Environment Waikato Technical Report 2004/29

Management Options for Air Quality in Tokoroa and Taupo

An Assessment of Management Options to Achieve National Environmental Standards

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Executive Summary

Air quality monitoring for PM_{10} (particles in the air less than 10 microns in diameter) has been carried out in both Tokoroa and Taupo since 2001. Concentrations measured at both sites have exceeded the national and Environment Waikato ambient air quality guideline for PM_{10} of 50 µg m^{-3} (24-hour average) each year. These PM_{10} particles are of concern because of their ability to penetrate the lungs and cause adverse health impacts.

In September 2004, the Ministry for the Environment introduced national environmental standards (NES) for air quality including an ambient air quality standard of 50 µg m^{-3} (24-hour average) for PM_{10}. The NES comes into force in September 2005. The NES allows for one guideline exceedence per year. Should there be more than one exceedence, the NES expects that strategies will be put in place to ensure that there will be just one exceedence per year by 2013.

Air quality monitoring in Tokoroa shows guideline exceedences have occurred on around 15 to 41 days per year. The maximum measured PM_{10} concentration of 97 µg m^3 occurred during 2004. In Taupo, monitoring has been based on a sampling regime of one day in six in 2001 and one day in three since August 2002. Measured guideline exceedences range from one day per year in 2001 and 2002 to four days in 2003. Because the monitoring is not continuous, actual exceedences are likely to be higher (e.g., 5-12 days). The magnitude of the PM_{10} concentrations was lower in Taupo with a maximum of 62 µg m^{-3} being measured during 2003.

The main source of PM_{10} emissions in the urban areas of Taupo and Tokoroa is solid fuel burning for domestic home heating. In Taupo the inventory indicates that domestic heating contributes around 88% of the PM_{10} with motor vehicles contributing 9% and outdoor burning 3%. The inventory does not account for the potential contribution of natural sources such as dusts or industrial emissions from processes such as sanding.

In Tokoroa, the industrial emissions within the study area (which excludes Kinleith) are less than 2% of the total PM_{10} discharges and domestic heating is dominant at around 83%. While emissions from Kinleith and the Kinleith industrial park may be transported into the urban areas of Tokoroa under some meteorological conditions, it appears unlikely that they were a significant contributor on days when PM_{10} concentrations are highest during 2004. Outdoor burning also comprises around 9% of the emissions from within the urban area.

Monitoring data suggest that reductions in PM_{10} concentrations of 19% and 46% are required in Taupo and Tokoroa respectively to meet the NES and 19% and 48% to meet a target of 50 µg m^{-3} with no exceedences. Reductions in the order of 47% and 65% are required to meet 66% of the guideline, i.e. the level at which the Regional Plan considers air quality to be degraded. Analysis of the effectiveness of management measures indicates that the NES may be met in Taupo by natural attrition of old heating systems being replaced by woodburners that meet a new emission standard of 1.5 grams of particles per kilogram of fuel burnt. No additional management measures may be required achieve these reductions by 2013 in Taupo. However, there are a number of uncertainties in the analysis and additional measures may be considered to improve the probability of compliance with the NES. In Tokoroa, management options such as a prohibition on outdoor rubbish burning and the use of open fires are likely to be needed as well as additional measures such as an incentives programme to encourage household to replace solid fuel burners with cleaner heating methods.

Further investigations that would provide useful information relevant to this assessment include an assessment of the potential contribution of natural dusts in Taupo.

1 Introduction

Tokoroa is a small urban town located in the southern Waikato Region about mid-way between Taupo and Hamilton on State Highway 1. Tokoroa services the vast plantation forests of the central north island and pulp and paper industries. The 2001 census gives a usually resident population for Tokoroa of around 14,250.

The town of Taupo is located on the northeastern edge of Lake Taupo, which is located in the centre of the North Island of New Zealand. Taupo is known for its tourism, scenic and recreational attractions but also services local industry including forestry, agriculture, hydroelectric and geothermal energy. The usually resident population was around 17,000 in 2001 and is predicted to increase. The number of occupied houses in the urban areas of Tokoroa and Taupo for 2004 is estimated to be around 4451 and 6461 respectively.

Poor air quality is experienced in both Tokoroa and Taupo on occasion during the winter months. The main air contaminant of concern is PM_{10} (particles in the air less than 10 microns in diameter). Air quality monitoring for PM_{10} has been carried out in both areas since 2001.

The types of health effects associated with concentrations of PM_{10} include coughs, asthma symptoms, bronchitis, respiratory illness and premature mortality. Those most susceptible to the more serious impacts include the elderly, children and those with existing respiratory conditions such as cardio-obstructive pulmonary disease (COPD). A health impacts assessment indicates that around 970 premature deaths are likely to occur in New Zealand each year as a result of exposure to PM_{10} concentrations[1].

1.1 Air quality guidelines and standards

The first air quality guidelines for New Zealand were released by the Ministry for the Environment in 1994 and included an annual average guideline for PM_{10} of 50 μgm^{-3} and a 24-hour average guideline of 120 μgm^{-3}. In 2002, the Ministry for the Environment published a revised ambient air quality guideline document that included a PM_{10} guideline of 50 μgm^{-3} (24-hour average) as well as an annual average guideline for PM_{10} of 20 μgm^{-3}. In the lead up to the latter report, consideration had been given to the establishment of an interim guideline for $PM_{2.5}$ (the finer fraction of PM_{10}) as health studies suggested this size fraction was of greatest concern. This interim guideline was dropped prior to the establishment of the 2002 guidelines in favour of further investigations into the establishment of a formal guideline for this contaminant.

In 2004, the Ministry for the Environment introduced national environmental standards (NES) for air quality including an ambient air quality standard of 50 $\mu g\ m^{-3}$ (24-hour average) for PM_{10}. The NES allows for one guideline exceedence per year . Should there be more than one exceedence, the NES expects that strategies will be put in place to ensure that there will be just one exceedence per year by 2013. The NES specifies that where ambient air standards are breached, no resource consents for air discharges for the offending contaminant may be granted.

The NES also include a design standard for the installation of new solid fuel burners. The standard specifies an emission limit of 1.5 grams of particulate per kilogram of fuel burnt (test method - NZS 4013) and an efficiency criteria of 65% (test method - NZS 4012). The standard applies to all dwellings on less than two hectares of land.

In addition to setting guideline values, the Ministry for the Environment's ambient air quality guidelines provide guidance on the application of the guideline values. They

[1] Fisher, G., Rolfe, K., Kjellstrom, T., Woodward, A., Hales, S., Sturman, A., Kingham, S., Peterson, J., Shrestha, R., King, D., 2002. *Health effects due to motor vehicle air pollution in New Zealand*. Report to the Ministry of Transport.

propose the use of Environmental Performance Indicator (EPI) categories (Table 1.1), in part to ensure that the guidelines are not treated as a level to pollute up to, and include a recommendation that councils aim to maintain air quality at existing levels where it is below 66% of the guideline value, and enhance it when it is above. While this provides a signal that levels below the guideline are desirable, in areas where the guideline is exceeded, achievement of the NES is an appropriate initial target.

Figure 1-1 Ministry for the Environment EPI categories for air quality

Category	Value relative to guideline	Comment
Excellent	Less than 10% of the guideline	Of little concern: if maximum values are less than a tenth of the guideline, average values are likely to be much less
Good	Between 10% and 33% of the guideline	Peak measurements in this range are unlikely to affect air quality
Acceptable	Between 33% and 66% of the guideline	A broad category, where maximum values might be of concern in some sensitive locations but generally they are at a level which does not warrant urgent action
Alert	Between 66% and 100% of the guideline	This is a warning level, which can lead to exceedences if trends are not curbed
Action	More than 100% of the guideline	Exceedences of the guideline are a cause for concern and warrant action, particularly if they occur on a regular basis

2 Air quality in Tokoroa and Taupo

Tables 2.1 and 2.2 show summary statistics for PM_{10} monitoring at Tokoroa and Taupo from 2001 to 2003. The number of exceedences shown has been adjusted to account for missing data. This extrapolation is based on the assumption that guideline exceedences occurred on days of missing data at the same rate as for the days monitored during the winter months. That is, if exceedences occurred on 20% of days monitored from May to August inclusive, then exceedences also occurred on 20% of the days during this time when concentrations were not measured.

In Taupo PM_{10} concentrations were initially measured on a one day in six sampling regime. This was revised to a one day in three regime in August 2002. Measured guideline exceedences in Taupo range from one per year for 2001 and 2002 to four in 2003. In Tokoroa measured exceedences range from 10 in 2003 to 15 in 2002. However, the number could be as high as 24 once missing data are accounted for.

The maximum measured PM_{10} concentration for Tokoroa was 75 µg m^{-3} and was measured in 2001. This compared to 62 µg m^{-3} in Taupo. The 99.7 percentile concentrations in each location are 70 µg m^{-3} and 62 µg m^{-3} respectively. Although data are not available for the full year of 2004, results to the end of winter for Tokoroa indicate a greater number of exceedences than measured previously (41 days) and a maximum measured PM_{10} concentration of 97 µg m^{-3}. This gives an annual 99.7 percentile concentration of 93 µg m^{-3} for 2004. Summary statistics for 2004 are not reported in Tables 2.1 and 2.2 because the full year's data were not available at the time this report was prepared.

Table 2-1: Summary statistics for air quality monitoring in Tokoroa

	PM_{10} 2001	PM_{10} 2002	PM_{10} 2003
"Good" 0-33% of guideline	12%	15%	25%
"Acceptable" 33-66% of guideline	64%	71%	58%
"Alert" 66-100% of guideline	17%	10%	11%
>Guideline	8%	4%	5%
Percentage of valid data	47%	98%	55%
Annual average (µg m-3)	27	24	24
Guideline exceedences (extrapolated)	24	15	18
99.7 %ile concentration (µg m-3)	70	66	59
Annual maximum (µg m-3)	75	70	62

Table 2-2: Summary statistics for air quality monitoring in Taupo

	PM10 2001	PM10 2002	PM10 2003
"Good" 0-33% of guideline	43%	59%	52%
"Acceptable" 33-66% of guideline	36%	33%	32%
"Alert" 66-100% of guideline	18%	7%	12%
>Guideline	2%	1%	4%
Percentage of valid data	12%	21%	29%
Annual average (µg m-3)	20	16	18
Guideline exceedences (extrapolated)	7	6	12
99.7 %ile concentration (µg m-3)	55	51	62
Annual maximum (µg m-3)	57	54	62

2.1 Reductions required in PM_{10} concentrations

The reduction required in PM_{10} concentrations to meet an air quality target of 50 μgm^{-3} (24-hour average), based on the maximum measured PM_{10} concentration, can be calculated using Equation 2.1.

$$R = 100(1 - \frac{t}{c}) \qquad \text{Equation 2.1}$$

where

R = the percentage reduction

t = the air quality target (e.g., 50 μgm^{-3})

c = the percentile concentration (e.g., 99.7 percentile for one allowable exceedence)

Based on Equation 2.1 the required reduction to meet the air quality target of 50 μgm^{-3} with one allowable exceedence is 19% for Taupo and 29% for Tokoroa based on 2001-2003 data. The latter increases to 46% based on the 99.7 percentile concentration

(which allows for one annual exceedence) of 93 µg m^{-3} for Tokoroa based on 2004 data.

