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Health Impacts of PM_{10} Pollution in Hamilton, Tokoroa, Te Kuiti and Taupo

An Assessment of the Health Benefits of Management Options to Reduce PM_{10}

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Table of Contents

List of Figures

List of Tables

Executive Summary

Concentrations of PM_{10} measured at Hamilton, Tokoroa, Te Kuiti and Taupo generally exceed the National and Regional Air Quality Guideline for PM_{10} of 50 $\mu g\ m^{-3}$ (24-hour average) most years during the winter months.

Tokoroa typically experiences the worst air pollution, with PM_{10} breaches occurring between 15 and 41 occasions per year. The maximum measured PM_{10} concentration in Tokoroa (97 $\mu g\ m^{-3}$) is also higher than in the other urban areas. Taupo, Te Kuiti and Hamilton generally record fewer breaches (typically 0 – 12 per location) with maximum concentrations between 60 and 70 $\mu g\ m^{-3}$. Concentrations of PM_{10} in Tokoroa also exceed the national annual average guideline for PM_{10} of 20 $\mu g\ m^{-3}$. All locations also fail to meet the National Environmental Standard (NES) for PM_{10} that allows for one exceedance per year of 50 $\mu g\ m^{-3}$ (24-hour average).

Although the guidelines for PM_{10} have been set at 50 $\mu g\ m^{-3}$ (24-hour average) and 20 $\mu g\ m^{-3}$ (annual average), PM_{10} is considered a no threshold contaminant. This means there is no known safe level below which effects will not occur. Thus even at the guideline concentrations, health impacts can occur with exposure to PM_{10}. Concentrations of PM_{10} measured at Hamilton, Tokoroa, Te Kuiti and Taupo are therefore likely to result in health impacts on residents of these towns.

The types of health impacts associated with exposure to PM_{10} range from minor nose and throat irritations to more severe effects such as hospital admissions and premature mortality. The elderly and people with pre-existing conditions are more susceptible to health impacts associated with exposure to PM_{10}.

An evaluation of management options to reduce PM_{10} concentrations has been carried out for Hamilton, Tokoroa, Te Kuiti and Taupo. This indicates a range of measures for achieving reductions in each location and an indication of the impact on PM_{10} concentrations relative to the NES for PM_{10}. This report evaluates some of the health benefits of these management options in each location.

Table i outlines estimates of mortality likely to occur as a consequence of exposure to PM_{10}. Results indicate that although Tokoroa experiences the worst air quality in the Region, the most effective method for reducing the mortality impacts of PM_{10} in the Region would be to implement measures to reduce PM_{10} concentrations in Hamilton.

Table i **Estimates of mortality for each area based on: (a) the existing PM_{10} concentrations, (b) reductions in PM_{10} required to achieve the NES, (c) baseline scenario including NES design standard for woodburners (the status quo), and (d) the status quo scenario along with reductions in PM_{10} via a ban on outdoor burning and open fires.**

	a. Current 2004	b. NES 2013	c. Status quo 2020	d. Management measures 2020
Hamilton	52	51	56	42
Tokoroa	10	7	7	7
Taupo	9	7	9	6
Te Kuiti	3	3	2	2

1 Introduction

For most of the year air quality in the Waikato Region is within acceptable levels. However, during the winter months concentrations of PM_{10} in urban areas of the Region can exceed National and Regional Air Quality Guidelines and the National Environmental Standards for air.

Of the urban towns in the Region, Tokoroa typically experiences the worst air pollution, with PM_{10} breaches occurring between 15 and 41 occasions per year. The maximum measured PM_{10} concentration for the Region (97 μg m^{-3}) was also measured in Tokoroa during 2004. Other urban towns where PM_{10} concentrations in excess of the 24-hour average guideline for PM_{10} include Taupo, Te Kuiti and Hamilton. These areas generally record fewer exceedances (typically 0 – 12 per location) with maximum concentrations between 60 and 70 μg m^{-3} (figure 1.1).

Annual average concentrations of PM_{10} in Tokoroa also exceed the national guideline for PM_{10} of 20 μg m^{-3}. All locations also fail to meet the National Environmental Standard (NES) for PM_{10} that allows for one exceedance per year of 50 μg m^{-3} (24-hour average).

