 and 5 from Figure 3.6) by year is shown in Figure 3.7. This suggests no improvement in PM_{10} emissions from 2017 to 2021. It is noted that 2017 and 2021 data are based on a small number of qualifying days and are of limited value in inferring trends.

4 COMPARISON TO 2013 ASSESSMENT

An evaluation of the relationship between PM_{10} concentrations and meteorological conditions at the old Reefton site was carried out in 2013 to determine characterise meteorological conditions and their relationship to elevated PM_{10} concentrations at that site.

Meteorological conditions with the potential for the highest PM_{10} concentrations in Reefton at that site were:

- 24-hour average wind speed less than 0.9 ms^{-1}.
- 24-hour average temperature less than 4.5 degrees.
- Difference between the maximum hourly temperature on the sample day and the preceding day of more than 10.6 degrees.

As with the 2021 analysis the variable for explaining the PM_{10} concentrations was wind speed. Temperature was also a determining variable in both analyses.

In the 2013 evaluation PM_{10} concentrations were significantly higher than for the 2021 with an average breach frequency of around 18 compared with only two exceedances for the whole 2017 to 2021 period (both in 2020).

5 NORMALISING PM_{10} CONCENTRATIONS

One of the objectives of this work is to enable an assessment of trends in PM_{10} concentrations in future years.

As all meteorology has some impact, one of the biggest issues in establishing a methodology for normalising data was determining what constitutes “no impact”, that is, what concentrations should be normalised to. The method used aims to minimise the impact of varying meteorology for high pollution events. The method for minimising the impact of meteorology on concentrations has been based on days meeting the meteorological criteria in nodes 2-5 of the regression tree shown in Figure 3.4.

It should be noted that the following method provides only an indication of trends in high PM_{10} concentrations and results are not expected to give an indication of day-to-day variability in PM_{10} emissions but may provide some indication of annual trends in emissions.

Select days which meet the meteorological criteria of 24-hour average wind speed less than 0.74 ms^{-1}.

- If the 24-hour average wind speed is greater than 0.29 ms^{-1}, and the average temperature between 8pm and midnight is more than 3.3 do not adjust data.
- If the 24-hour average wind speed is greater than 0.29 ms^{-1}, the average temperature between 8pm and midnight is less than 3.3 and the minimum hourly average wind speed between 5pm and midnight is more than 0.27 ms^{-1} subtract 2.2 $\mu g/m^3$.
- If the 24-hour average wind speed is greater than 0.29 ms^{-1}, the average temperature between 8pm and midnight is less than 3.3 and the minimum hourly average wind speed between 5pm and midnight is less than 0.27 ms^{-1} subtract 13 $\mu g/m^3$.
- If the 24-hour average wind speed is less than 0.29 ms^{-1}, and the average wind speed between 5pm and midnight is more than 0.37 ms^{-1} subtract 1.4 $\mu g/m^3$
- If the 24-hour average wind speed is less than 0.29 ms^{-1}, and the average wind speed between 5pm and midnight is less than 0.37 ms^{-1} subtract 15.8 $\mu g/m^3$

6 CONCLUSIONS

The objectives of this study were to characterise meteorological conditions in terms of impact on PM_{10} concentrations for the new air quality monitoring site in Reefton and assess trends in PM_{10} concentrations from 2017 to 2021 at the new air quality monitoring site.

An evaluation of trends from the previous site was also carried out to update a 2013 analysis with data from 2014 to 2016. The PM_{10} data adjusted for the impact of meteorological conditions was indicative of a reduction in PM_{10} from 2014 to 2016. Further monitoring was unable to confirm this owing to the relocation of the monitoring site in September 2017.

Concentrations of PM_{10} at the new site are lower than the old site with only two exceedances for the period 2017 to 2021 which were recorded during 2020. It is unlikely that improvements in air quality account for the differences between the old and new monitoring sites. There is some indication based on the assessment that concentrations in Reefton have improved between the years 2014 and 2016 or potentially 2017.

The meteorological conditions which result in the highest PM_{10} concentrations at the new site were 24-hour average wind speeds with highest pollution potential being identified as days when this value was less than 0.74 $\mu g/m^3$. A further analysis of high pollution potential days identified additional wind speed and temperature variables to further quantify pollution potential.

An evaluation of trends in high pollution potential days from 2017 to 2021 indicates no improvement in PM_{10} in Reefton over this period. Data from 2006 to 2014 are also indicative of no trend in PM_{10} concentrations. It is possible that some reduction in PM_{10} concentrations occurred from 2015 to 2016 and a reduction between 2016 and 2017 is also possible but unquantified owing to the relocation of the monitoring site. Characterisation of the relationship between the old and new air quality monitoring sites would assist with understanding any change in PM_{10} in Reefton from 2015 to 2017.

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