The Environment Waikato Regional Plan indicates that air quality is degraded if it exceeds 66% of the air quality guideline e.g., 50 µg m^{-3} for PM_{10}. The reduction required to meet a target of 50 µg m^{-3} with no annual exceedences is around 19% in Taupo and 48% in Tokoroa. If an air quality target were set at 66% of the guideline, the reduction in PM_{10} concentrations would be around 65% in Tokoroa and 47% in Taupo. The assessments of management options in subsequent sections of this report include an indication of the likelihood of different management scenarios relative to the NES target, with one allowable breach.

3 Sources of PM_{10} in Tokoroa and Taupo

3.1 Emission inventory

An emission inventory for both areas was carried out during 2004. The inventory quantified emissions to air of PM_{10}, CO, SOx, NOx and CO_2 in the urban areas of Tokoroa and Taupo. Sources included in the inventory were domestic home heating, motor vehicles, outdoor burning and industry. Emissions of PM_{10} from abrasive and sanding industrial processes were not included because of poor information on emission rates. The contribution of natural sources e.g., dusts, was also unable to be quantified.

Results indicated that the main source of PM_{10} in the urban areas of Tokoroa during the winter was domestic heating (Figure 3.1).

In Taupo, domestic heating contributed 84% of the emissions with motor vehicles producing around 13% of the PM_{10} emissions, outdoor burning 3% and industry less than 1%. Figure 3.2 shows the estimated contribution of different sources to PM_{10} emissions in Taupo.

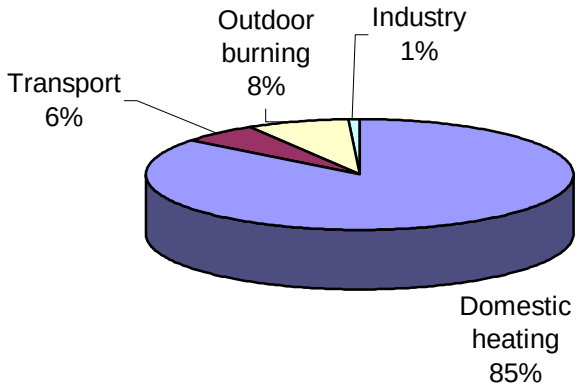

Figure 3-1: Sources of PM10 emissions in the urban areas of Tokoroa in 2004

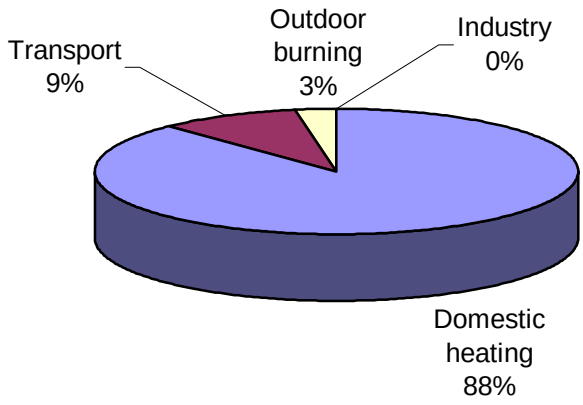

Figure 3-2: Sources of PM10 emissions in the urban areas of Taupo in 2004

Figure 3.3 shows the breakdown of domestic heating emissions by appliance type and fuel in Tokoroa and Taupo for 2004. The distribution across different appliance types and ages is similar for Tokoroa and Taupo with the exception of open fires, which contribute almost twice as much in Taupo (15%) as in Tokoroa (8%).

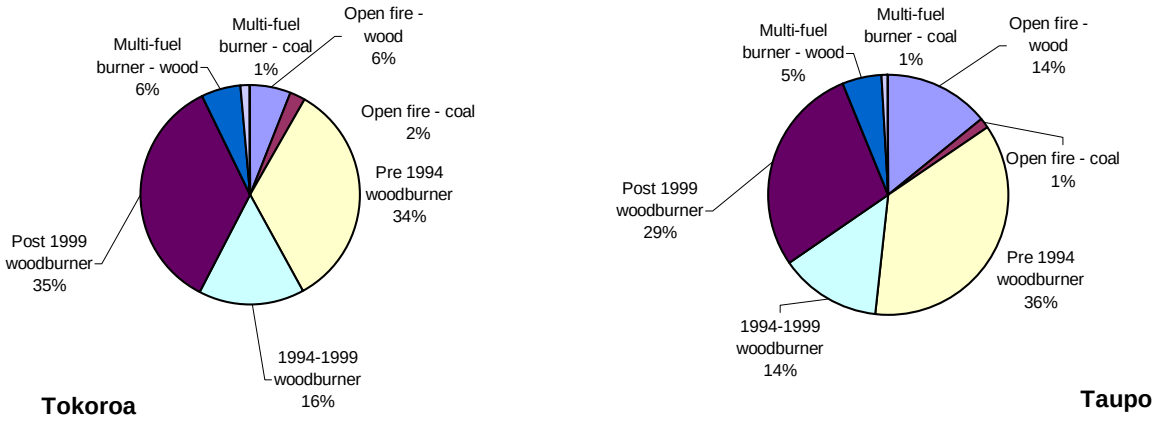

Figure 3-3: Domestic heating emissions for Tokoroa and Taupo by heating method

3.2 Contribution from Kinleith and Kinleith Industrial Park

An estimate of mass PM_{10} emissions from Kinleith and the Kinleith Industrial Park was not included in the emission inventory because the area is outside of Tokoroa. It is possible, however, that emissions from Kinleith and the Industrial Park contribute to PM_{10} concentrations measured in Tokoroa. Previous studies[2] indicate the total mass discharge from Kinleith and the industrial park to be in the order of two tonnes per day. This is more than three times the total from within the Tokoroa urban area.

The Kinleith site is located outside of the urban areas of Tokoroa, about six kilometres from the monitoring site at a direction of around 160 degrees from north. Emissions from Kinleith will only reach the Tokoroa Township under certain meteorological conditions.

[2] Noonan, M., 1997, *Environment Waikato Industrial Emissions Inventory.* Environment Waikato unpublished report

Atmospheric dispersion modelling carried out as a part of the resource consent application for Kinleith predicts a maximum ground level PM_{10} concentration of around 65 µg m^{-3}. However, modelling was not based on a meteorological data set for Tokoroa and does not include all sources of PM_{10} at Kinleith. Depending on the meteorological data set used in the modelling, maximum ground level concentrations occur either at 400 metres from the site or at a distance of 1 and 2-3 kilometres.

Some monitoring for PM_{10} carried out by Carter Holt Harvey[3] at a distance of about 1.5 kilometres from Kinleith, in the direction of Tokoroa, showed a maximum 24-hour average concentration of 17 µg m^{-3}. However, sampling was limited to 74 days so the probability that worst case conditions were recorded is low.

To determine the times when emissions from Kinleith were likely to reach the air quality monitoring site, wind direction and wind speed data were tracked to give wind trajectories for the period May to August 2004. Note, this method does not take into account plume characteristics and dispersion and estimates resulting concentrations. It assumes that the direction of the plume will be consistent with the general wind direction and identifies times when it is possible that emissions from Kinleith might have ended up at the air quality monitoring site.

Wind direction and wind speed data measured at the air quality monitoring site were used to determine if the air the monitoring site was exposed to could have originated from the Kinleith area. The analysis was based on 10-minute average meteorological data, which were plotted for periods from 30 minutes to 4 hours and 40 minutes. Anytime between 10 minutes and 4 hours 40 minutes that the origin of the wind was located between 140 and 180 degrees from the monitoring site and at a distance from 5-7 kilometres was recorded as a time that Kinleith could have been contributing to PM_{10} concentrations at the monitoring site. Wind trajectories for periods longer than about 4 hours that ended up at the monitoring site typically travelled for a significant distance before reaching the monitoring site. The further the distance of travel, particularly at higher wind speed, the more the air contaminants will be dispersed before reaching the monitoring site.

The dates and times of wind trajectories that may have resulted in contaminants from Kinleith contributing to contaminant concentrations at the monitoring site were recorded. Figures 3.4 to 3.9 illustrate these times relative to hourly average PM_{10} concentrations for days when 24-hour average PM_{10} concentrations exceeded 50 µg m^{-3} during May to August 2004. The green line represents the potential for contribution from Kinleith at any time during the preceding hour, based on the methodology described above. Although located at a point of 50 (on the y axis), the line represents only the presence or absence of contribution and has no value.

Figure 3.4 shows that Kinleith may be contributing to PM_{10} concentrations for a reasonable part of the day on a number of days when the air quality guideline was exceeded during May. However, Kinleith was unlikely to be contributing during the period of highest PM_{10} concentrations (5pm to midnight) on 21 May. The maximum 24-hour average PM_{10} concentration measured during 2004 was 97 µg m^{-3} on the 8 June. Figure 3.4 shows that for the majority of this day, Kinleith was not likely to have been contributing to PM_{10} concentrations.

[3] Wilton, 2002, Sources of PM_{10} in Tokoroa, Unpublished report prepared for Environment Waikato.