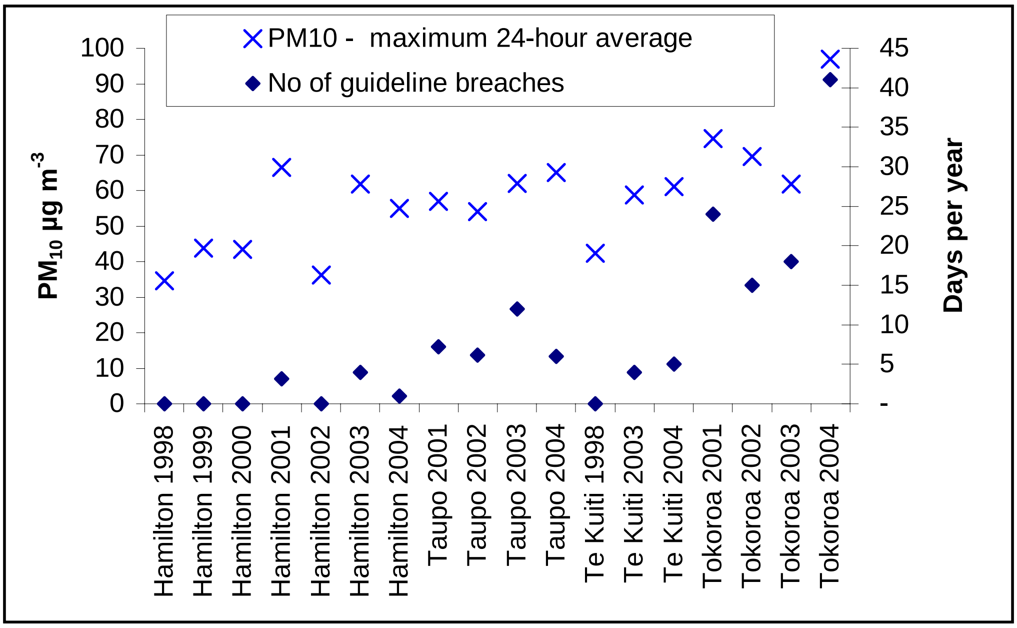

Figure 1-1: Maximum 24-hour average PM10 concentrations and number of guideline exceedances per year in Hamilton, Tokoroa, Te Kuiti and Taupo

Concentrations of PM_{10} measured in these towns are likely to result in adverse health impacts. PM_{10} is considered a no threshold contaminant, which means that there is no known safe level below which effects will not occur. Thus even at the guideline concentrations, detrimental health effects can occur with exposure to PM_{10}.

1.1 Health impacts of particulate pollution

The types of health impacts associated with exposure to PM_{10} range from minor nose and throat irritations to more severe impacts such as hospital admissions and premature mortality. The elderly and people with pre-existing conditions are more susceptible to health impacts of exposure to PM_{10}.

Health research of the impacts of PM_{10} is based largely on epidemiological studies. The most common type of epidemiological study examining the impacts of particulate pollution is a times-series study. This methodology examines statistical relationships between concentrations of PM_{10} and increased mortality, hospital admissions and other health impacts when adjustments are made for confounding factors such as temperature and meteorology.

Two epidemiological studies of the relationships between concentrations of particles and health have been carried out in New Zealand using the time-series design. One study considered the impact of both PM_{10} concentrations and temperature on mortality in Christchurch (Hales et. al., 1999). The other study examined the relationship between hospital admissions and particulate pollution in Christchurch (McGowan et. al., 2002). In the Hales (1999) study, both all cause mortality and respiratory mortality (with a one-day lag) were associated with PM_{10} concentrations measured at the St Albans monitoring site in central Christchurch. The size of the effect, 1% (0.5-2.2%) for all cause mortality was reasonably consistent with similar studies carried out in other countries (e.g., Dockery et. al., 1994). An association between respiratory mortality and PM_{10} concentrations of 4% (1.5 – 5.9%) per 10 μgm^{-3} increase in daily PM_{10} concentrations was also recorded. Results from McGowan et. al., (2002) indicated a 3.37% increase in respiratory hospital admissions and a 1.26% rise in cardiac admissions for each interquartile rise in PM_{10} concentrations (interquartile value 14.8 $\mu g\ m^{-3}$).

A more detailed study methodology is a prospective cohort design, which considers health data in a group of subjects over a number of years. This approach was used in two US studies, the Harvard Six Cities study (Dockery et al., 1993) and the American Cancer Society study (Pope et al., 1995). These studies followed groups of 8111 and 552,138 adult subjects for 14-16 and seven years respectively. Results from these studies showed concentrations of particles were associated with increased mortality.

Results from epidemiological studies have been used to develop dose-response relationships between PM_{10} concentrations and adverse health impacts such as mortality and hospital admissions. Dose-response relationships based on time-series type studies are typically lower than those based on the cohort type studies. For example time-series studies indicate around a 1% increase in mortality per 10 $\mu g\ m^{-3}$ increase in 24-hour average $PM_{10.}$ In contrast, Kunzli et al. (2000) estimate a dose-response relationship for mortality based on the cohort studies of around 4.3 % per 10 $\mu g\ m^{-3}$ increase in annual average PM_{10}. The latter estimates are conservative relative to the WHO (2000) recommendations, which indicate a 10% increase in mortality per 10 $\mu g\ m^{-3}$ increase in PM_{10} for the impacts of long-term exposure.