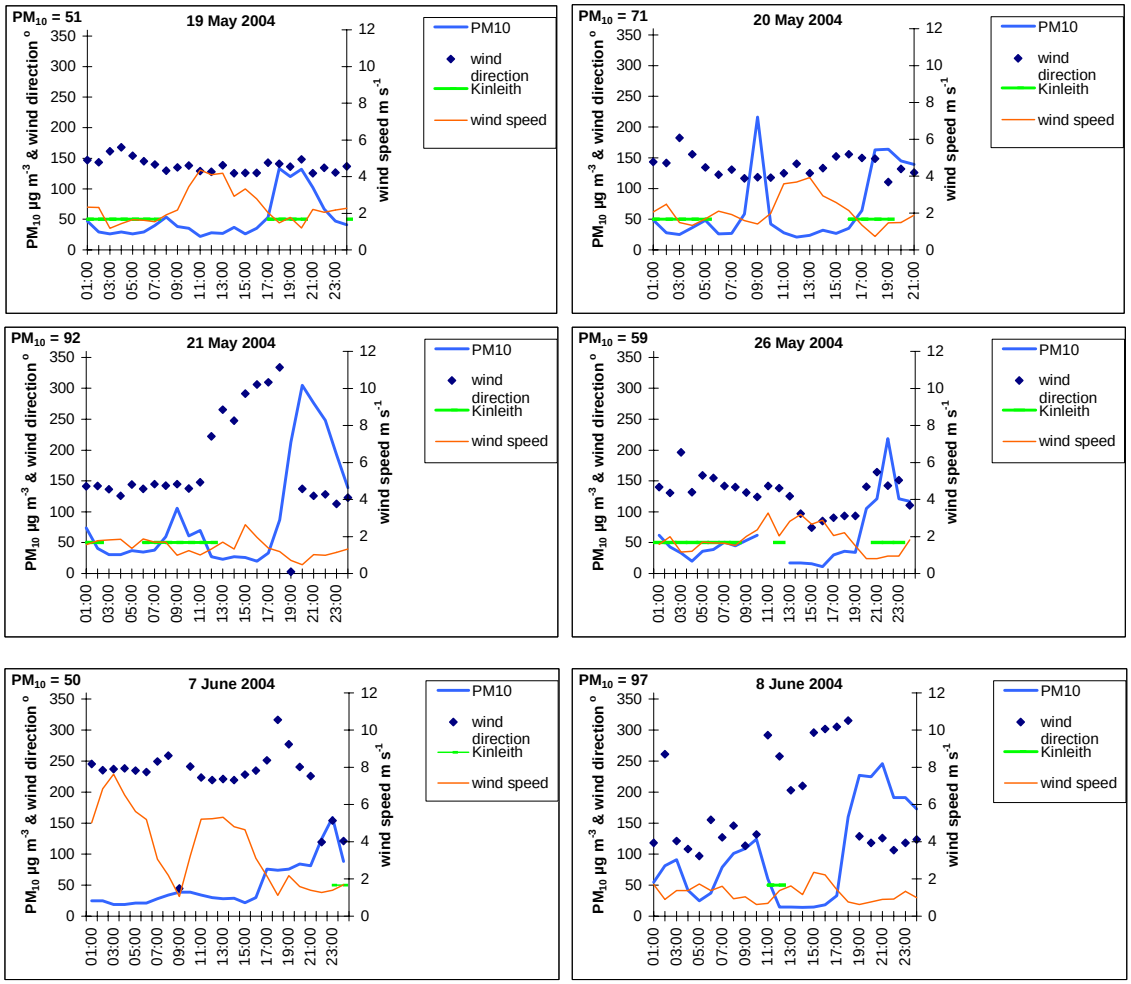

Figure 3-4: Hourly average wind speed, wind direction and PM10 concentrations measured at Tokoroa on high pollution days from 19 May – 8 June 2004

Kinleith was unlikely to be contributing to PM_{10} concentrations for the majority of the time PM_{10} was elevated on the high pollution days from the 9 June to the 24 June (Figure 3.5). The main exception is a period from 9pm to midnight on the 23 June.

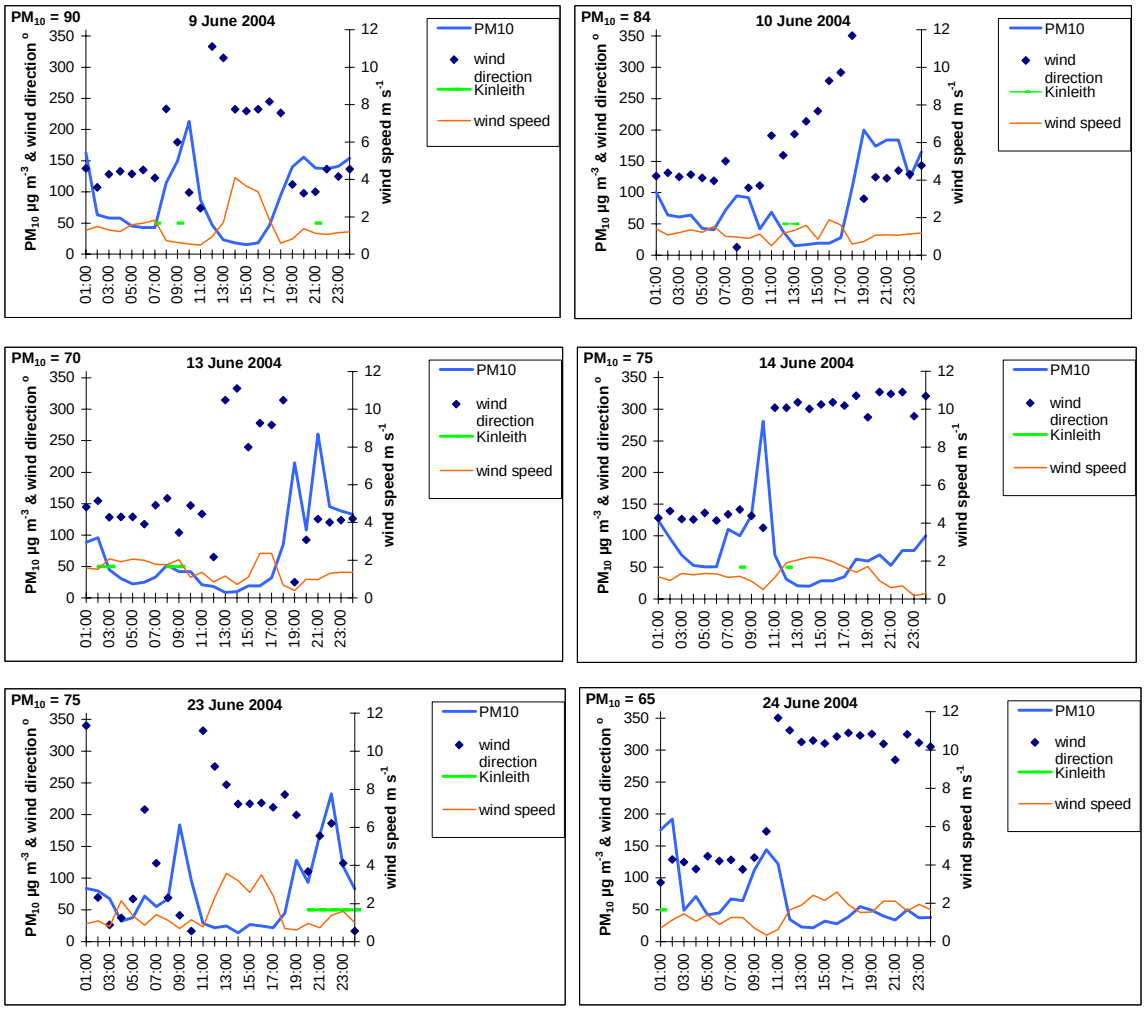

Figure 3-5: Hourly average wind speed, wind direction and PM10 concentrations measured at Tokoroa on high pollution days from 9 June – 24 June 2004

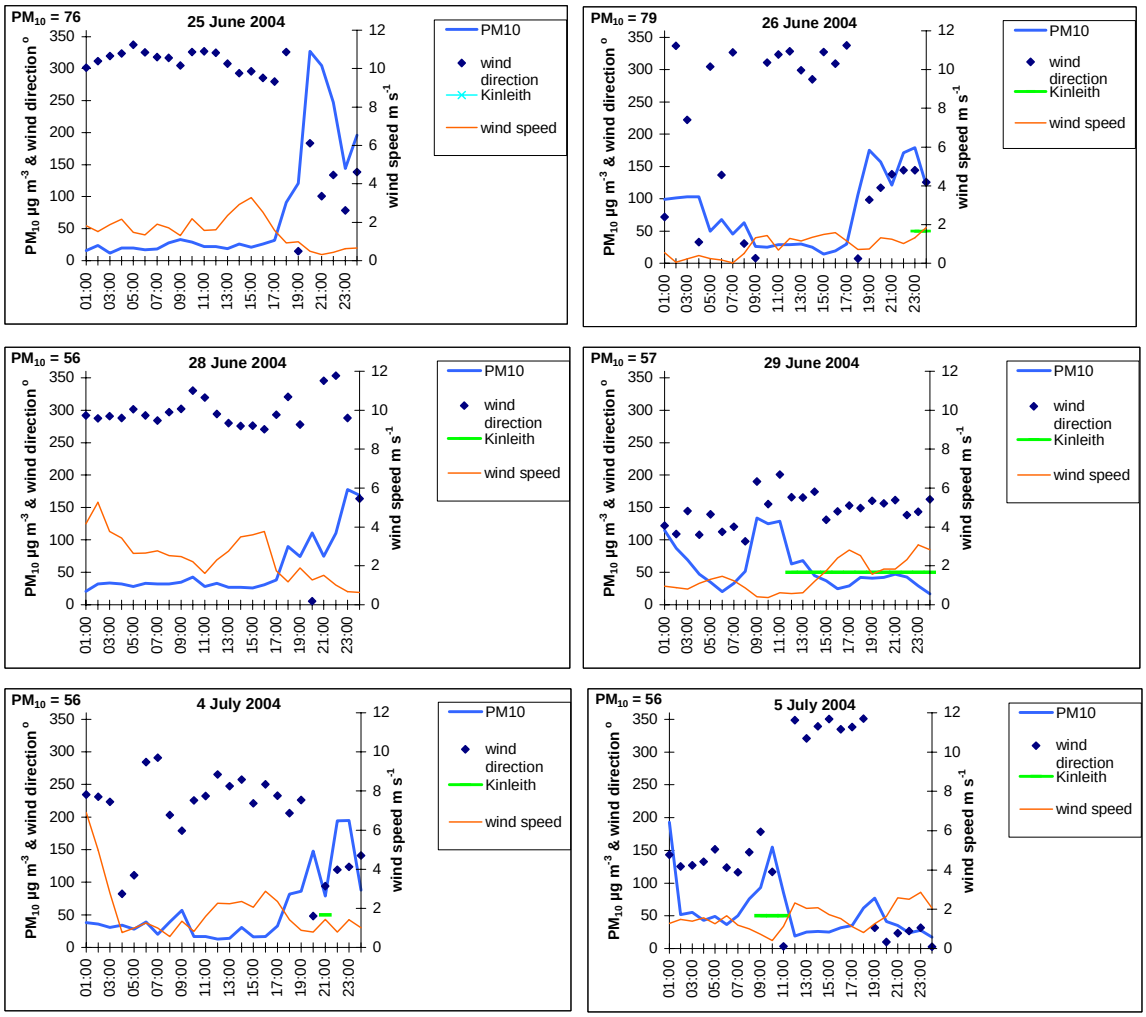

Figure 3-6: Hourly average wind speed, wind direction and PM10 concentrations measured at Tokoroa on high pollution days from 25 June – 5 July 2004

On the 29 June, the wind could transfer PM_{10} from Kinleith to the monitoring site for the period from midday to midnight (Figure 3.6). However, the main peak in concentrations on this day is in the morning between 9am and 11am. Figure 3.7 shows that Kinleith may have been contributing on the 24 July and on the 31 of July, but that for most other days, the plant is unlikely to have had any significant impact on measured PM_{10} concentrations. On the 24 July, the wind trajectories are from around Kinleith for most of the day. The exception is the period from 5 pm to 10 pm when PM_{10} concentrations are highest. On the 31 July, wind trajectories from the Kinleith area coincide with the evening peak PM_{10} concentrations.