The difference between the 1% of the time-series studies and 4.3% (and higher) derived from the cohort studies is thought to occur because the time-series studies do not capture chronic effects of particulate pollution or acute effects not occurring at the time of a specific pollution event. That is, they are limited to a selection of the acute impacts but do not estimate the reduced life expectancy due to long-term morbidity enhanced by air pollution (Kunzli et al., 2000).

Exposure to PM_{10} concentrations can also result in less extreme health impacts such as days spent in bed, missed from work, or days in which activities are altered[1] because of exposure to particles. These more minor impacts are collectively referred to as restricted activity days (RAD). Unlike the more severe health impacts, which are more likely to affect the elderly, or those with pre-existing medical conditions, RAD impacts are common amongst the general population.

[1] Altering activities refers to changing what they would otherwise have done. For example, altered activities might include not walking out to the mailbox to get their mail or not attending an activity such as a sport practice or social event.

1.2 Health impacts estimates for New Zealand

The impact of PM_{10} concentrations on health in urban areas of New Zealand has been estimated using dose-response relationships derived by the epidemiological studies. Table 1.1 shows an estimate of some of the health impacts of particulate pollution in urban areas of New Zealand. The estimates of hospitalisations in table 1.1 are based on the time-series studies and are therefore likely to significantly underestimate the magnitude of impact. Estimates of RAD are based on a single study and involve a high degree of uncertainty. Mortality estimates are based on the Kunzli et al. (2000) dose-response relationship (4.3% increase in mortality per 10 $\mu g\ m^{-3}$ increase in annual average PM_{10}).

Table 1-1: Estimates of health impacts of particle concentrations in New Zealand (from Wilton, 2003)

	Estimated annual mortality	Estimated Hospitalisations per year	Estimated Restricted Activity Days per year
Auckland	436(3)	200	750,000
Wellington	79(3)	30	100,000
Christchurch	182(3)	80	300,000(1)
Dunedin	48(3)	20	80,000
Nelson	20(4)	14(2)	58,000(2)
Hamilton	40(4)	30	90,000
Timaru	20(4)	10	30,000
Lower Hutt	10(4)	20	60,000
Upper Hutt	20	10	30,000
Alexandra	5	<5	10,000
Tokoroa	10	5	20,000

[1] Lower limit estimate from Wilton (2001)
[2] From Wilton (2002)
[3] from Fisher et. al., (2002)
[4] *Rupendra Shresthra from Fisher et. al., (2002) analysis*

2 Methodology for estimating health benefits

2.1 Mortality

Premature mortality was estimated based on the dose-response relationships from the cohort studies as described by Kunzli et al. (2000). Using this approach, the formulae for calculation of mortality is:-

$$Po = \frac{Pe}{1 + [(RR - 1)(E - B) / 10]}$$

Po = baseline mortality, after deducting the air pollution effect (this will depend on the other variables)
Pe = the mortality rate per 1000
E = PM_{10} exposure level for the study area
B = threshold PM_{10} exposure level for mortality effect
RR = the epidemiologically derived relative risk for a 10 $\mu g\ m^{-3}$ increment

of PM_{10}, assuming a liner dose-response relationship above the threshold (B)

The increased mortality is then calculated: -

$$D_{10} = P_o * (RR - 1)$$

D_{10} = the number of additional deaths per 1000 people to the baseline mortality for a 10 $\mu g\ m^{-3}$ increase in PM_{10}

And then: -

$$N_c = D_{10} * P_c * (X_c - B) / 10$$

N_c = the number of deaths due to PM_{10}
P_c = the population ('000s)
X_c = the PM_{10} exposure level

2.2 Hospitalisations

The risk assessment for hospitalisations is based on the assumptions of a 2.3% increase in respiratory admissions (including asthma) per 10 $\mu g\ m^{-3}$ increase in PM_{10} concentrations, a 1.25% increase in asthma admissions per 10 $\mu g\ m^{-3}$ increase in PM_{10} concentrations and a 0.85% increase in cardiac admissions per 10 $\mu g\ m^{-3}$ increase in 24-hour average PM_{10} concentrations (McGowan, et al., 2002).

Calculations are based on the assumption that for each 10 $\mu g\ m^{-3}$ increase in daily PM_{10}, respiratory hospitalisations increase 2.3%, cardiac hospitalisations increase 0.85% and asthma hospitalisations increase 1.25%. Note that asthma admissions are a subset of respiratory hospital admissions.

Annual hospital admissions = Daily hospital admission rate x dose response rate x no. of 10 $\mu g\ m^{-3}$ increments in PM_{10} per year.

For example, if the daily respiratory hospital admission rate was 0.3 admissions per day and the number of 10 $\mu g\ m^{-3}$ increments in PM_{10} was 1000, the number of respiratory admissions would be:

0.30 x 0.023 x 1000 = 7

The International Classification of Disease (ICD) codes used for respiratory diseases were: 480-486, 490-493, 496-507.