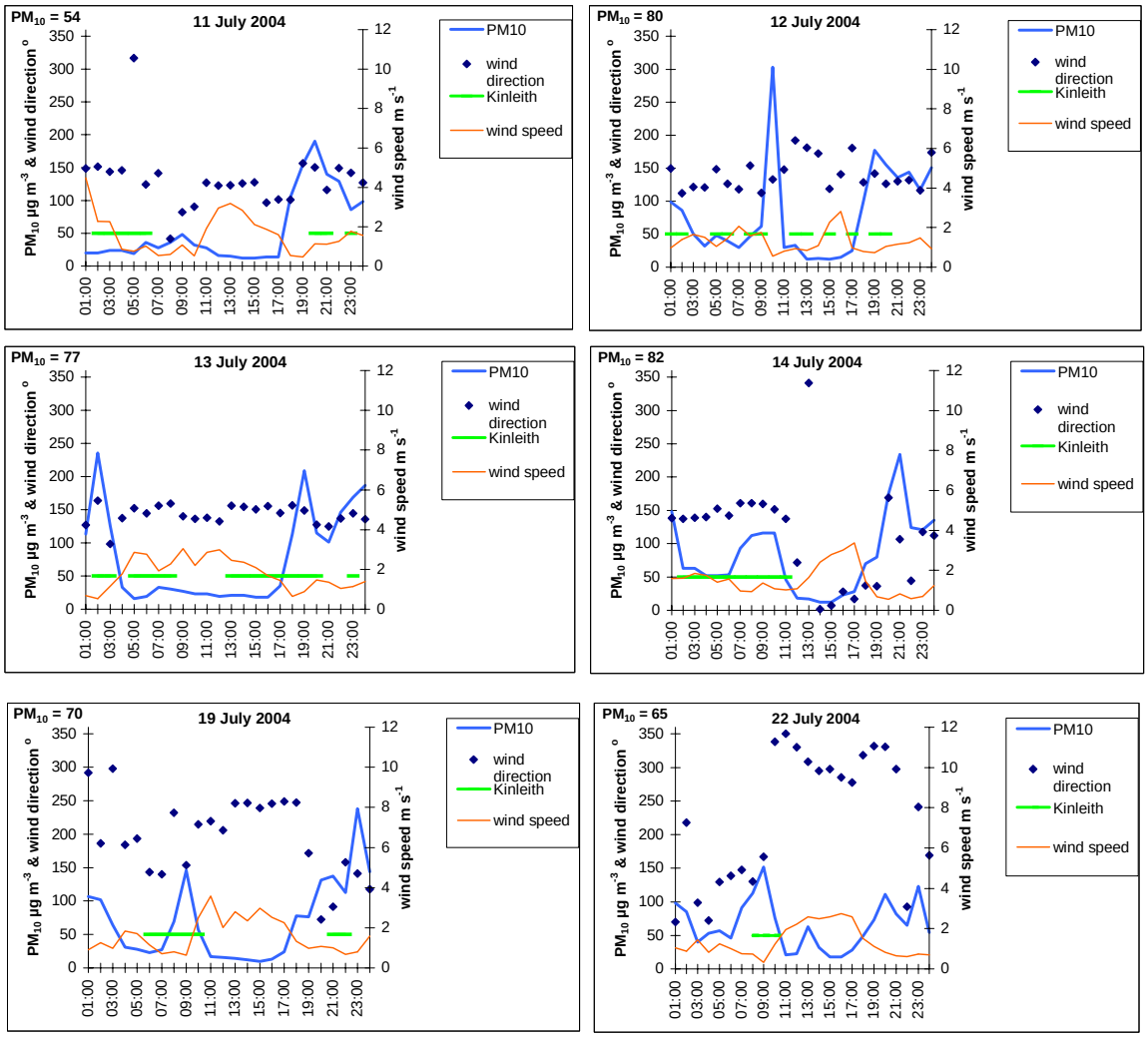

Figure 3-7: Hourly average wind speed, wind direction and PM10 concentrations measured at Tokoroa on high pollution days from 11 – 22 July 2004

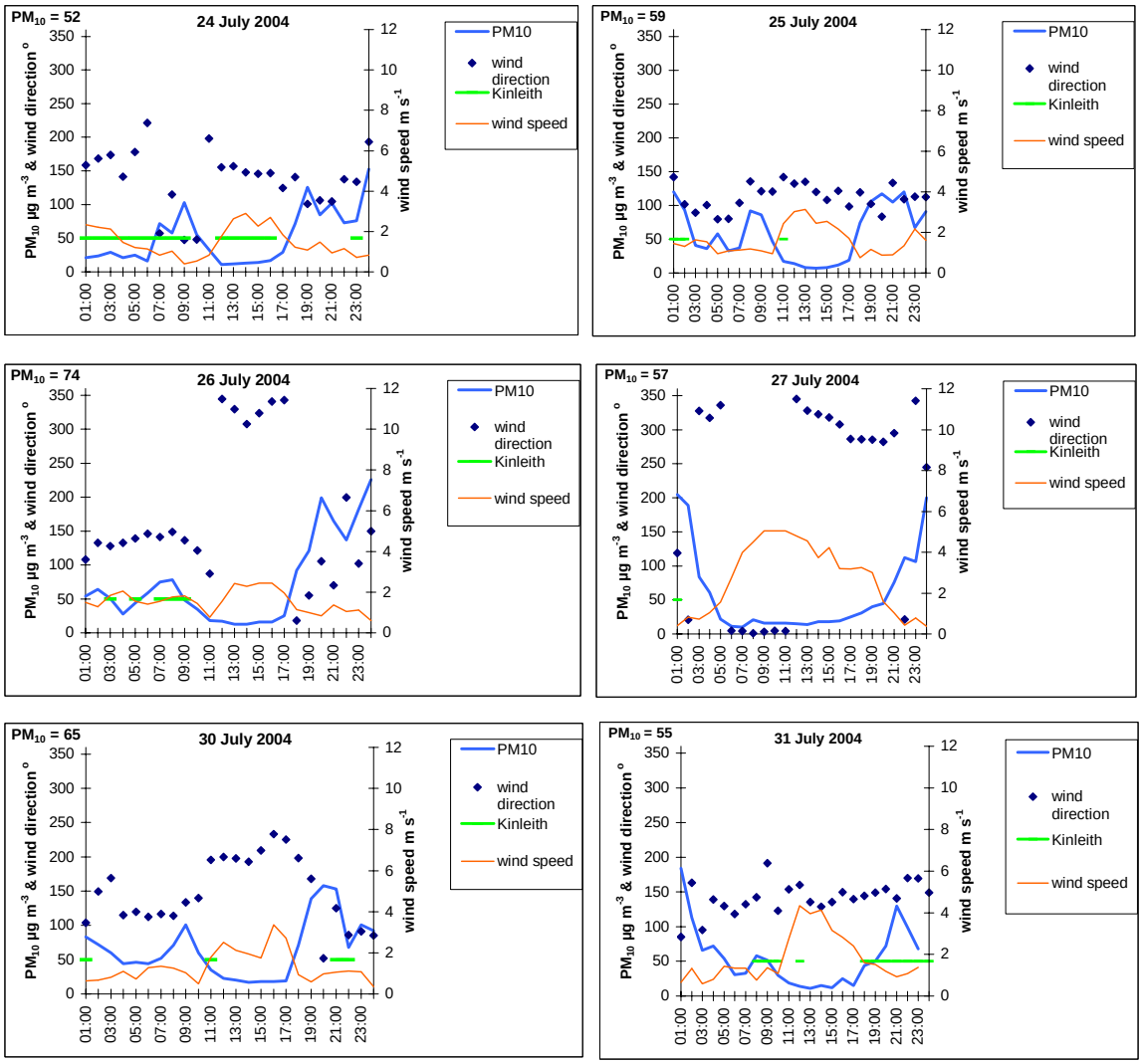

Figure 3-8: Hourly average wind speed, wind direction and PM10 concentrations measured at Tokoroa on high pollution days from 24 – 31 July 2004

Figure 3.9 shows seven high pollution days during August. The main days that Kinleith could be contributing to PM_{10} concentrations are the 1, 26 and 29 August. On all other days during August, the time period when the wind originates from Kinleith is either very short in duration or coincides with times when PM_{10} are low.

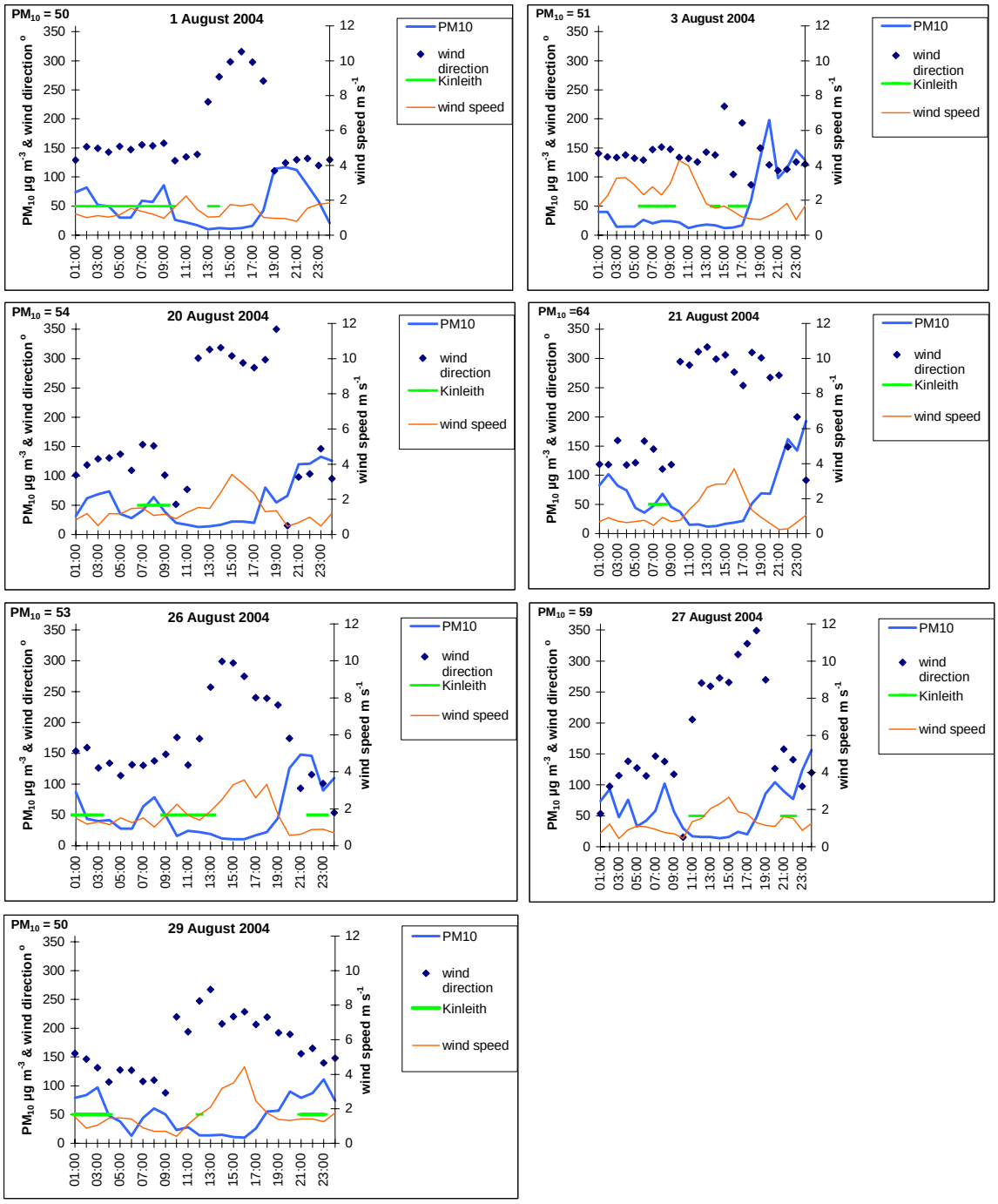

Figure 3-9: Hourly average wind speed, wind direction and PM10 concentrations measured at Tokoroa on high pollution days during August 2004

3.2.1 Summary

There are definite times when emissions from Kinleith could be contributing to PM_{10} concentrations in Tokoroa. On some days, e.g., 13 July the wind trajectories were from Kinleith for the majority of the day. However, on at least 25 of the 37 days examined, emissions from Kinleith were unlikely to contribute significantly to measured PM_{10} concentrations. This includes the 8 June 2004, when the maximum measured PM_{10} concentration of 97 µg m^{-3} was recorded.

Daily variations in PM_{10} concentrations typically show a peak in the mid morning around 9am and decreasing by the afternoon. In the early evening PM_{10} concentrations often increase from around 5pm. The impact of changes in wind speed on PM_{10} concentrations throughout the day is apparent with slight drops or increases occurring as the wind picks up or drops off. Concentrations of PM_{10} do not appear to

change significantly relative to the wind trajectories occurring from the Kinleith direction, except where these coincide with typically daily patterns or changes in wind speed.

Overall it appears unlikely that PM_{10} from Kinleith was a significant contributor to PM_{10} concentrations measured in Tokoroa on days when the guideline was exceeded during 2004.

3.3 Solid fuel burners in Tokoroa

Information on consents for installations of solid fuel burners since 1992 in Tokoroa was obtained from the South Waikato District Council. Analysis of this data showed that around 10% of the consents were for installations of second hand burners and installation records include the occasional installation of an older style multifuel burner, such as a potbelly stove or a chip incinerator.

A comparison of the installation records and the number of households using different category burners from the home heating survey suggests that either there are a significant number (e.g., about 50%) of burner installations for which consents are not obtained or that households have a poor understanding of the age of their burners, believing their burners to be more modern than they are.

Results also indicate that the location of burners is relatively even across Tokoroa with no one area of town with a greater density of burners.

The consents data is also useful in evaluating appropriate emission factors for the different burners age categories. The types of burners that are being installed (including second-hand burners) and the indication that the existing burners being used may be older on average than the inventory suggests supports the use of slightly higher emission rates for modern burners than what might be assumed for other areas where burner types have been evaluated e.g., Nelson.

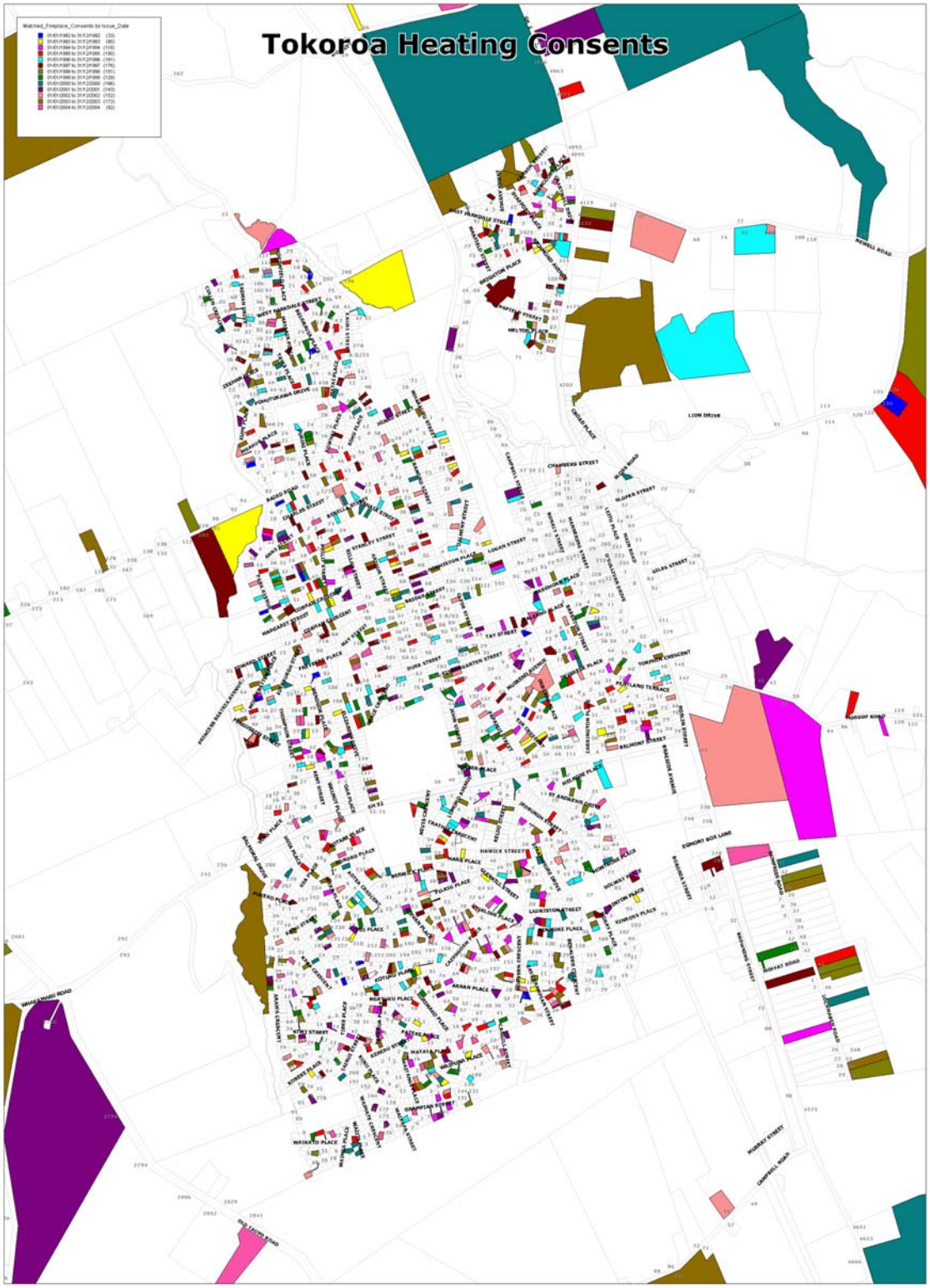

Figure 3-10: Solid fuel burner installation in Tokoroa from 1992 to 2004

4 Managing air quality in Tokoroa

The main factors contributing to poor air quality in most areas include meteorological conditions conducive to elevated pollution, emissions from within the area, the transportation of pollutants from other areas and atmospheric reactions between contaminants. Options for air quality management of PM_{10} in Tokoroa include targeting

primary emissions from within the area and emissions from outside of the area that may contribute to elevated concentrations in Tokoroa.

4.1 Sources within Tokoroa

The Tokoroa emissions inventory shows the main source of emissions from within the area during the winter months is domestic home heating (83%), although outdoor burning also contributes 9% of PM_{10} emissions. Figure 4.3 shows estimated trends in emissions from domestic heating, outdoor burning, industry and motor vehicles. These are based on the following assumptions:

- No population change in Tokoroa from 2001 to 2021 (Appendix two)
- A consequent decrease in occupied dwellings, and vehicle kilometres travelled.
- The replacement of older solid fuel burners 15 years following installation.
- Improvements in vehicle engine technology as per the Ministry of Transport's Transport Emission Model (NZTER).
- A reduction in outdoor burning emissions associated with predicted decreases in population.
- No significant changes in industrial emissions.
- The NES design standard for new installations of solid fuel burners is effective from 2005.

Figure 4-1: Projections in emissions from all sources in Tokoroa

The effectiveness of different management options in reducing PM_{10} concentrations also depends on the relationship between emissions and concentrations in Tokoroa. This includes the impact of the time of day emissions occur relative to meteorological conditions and how reductions in PM_{10} emissions influence reductions in PM_{10} concentrations.

The time of day impact relates to how emissions occurring at different times of the day influence the 24-hour average concentration. For example, emissions that occur when wind speeds are lowest and temperature inversions are present (typically evening and early morning) will have a greater impact on 24-hour average concentrations.

Although the relationship between emissions and concentrations at different times of the day has not been established for Tokoroa, it is most likely that emissions that occur in the evening and early morning will have the greatest impact on 24-hour average PM_{10} concentrations. Table 4.1 shows an estimate of daily variations in emissions sources from the 2004 Tokoroa emissions inventory. This shows that just under half of the domestic heating emissions occur in the evening (4pm-10pm) period, compared to one third of motor vehicle PM_{10} emissions and about one quarter of industrial PM_{10}

emissions. Based on these data, it is likely that the time of day impact may result in a slightly higher contribution to PM_{10} concentrations from domestic home heating. However, this effect is unlikely to be as large as for Christchurch, where quantification of the impact of time of day increases the domestic heating contribution from 80% for PM_{10} emissions to 90% for PM_{10} concentrations. This is because a greater proportion (65%) of the PM_{10} emissions in Christchurch occur during the evening (4pm to 10pm) period.

Table 4-1: Source contributions to PM10 emissions at different times of the day

	6am-10am kg	10am-4pm kg	4pm-10pm kg	10pm-6am kg	Total kg
Domestic heating	75	99	248	114	536
Motor vehicles	8	18	14	3	42
Outdoor burning	15	45			59
Industry	1	1	1	2	6
Total	98	163	263	119	643

The other impact of meteorology is how reductions in PM_{10} emissions influence reductions in PM_{10} concentrations. In Christchurch, modelling work carried out by NIWA suggests that this relationship is linear, indicating a proportional reduction in concentrations for a reduction in emissions (Gimson & Fisher, 1997). That is, if emissions were reduced evenly across all time periods.