The ICD codes used for cardiopulmonary disease were: 402, 410-414, 426-429.

The ICD code used for asthma was: 493.

2.3 Restricted Activity Days

Estimates of restricted activity days (RAD) are based on the results of a single study carried out by Ostro (1987), which has been interpreted by the American Lung Association (ALA) to show approximately 91,200 RAD each year per one million population per 1 $\mu g\ m^{-3}$ increase in annual average $PM_{2.5.}$

The estimates are very limited by the reliance on a single study and interpretation should therefore be treated only as indicative of order of magnitude of impact.

Calculations of RAD are based on the following equation:

Annual RAD = population x 91200 x annual average $PM_{2.5}$

As no measurements of $PM_{2.5}$ concentrations have been made for the Waikato Region, annual average $PM_{2.5}$ concentrations were estimated based on the assumption that 60% of the PM_{10} is $PM_{2.5}$[2].

3 Health benefits of improving air quality in Tokoroa

3.1 Health impacts of existing air quality

Health impacts of air quality in Tokoroa were estimated for PM_{10} concentrations measured during 2004.

An annual average PM_{10} concentration of 31 $\mu g\ m^{-3}$ was used to estimate premature mortality associated with PM_{10} concentrations in Tokoroa for 2004. This is higher than previous annual average concentrations for Tokoroa, which range from 24 to 27 $\mu g\ m^{-3}$.

Baseline mortality statistics for Tokoroa were based on 1999 data, as these were the most recent data that were available. The latter indicated a mortality rate for Tokoroa of 89 deaths per year. This was adjusted for an estimated population decrease of 2% from 1999 to 2004 (as indicated by census data).

Estimates of mortality for Tokoroa based on the Kunzli 4.3% dose-response relationship were:

- 10 deaths per year (based on Kunzli assuming zero threshold)
- 8 deaths per year (based on Kunzli assuming a 7.5 $\mu g\ m^{-3}$ threshold)

In comparison, the time-series approach, assuming no threshold, would result in an estimated 5 deaths per year for Tokoroa.

Hospital admissions estimates were made based on an assumed baseline hospital admissions rate of 0.09 per day for respiratory hospital admissions and 0.26 per day for cardiac admissions. These are relatively crude estimates based on the relationship between hospital admissions and mortality in Christchurch and Nelson.

Health estimates are based on the assumption that measured PM_{10} concentrations in these areas are indicative of average exposure across the urban areas.

3.2 Management options for Tokoroa

The impact of a range of management options on PM_{10} concentrations in Tokoroa has been evaluated (Wilton, 2004). Figure 3.1 shows the estimated impact on PM_{10} emissions relative to 2004 for the baseline scenario, the NES for wood burners, an emissions standard for multi fuel burners, a ban on open fires and a ban on outdoor burning in Tokoroa. These estimates are based on the following assumptions:

- Household numbers, emission factors and average fuel weights as per the Tokoroa 2004 emission inventory (Wilton, 2004).
- The phase out of pre 1999 solid fuel burners 15 years after installation.
- A slower phase out of 1999-2005 burners, with 60% phased out by 2021.
- All phased out wood or multi fuel burners are replaced with either new wood burners (80%) or new or second hand multi fuel burners (20%)[3].

[2] This is based on relationships estimated for Christchurch based on collocated PM_{10} and $PM_{2.5}$ monitoring (Foster, 1997).
[3] Except for management options which require all burners, including multi fuel burners to meet the NES criteria for wood burners

- A decrease in open fires of 5% by 2021[4].
- For an open fire ban, 50% of households replace the open fire with a wood burner or multi fuel burner[3].
- Emission factors and average fuel use rates as per the Tokoroa 2004 emission inventory (Wilton, 2004).