In the absence of modelling of the relationship between emissions and concentrations for Tokoroa, the assessment of effects has been based on the assumption of a linear relationship between emissions and concentrations and no impact of time of day emissions occurring relative to meteorological conditions. The impact of the latter assumption is likely to be a conservative estimate of the effectiveness of management options for domestic heating (i.e., the assessment will slightly under predict the impact of options targeting domestic heating PM_{10} emissions).

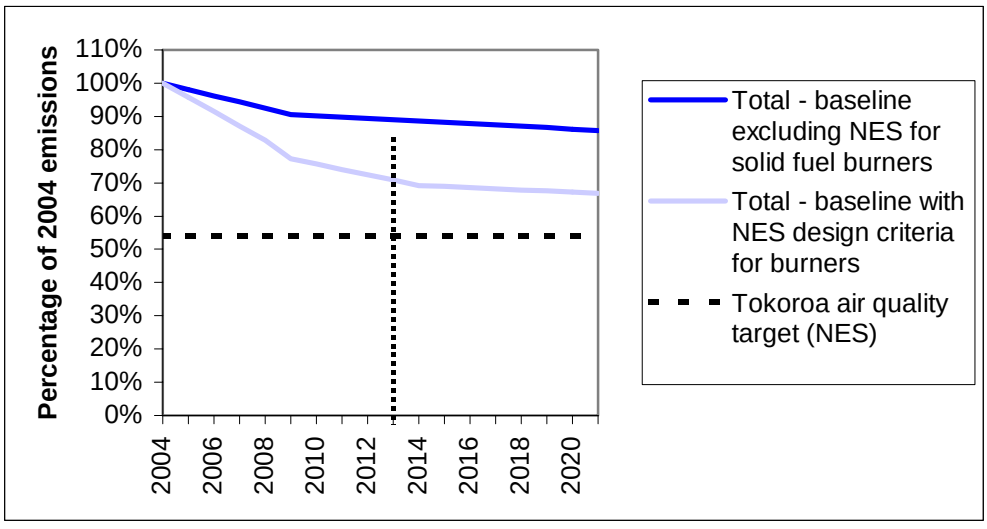

Figure 4-2: Projections for PM10 emissions in Tokoroa with and without the NES design criteria for solid fuel burners

Figure 4.2 shows the combined impact of estimated trends in PM_{10} emissions within Tokoroa. This suggests that the introduction of the design criteria for new installations of solid fuel burners in Tokoroa is unlikely to be sufficient to achieve the NES by 2013 on its own. Additional obstacles that may limit achievement of the NES include:

- An increase in the proportion of households using open fires or solid fuel burners.
- Non-compliance with the NES design standard for solid fuel burners.

- Households not replacing solid fuel burners at the end of their anticipated useful life (15 years).
- An increase in the quantity of fuel burnt on existing burners or open fires.
- The contribution of sources from outside of the urban areas of Tokoroa or non-anthropogenic sources within Tokoroa.
- Meteorological conditions more conducive to air pollution than those occurring from 2001 to 2004.

Other assumptions underlying the projections are outlined in Table 4.2. There are uncertainties associated with these assumptions and those associated with the underlying data, e.g., the emission inventory and air quality monitoring. Where assumptions are made about human behaviour there is the potential for variations in the associated emissions, for example, changes in electricity prices, electricity shortages or concerns about gas supplies can influence heating choices. Other factors such as economic conditions or uncertainties, income levels, or interest and mortgage rates, can also affect the choices that people make about their heating methods and consequently affect the real life emissions from solid fuel burning.

Table 4-2: Assumptions underlying the assessment of the effectiveness of management options for reducing PM10 emissions

1	A decrease in PM_{10} emissions from motor vehicles of around 60% by 2021. This is likely to be conservative, i.e., a greater reduction is probable given the NZTER predictions for PM_{10} emissions as a result of improvements in vehicle technology.
2	**The industry contribution to PM_{10} emissions is less than 2% and there is no change in emissions from industry with time.**
3	Current outdoor burning emissions occur throughout the week and weekend.
4	Emission factors for burners as per the 2004 Tokoroa emission inventory (appendix one).
5	**Average fuel use for 1.5 g/kg burners of 28 kg per night as per the post 1999 burners in the 2004 emission inventory survey**.
6	Average fuel use for other burners as per the 2004 Tokoroa emission inventory survey.
7	A proportional reduction in concentrations for any given reduction in emissions.
8	No variations in the impact of emissions occurring at different times of the day.
10	No change in the number of households in Tokoroa from 2001 to 2021
11	Unless otherwise stated, 100% of households replacing open fires or older solid fuel burners will install solid fuel burners.
12	An emission factor for 1.5 g/kg burners of 3 g/kg.
13	All new installations of solid fuel burners from 2005 will meet an emission criterion of 1.5 g/kg when tested to NZS 4013.

Additional management measures for reducing PM_{10} concentrations in Tokoroa include:
- A ban on outdoor rubbish burning.
- A ban on the use of open fires.
- Economic incentives for households to replace older solid fuel burners.
- Further prohibitions on the use of solid fuel burners.

In many urban areas of New Zealand outdoor rubbish burning is already prohibited because of the nuisance effects of smoke and odour. Figure 4.3 shows the estimated impact on PM_{10} concentrations in Tokoroa if outdoor burning were prohibited in 2005. The costs associated with implementing this option include enforcement and costs to households and orchards in finding alternative disposal methods.

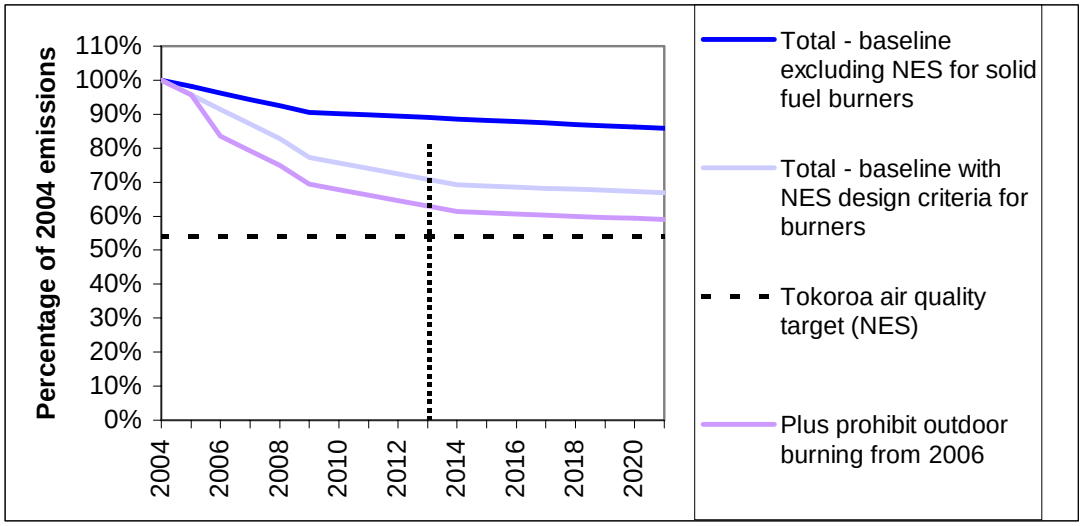

Figure 4-3: Projections for PM10 emissions in Tokoroa if outdoor burning is prohibited by 2006

An additional management option to reduce emissions from domestic home heating is a ban on the use of open fires. Open fires contribute about 8% of PM_{10} emissions from domestic heating in Tokoroa and are an inefficient method of home heating. Figure 4.4 suggests that this combination of options may be sufficient to achieve the air quality target by 2013.

While there is still some uncertainty in the projections, it should be noted that prior to monitoring in 2004, the reduction required in PM_{10} concentrations was less (29% as opposed to 46%) as the maximum measured PM_{10} concentration in Tokoroa was 75 µg m^{-3}, rather than the 97 µg m^{-3} (24-hour average) measured in 2004. The probability of achieving compliance with the NES in 2013 and subsequent years will also depend on the meteorology during those years.

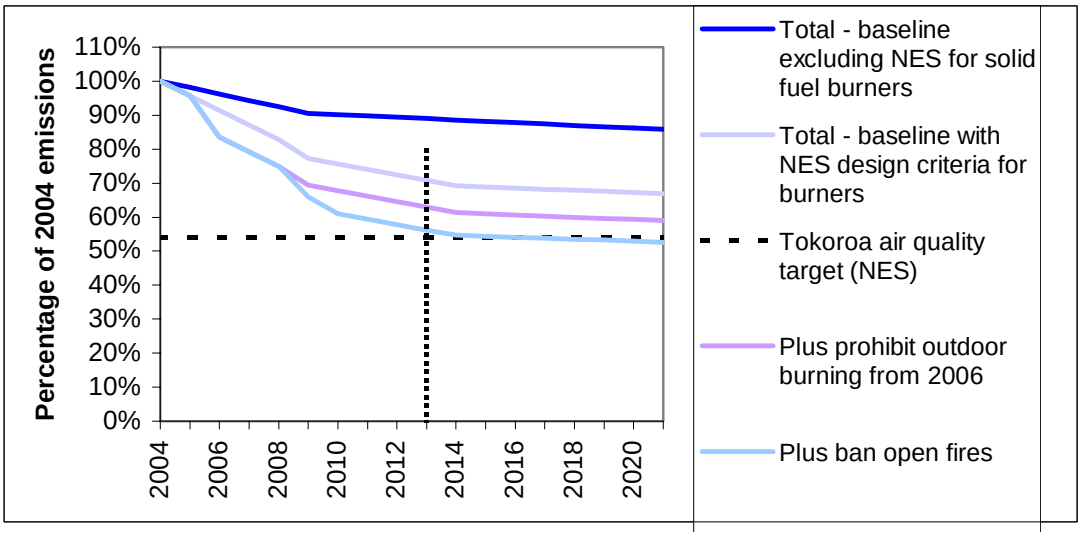

Figure 4-4: Projections for PM10 emissions in Tokoroa if outdoor burning is prohibited by 2006 and open fires are replaced with low emission burners by 2010

One issue that has a reasonable impact on the effectiveness of different management options in reducing PM_{10} concentrations in Tokoroa is the projected population statistics. Previous graphs are based on the assumption of a stable population base. Figure 4.5 shows the estimated PM_{10} projections if the population does not remain

stable but decreases by about 20% from 2001 til 2021. Appendix two outlines the basis for the different population projections.