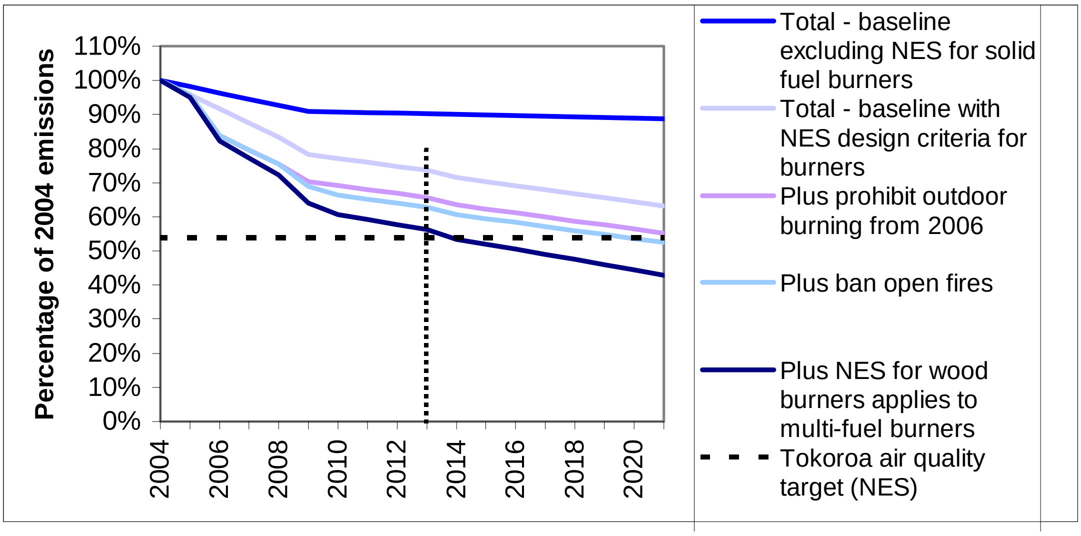

Figure 3-1: Estimates of the impacts of management options for Tokoroa

Appendix A provided an indication of the uncertainty surrounding the projections analysis. Because of the high degree of uncertainty additional measures such as the provision of incentives to encourage households towards cleaner heating methods should be considered.

3.3 Health impacts of management measures

The impact of management options in reducing PM_{10} in Tokoroa are based on an evaluation of estimated changes in the 24-hour average wintertime PM_{10} concentrations. In comparison, the health impacts assessment methodology is based on annual average concentrations. The impact of management measures to reduce 24-hour average PM_{10} concentrations on annual average concentrations has been estimated based on the following assumptions:

- Inventory estimates of the relative contributions of different sources apply for the months April to September.
- Domestic heating emissions during the remaining months (referred to here as summer) are around 5% of the winter values[5].
- Inventory estimates for industry, outdoor burning and motor vehicles apply during the summer months.
- Other sources such as wind blown dusts contribute around 19% of the summer emissions.

The average annual contribution[6] of Kinleith pulp and paper mill (which is not included in the Tokoroa inventory) is around 5 $\mu g\ m^{-3}$. Although the actual contribution of Kinleith is unknown, the implication of using this assumption for this application is not too significant. This is because the Kinleith contribution is treated as a background concentration of 5 $\mu g\ m^{-3}$ of PM_{10} that remains constant over time and is therefore included in the baseline mortality statistics for all scenarios.

[4] Except for management options banning the use of open fires
[5] This is an estimate based loosely on domestic heating surveys for other areas which indicate a small proportion of households using solid fuel burning for domestic heating during the summer months
[6] While it is assumed that the contribution is negligible on days when PM_{10} concentrations in excess of 50 µg m^{-3} are recorded, it is likely that Kinleith will make some contribution to the annual average PM_{10} concentrations in Tokoroa.

Figure 3.2 shows the estimated health benefits in reduced premature mortality per year for the different management options for Tokoroa. Achievement of the NES for PM_{10} in Tokoroa would reduce 2004 mortality estimates from 10 deaths per year (assuming no threshold) to 7 deaths per year.

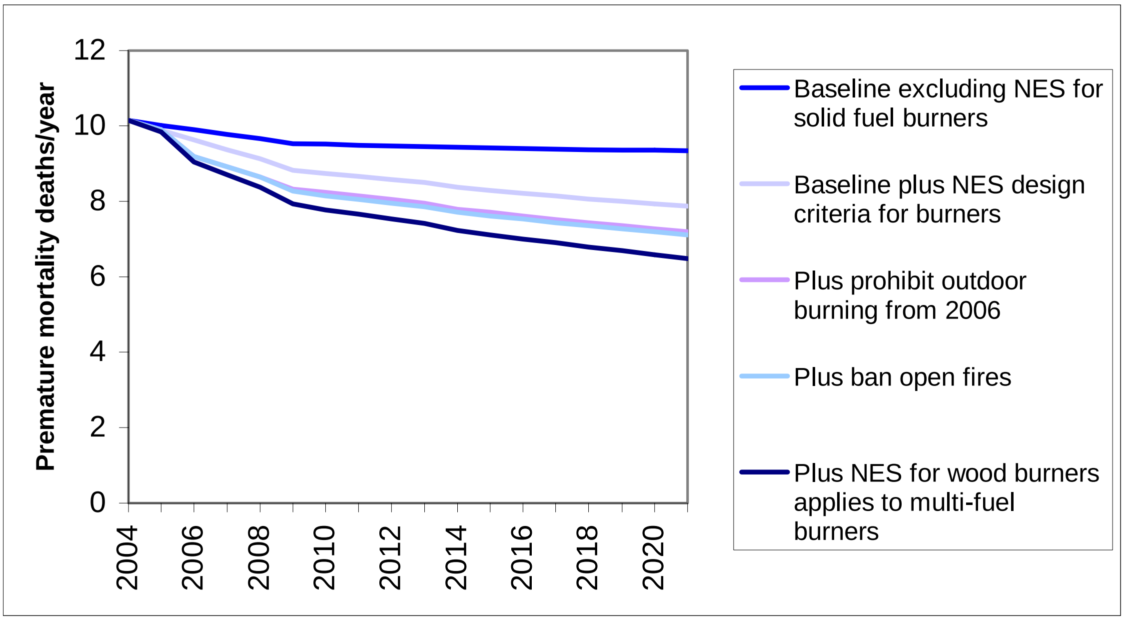

Figure 3-2: Estimates of the impact of management options on mortality in Tokoroa