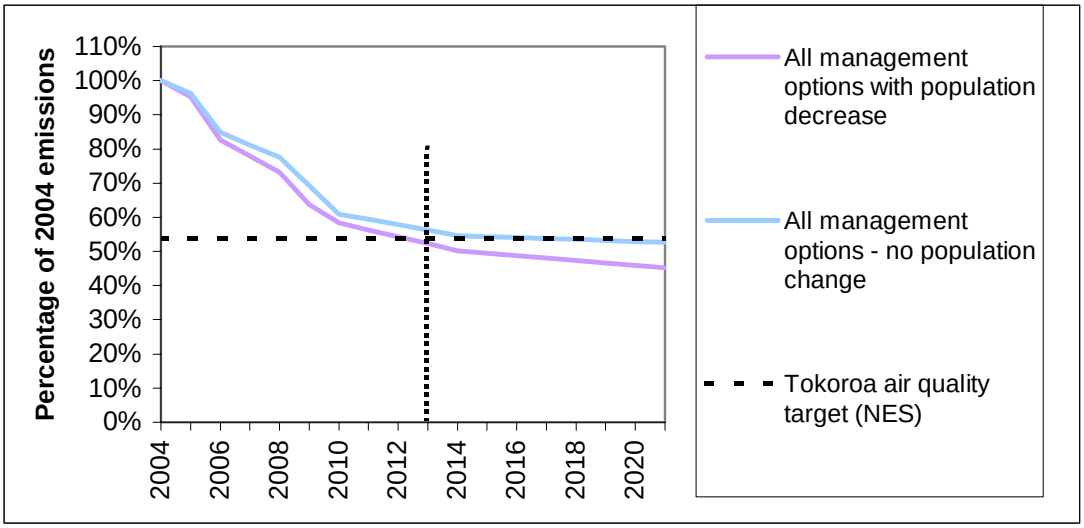

Figure 4-5: Projections for PM10 emissions in Tokoroa if outdoor burning is prohibited by 2006 and open fires are replaced with low emission burners by 2010, with and without a 20% decrease in population by 2021.

5 Managing air quality in Taupo

Like Tokoroa, the main source of PM_{10} within the urban areas is domestic home heating. There are also a number of significant industrial air discharges located outside of the urban areas to the northeast. The topography of the area is such that contribution from these areas to the urban areas of Taupo would seem unlikely. Consequently, evaluation of management options to reduce PM_{10} concentrations in Taupo focuses on discharges from within the urban area only.

5.1 Sources within Taupo

The main source of emissions from within the urban area of Taupo during the winter months is domestic home heating (88%). Motor vehicles contribute 9% of PM_{10} emissions, with outdoor burning resulting in 3% and industry less than 1%. Figure 5.3 shows estimated trends in emissions from domestic heating, outdoor burning, industry and motor vehicles. These are based on the following assumptions:

- An increase in population of around 8% from 2001 to 2021 (Appendix two)
- A consequent increase in the number of usually occupied dwellings
- The replacement of solid fuel burners 15 years after installation.
- An increase in VKTs and traffic congestion as predicted by Gabites Porter based on road network modelling and a “do minimum” scenario for transport management.
- Improvements in vehicle engine technology as per the Ministry of Transports Transport Emission Model (NZTER).
- An 11% increase in emissions from outdoor burning.
- No significant changes in industrial emissions.
- The NES design standard for new installations of solid fuel burners is effective from 2005.

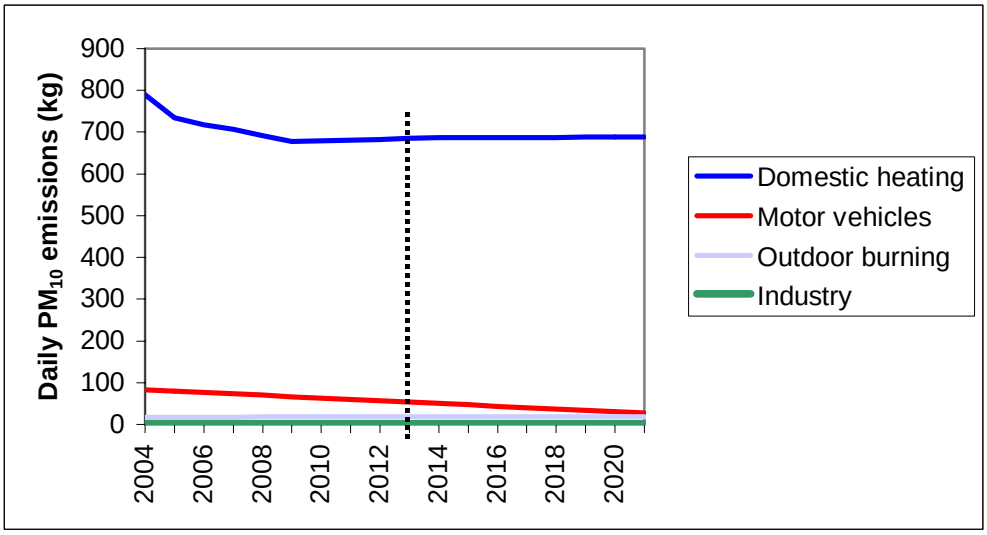

Figure 5-1: Projections in emissions from all sources in Taupo

The effectiveness of different management options in reducing PM_{10} concentrations also depends on the relationship between emissions and concentrations in Taupo. This includes the impact of the time of day emissions occur relative to meteorological conditions and how reductions in PM_{10} emissions influence reductions in PM_{10} concentrations.

The time of day impact relates to how emissions occurring at different times of the day influence the 24-hour average concentration. For example, emissions that occur when wind speeds are lowest and temperature inversions are present (typically evening and early morning) will have a greater impact on 24-hour average concentrations.

Although the relationship between emissions and concentrations at different times of the day has not been established for Taupo, it is most likely that emissions that occur in the evening and early morning will have the greatest impact on 24-hour average PM_{10} concentrations. Table 5.1 shows an estimate of daily variations in emissions sources from the 2004 Taupo emissions inventory. This shows that about 59% of the domestic heating emissions occur in the evening (4pm-10pm) period, compared to one third of motor vehicle PM_{10} emissions. Based on these data, it is likely that the time of day impact may result in a slightly higher contribution to PM_{10} concentrations from domestic home heating relative to motor vehicles.

Table 5-1: Source contributions to PM10 emissions at different times of the day

	6am-10am kg	10am-4pm kg	4pm-10pm kg	10pm-6am kg	Total kg
Domestic heating	75	106	465	140	786
Motor vehicles	16	35	27	5	83
Outdoor burning	6	19			25
Industry	0	1	0	0	1
Total	98	160	492	144	895

The other impact of meteorology is how reductions in PM_{10} emissions influence reductions in PM_{10} concentrations. In Christchurch, modelling work carried out by NIWA suggests that this relationship is linear, indicating a proportional reduction in concentrations for a reduction in emissions (Gimson & Fisher, 1997). That is, if emissions were reduced evenly across all time periods.

In the absence of modelling of the relationship between emissions and concentrations for Taupo, the assessment of effects has been based on the assumption of a linear relationship between emissions and concentrations and no impact of time of day emissions occurring relative to meteorological conditions. The impact of the latter assumption is likely to be a conservative estimate of the effectiveness of management options for domestic heating (i.e., the assessment will slightly under predict the impact of options targeting domestic heating PM_{10} emissions).

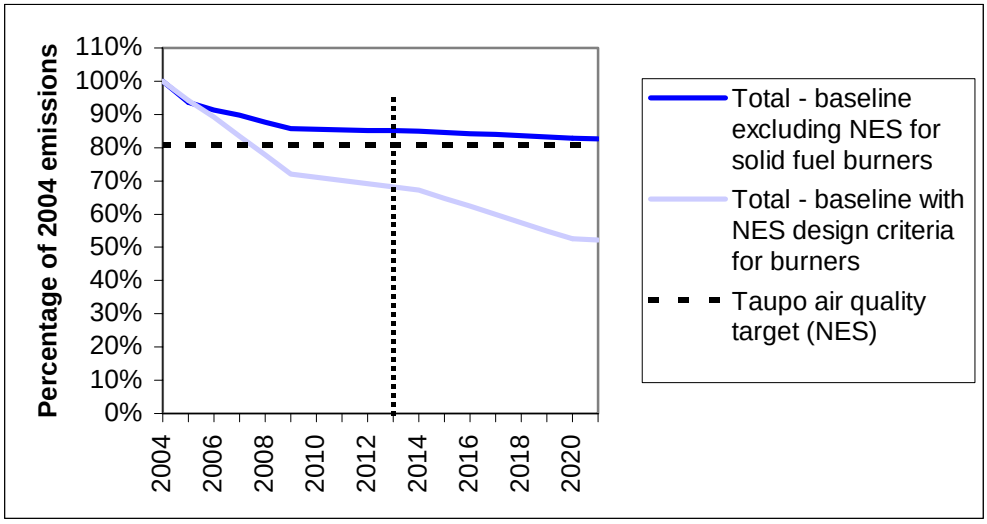

Figure 5-2: Projections for PM10 emissions in Taupo with and without the NES design criteria for solid fuel burners

Based on the projected PM_{10} concentrations shown in Figure 5.2 it is likely that the introduction of the NES for solid fuel burners should result in achievement of the ambient air target by around 2008. Factors that may contribute to the target not being met include:

- An increase in the proportion of households using open fires or older solid fuel burners.
- Non-compliance with the NES design standard for solid fuel burners.
- An increase in the quantity of fuel burnt on existing burners or open fires.
- The contribution of sources from outside of the urban areas of Taupo.
- If sources other than those considered, e.g., natural dusts are a major contributor to PM_{10} concentrations in Taupo.

Estimates of PM_{10} shown in Figure 5.2 are also based on a number of assumptions, which are outlined in Table 5.2. There are uncertainties associated with these assumptions and those associated with the underlying data, e.g., the emission inventory and air quality monitoring. Where assumptions are made about human behaviour there is the potential for variations in the associated emissions, for example, changes in electricity prices, electricity shortages or concerns about gas supplies can influence heating choices. Other factors such as economic conditions or uncertainties, income levels, or interest and mortgage rates, can also affect the choices that people make about their heating methods and consequently affect the real life emissions from solid fuel burning.

Table 5-2: Assumptions underlying the assessment of the effectiveness of management options for reducing PM10 emissions

1	A decrease in PM_{10} emissions from motor vehicles of around 66% by 2021. This is based on road transport modelling for a "do minimum" scenario and NZTER projections in tailpipe emissions.
2	**The industry contribution to PM_{10} emissions is less than 1% and there is no change in emissions from industry with time.**
3	Current and future outdoor burning emissions occur throughout the week and weekend.
4	**Emission factors for burners as per the 2004 Taupo emission inventory (appendix one).**
5	Average fuel use for 1.5 g/kg burners of 29 kg per night as per the post 1999 burners in the 2004 emission inventory survey.
6	**Average fuel use for other burners as per the 2004 Taupo emission inventory survey.**
7	A proportional reduction in concentrations for any given reduction in emissions.
8	No variations in the impact of emissions occurring at different times of the day.
10	**An increase in occupied dwellings in Taupo of around 11% from 2001 to 2021**
11	Unless otherwise stated, 100% of households replacing open fires or older solid fuel burners will install solid fuel burners.
12	An emission factor for 1.5 g/kg burners of 3 g/kg.
13	All new installations of solid fuel burners from 2005 will meet an emission criterion of 1.5 g/kg when tested to NZS 4013.

Although the projections for Taupo suggest that the NES for PM_{10} is likely to be met by 2013, Environment Waikato may also want to consider the option of banning outdoor burning in the urban areas of Taupo as an additional measure. This practice is already prohibited in many urban areas of New Zealand because of the nuisance effects of smoke and odour. Currently outdoor burning contributes around 3% of PM_{10} emissions in Taupo. Figure 5.3 shows the estimated impact on PM_{10} concentrations in Taupo if outdoor burning were prohibited in 2005. While this is not as significant as for Tokoroa, additional benefits include a reduction in smoke and odour nuisance occurring as a result of this practice. The costs associated with implementing this option include enforcement and costs to households and orchards in finding alternative disposal methods.

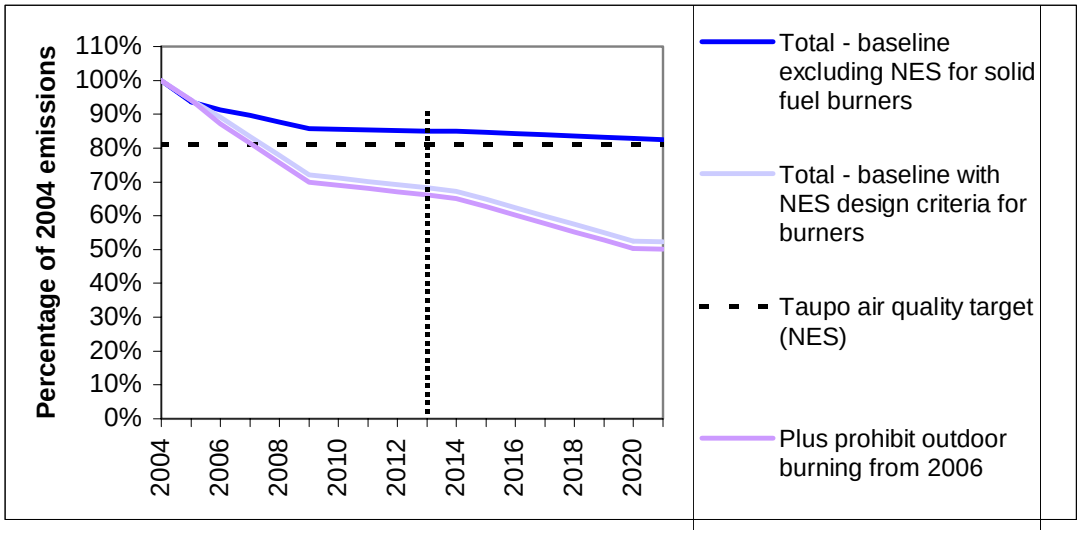

Figure 5-3: Projections for PM10 emissions in Taupo if outdoor burning is prohibited by 2006Open fires contribute about 15% of PM_{10} emissions from domestic heating in Taupo and are an inefficient method of home heating. Figure 5.4 shows the additional impact on PM_{10} concentrations in Taupo if all open fires were replaced with low emission solid fuel burners.

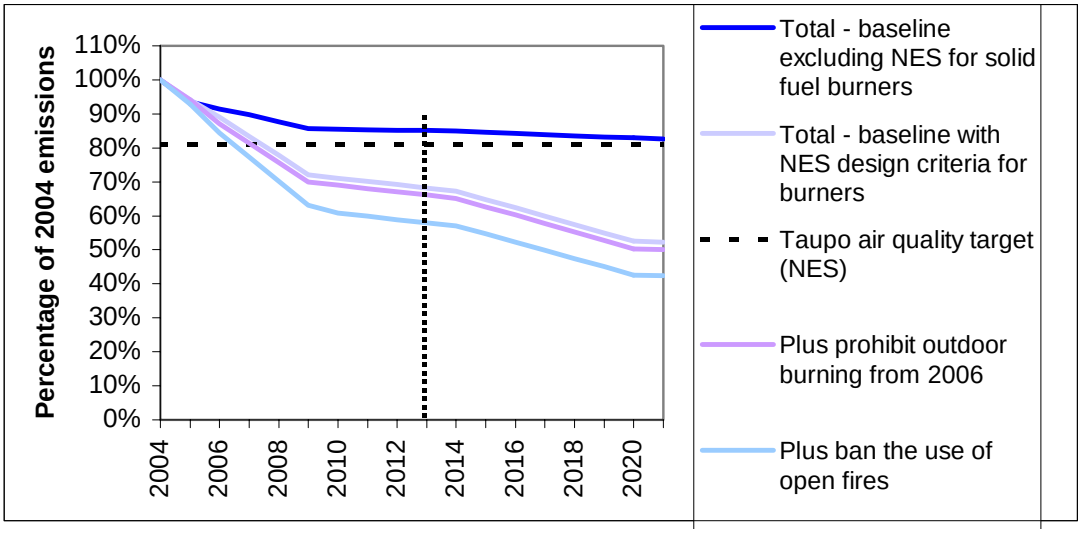

Figure 5-4: Projections for PM10 emissions in Taupo if outdoor burning is prohibited by 2006 and open fires are replaced with low emission burners by 2010

5.2 Other sources in and around Taupo

The contribution of sources from outside of the urban areas of Taupo is uncertain. Based on the location of the main industrial activities outside of this area, it would seem unlikely that they would contribute. It is possible, however that the NES is breached in the area to the northeast, where the majority of the Taupo industry is located.

The contribution of natural sources to PM_{10} concentrations measured in urban Taupo is uncertain. Sea spray is unlikely to be a significant contributor because of the distance to the sea. However, there is some suggestion, based on historical monitoring, that natural dust sources may contribute to measured PM_{10} concentrations. Natural sources are not included in the emissions inventory because of uncertainties in the estimation methods.

If natural sources such as dusts or industry located to the northeast of Taupo are a major contributor to PM_{10} concentrations in Taupo, additional management measures may be required to achieve the NES. A study of the chemical composition of PM_{10} collected on filters may provide additional information on the contribution of natural dusts to PM_{10} concentrations in Taupo.

6 Conclusions

Concentrations of PM_{10} measured in Tokoroa and Taupo have exceeded the National Environmental Standard of 50 µg m^{-3} (24-hour average) each year since monitoring commenced in 2001. Reductions required to meet the NES are 46% and 19% in Tokoroa and Taupo respectively. This is based on one allowable breach per year. If an air quality target of 50 µg m^{-3} with no allowable breaches were to be achieved, reductions of around 48% and 19% respectively would be required.

The main source of PM_{10} in both locations is solid fuel burning for domestic home heating.

An analysis of the effectiveness of measures to reduce PM_{10} concentrations suggest that in Taupo it is likely the NES would be met by 2013 in the absence of additional regulations. This is because the Ministry for the Environment has included in the NES a design standard for new installations of solid fuel burners, requiring them to meet an emission limit of 1.5 grams of particulate per kilogram of fuel burnt and an efficiency of 65%. Emissions of PM_{10} are predicted to decrease as older more polluting burners are replaced with efficient low emission burners meeting an emission limit of 1.5 g/kg.

In Tokoroa, additional measures are necessary to achieve compliance by 2013. The combination of a ban on outdoor rubbish burning combined with a ban on the use of open fires is unlikely to be sufficient to achieve the NES by 2013. Additional options such as incentives to encourage the replacement of older burners with cleaner heating alternatives are likely to be necessary.

The projections are based on a number of uncertainties, however, and additional measures may be considered to increase the probability of compliance. It is proposed that the banning of outdoor rubbish burning in Taupo also be considered because of the contribution to ambient PM_{10} concentrations as well as the localised smoke and odour nuisance.

The main barriers to achievement of the air quality target are the potential for contribution from non-anthropogenic sources and the occurrence of meteorological conditions more conducive to elevated pollution than those experienced from 2001 to 2004.

A study of the chemical composition of PM_{10} collected on filters may provide additional information on the contribution of non-anthropogenic sources such as natural dusts to PM_{10} concentrations.

Appendix I PM_{10} emission factors

Table A.1: PM_{10} emission factors for solid fuel burning

	Tokoroa PM_{10} g/kg	Taupo PM_{10} g/kg
Open fire - wood	10	10
Open fire - coal	21	21
Pre 1994 woodburner	13	13
1994-1999 woodburner	8.5	7
Post 1999 woodburner	7.2	6
Multi-fuel – wood	13	13
Multi-fuel – coal	28	28
1.5 g/kg wood burner	3	3

[1] - includes potbelly, incinerator, coal range and any enclosed burner that is used to burn coal

Appendix II Population projections

The population projection for Taupo is based on New Zealand Statistics population projections for medium growth of 8% from 2001 to 2021 for the Taupo District. In the absence of better information, it is assumed that the projection applies also to the number of occupied dwellings.

The same data source indicates a 20% decrease in the population of Tokoroa. However, local planner at the South Waikato District Council now consider a stable population projection is more realistic for Tokoroa (pers comm., Brent Sinclair, Environment Waikato, 2004).

The following is an exert from the New Zealand statistics website http://www.stats.govt.nz/domino/external/omni/omni.nsf/outputs/Demographic+Projections#SPP) which provides some explanation for the derivation of population projections.

Subnational Population Projections

Projections (2001-base to 2021 at five-year intervals) of the population usually living in the 16 regional council areas and 74 territorial authority areas (cities and districts) of New Zealand were released via a Hot Off the Press (Cat 03.507) on 21 November 2002.

Base Population

These projections have as a base the estimated resident population of each area at 30 June 2001. This population was based on the census usually resident population count of each area at 6 March 2001, with adjustments for:

a. net census undercount
b. residents temporarily overseas on census night
c. births, deaths and net migration between census night (6 March 2001) and 30 June 2001
d. reconciliation with demographic estimates at ages 0–9 years.

For more information about the base population, refer to Population Estimates.

Alternative Series

Three alternative series (designated low, medium and high) have been produced for each area using different fertility, mortality and migration assumptions. At the time of release, the medium projection series is considered the most suitable for assessing future population change and is consistent with series 4 of the 2001-base National Population Projections released on 24 October 2002. The medium projection series uses medium fertility, medium mortality and medium net migration for each area.

The low and high projection series are independent of any series of national population projections as they represent plausible alternative scenarios for each area rather than at the collective national level. The low projection series uses low fertility, high mortality and low net migration for each area. The high projection series uses high fertility, low mortality and high net migration for each area.