Table 3-1: Health benefits of management options to reduce PM10 concentrations in Tokoroa

Mortality (deaths per year)	**2005**	**2010**	**2015**	**2020**
Baseline excluding NES for solid fuel burners	10	10	9	9
Baseline plus NES design criteria for burners	10	9	8	8
Plus prohibit outdoor burning from 2006	10	8	8	7
Plus ban open fires	10	8	8	7
Plus NES for wood burners applies to multi fuel burners	10	8	7	6
Hospital admissions (annual)	**2005**	**2010**	**2015**	**2020**
Baseline excluding NES for solid fuel burners	5	5	5	4
Baseline plus NES design criteria for burners	5	4	4	4
Plus prohibit outdoor burning from 2006	5	4	4	3
Plus ban open fires	5	4	4	3
Plus NES for wood burners applies to multi fuel burners	5	4	3	3
Restricted Activity Days (annual)	**2005**	**2010**	**2015**	**2020**
Baseline excluding NES for solid fuel burners	22816	21524	21273	21095
Baseline plus NES design criteria for burners	22476	19571	18468	17433
Plus prohibit outdoor burning from 2006	22503	18333	17032	15819
Plus ban open fires	22503	18128	16827	15615
Plus NES for wood burners applies to multi fuel burners	22423	17426	15962	14604

Because of the reliance on the time-series studies for dose-response relationships for hospital admissions, it is likely that these estimates under predict the size of the effect.

4 Health benefits of improving air quality in Hamilton

4.1 Health impacts of existing air quality

Health impacts of existing air quality in Hamilton were estimated for PM_{10} concentrations measured during 2004.

An annual average PM_{10} concentration of 17 $\mu g\ m^{-3}$ was used to estimate premature mortality associated with PM_{10} concentrations in Hamilton for 2004. This was slightly higher than the annual average PM_{10} concentration of 15 $\mu g\ m^{-3}$ measured each year in Hamilton from 2000 to 2003. Baseline mortality statistics for Hamilton were based on 1999 data, as these were the most recent data available[7]. The latter indicated a mortality rate for Hamilton of 737 deaths per year.

Estimates of mortality for Hamilton for 2004, based on the Kunzli 4.3% dose-response relationship, were:

- 52 deaths per year (based on Kunzli assuming zero threshold)
- 30 deaths per year (based on Kunzli assuming a 7.5 $\mu g\ m^{-3}$ threshold)

In comparison, the time-series approach, assuming no threshold, would result in an estimated 14 deaths per year for Hamilton.

Hospital admissions estimates were made based on an assumed baseline hospital admissions rate of 0.8 per day for respiratory hospital admissions and 2.2 per day for cardiac admissions. These are relatively crude estimates based on the relationship between hospital admissions and mortality in Christchurch and Nelson.

Health estimates are based on the assumption that measured PM_{10} concentrations in these areas are indicative of average exposure across the urban areas.

4.2 Management options for Hamilton

Concentrations of PM_{10} in Hamilton exceed the 50 $\mu g\ m^{-3}$ (24-hour average) from 0-4 times per year. Although breaches are not observed during some years, reductions in PM_{10} concentrations would be required to meet the NES for those years when meteorological conditions are more conducive to elevated PM_{10} concentrations. The impact of a range of management options in reducing PM_{10} concentrations in Hamilton has been evaluated to determine the extent of regulations required to achieve the NES (Wilton, 2005). Figure 4.1 shows the estimated impact on PM_{10} emissions relative to 2004 for the baseline scenario, the NES for wood burners, a ban on open fires and a ban on outdoor burning in Hamilton. These estimates are based on the following assumptions:

- Heating methods, emission factors and average fuel weights as per the Hamilton domestic heating survey carried out for the Ministry for the Environment's "warm homes" project.
- The phase out of solid fuel burners 15 years after installation.
- All phased out wood or multi fuel burners are replaced with either new wood burners (84%) or new or second hand multi fuel burners (16%)8.
- A decrease in open fires of 10% by 20219.

[7] Data for more recent years may be available from New Zealand Health Information and Statistic Department.

[8] Except for management options which require all burners, including multi fuel burners to meet the NES criteria for wood burners

- For an open fire ban, 50% of households replace the open fire with a wood burner or multi fuel burner5.

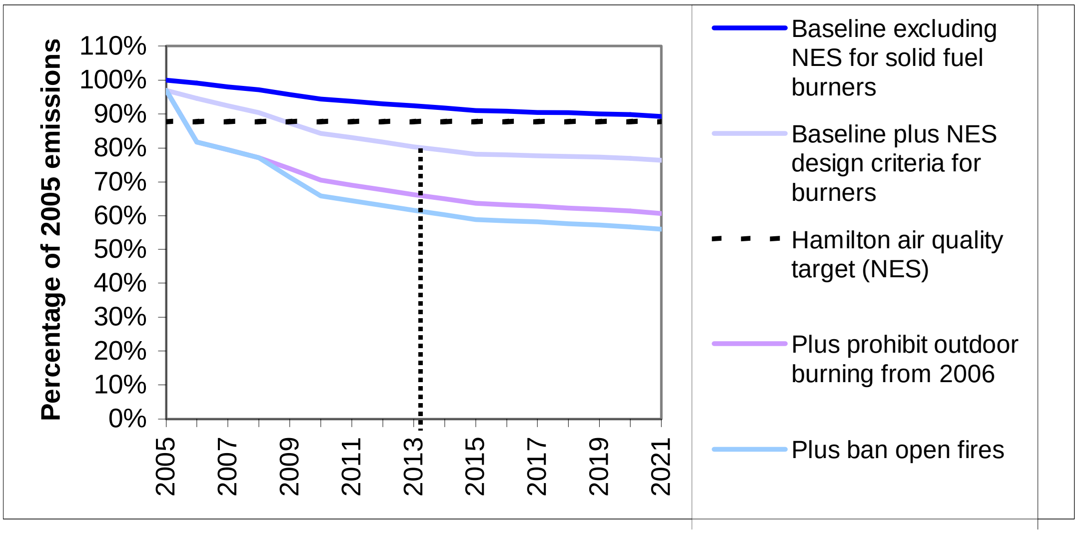

Figure 4-1: Estimates of the impacts of management options for Hamilton

4.3 Health impacts of management measures

The impact of management options in reducing PM_{10} in Hamilton are based on an evaluation of estimated changes in the 24-hour average wintertime PM_{10} concentrations. In comparison, the mortality impacts assessment methodology is based on annual average concentrations. The impact of management measures to reduce 24-hour average PM_{10} concentrations on annual average concentrations has been estimated based on the following assumptions:

- Inventory winter estimates of the relative contributions of different sources apply for the months April to September.
- Domestic heating emissions during the remaining months (referred to here as summer) are as estimated by the 2005 air emissions inventory for Hamilton.
- Inventory estimates from the 2005 Hamilton emission inventory for summer months for industry, outdoor burning and motor vehicles.
- In the absence of controls on outdoor burning, emissions from this source change over time at the same rate as the population increases.

Emissions from motor vehicles decrease with time as a result of improvements in vehicle technology as indicated by the NZTER emissions database. The magnitude of this reduction for Hamilton is estimated to be 55% by 2021 (Wilton, 2005).
Other sources such as wind blown dusts contribute around 15% of the 2004 summer emissions. Emissions from this source remain constant with time.

Figure 4.2 shows the estimated health benefits in reduced premature mortality per year for the different management options for Hamilton. Achievement of the NES for PM_{10} in Hamilton would reduce 2004 mortality estimates from 52 deaths per year (assuming no threshold) to 51 deaths per year. The reason the impact is so minimal is that the predicted increase in population offsets to some extent health benefits associated with reductions in concentrations of PM_{10}. Figure 4.3 shows the predicted impact on mortality if there were no population increase for Hamilton. Under this scenario, achievement of the NES would result in a reduction in premature mortality of around 10 deaths per year.

[9] Except for management options banning the use of open fires

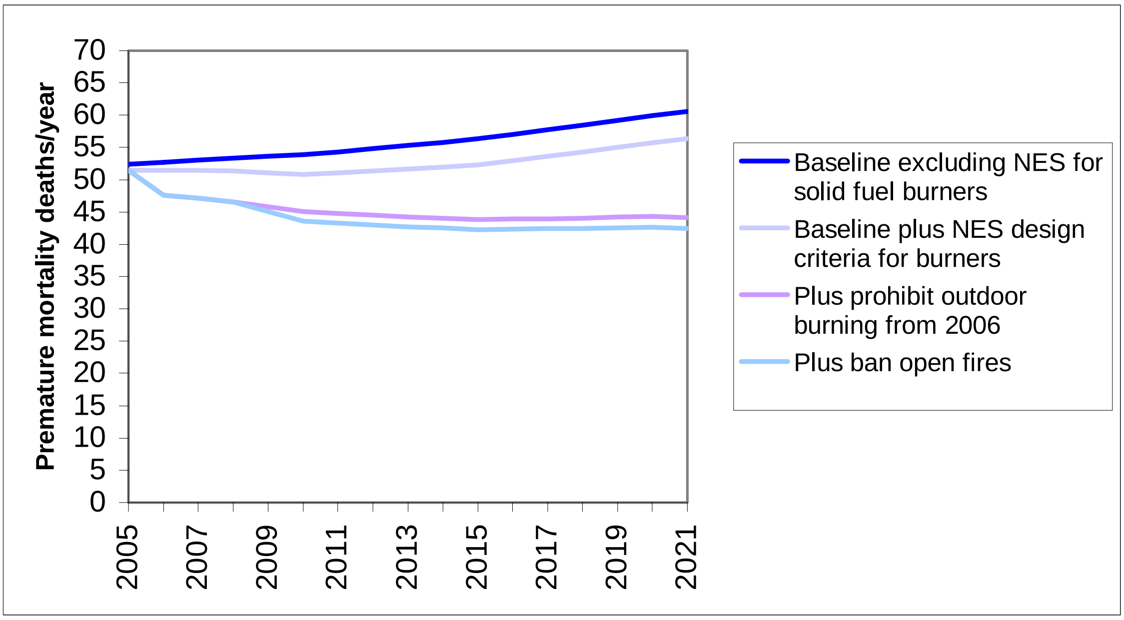

Figure 4-2: Estimates of the impact of management options on mortality in Hamilton

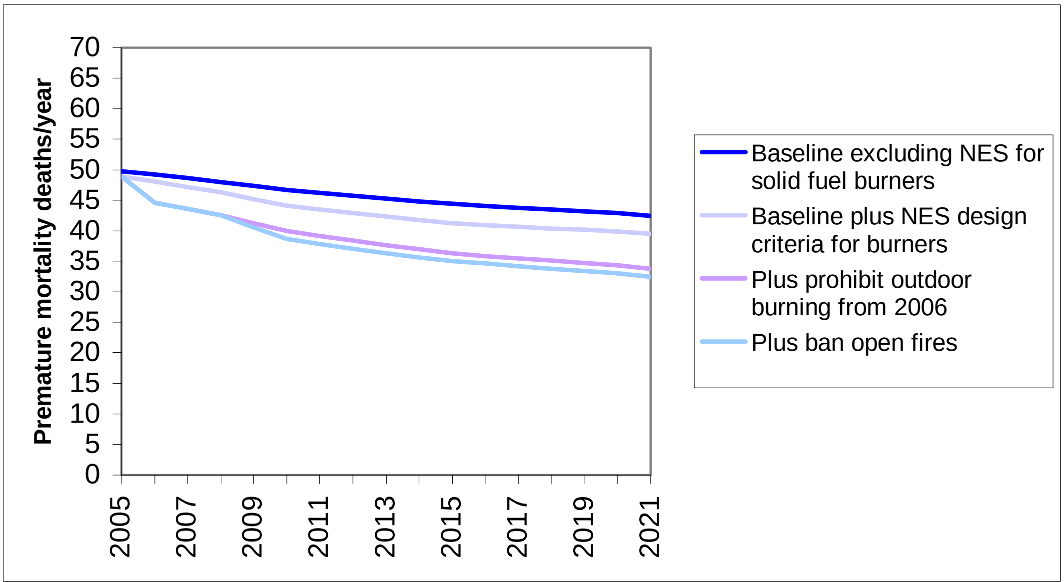

Figure 4-3: Estimates of the impact of management options on mortality in Hamilton if there were no increase in population

Table 4-1: Health benefits of management options to reduce PM10 concentrations in Hamilton

Mortality (deaths per year)	2005	2010	2015	2020
Baseline excluding NES for solid fuel burners	52	54	56	61
Baseline plus NES design criteria for burners	52	51	52	56
Plus prohibit outdoor burning from 2006	52	45	44	44
Plus ban open fires	52	44	42	42
Hospital admissions (annual)	**2005**	**2010**	**2015**	**2020**
Baseline excluding NES for solid fuel burners	24	25	26	28
Baseline plus NES design criteria for burners	24	23	24	26
Plus prohibit outdoor burning from 2006	24	20	20	20
Plus ban open fires	24	20	19	19
Restricted Activity Days (annual)	**2005**	**2010**	**2015**	**2020**
Baseline excluding NES for solid fuel burners	110743	113626	118776	127842
Baseline plus NES design criteria for burners	108749	106816	109740	118273
Plus prohibit outdoor burning from 2006	108749	93946	90991	91321
Plus ban open fires	108749	90704	87610	87721

Because of the reliance on the time-series studies for dose-response relationships for hospital admissions, it is likely that these estimates under predict the size of the effect.

5 Health benefits of improving air quality in Te Kuiti

5.1 Health impacts of existing air quality

Health impacts of existing air quality in Te Kuiti were estimated for PM_{10} concentrations measured during 2004.

An annual average PM_{10} concentration of 18 $\mu g\ m^{-3}$ was used to estimate premature mortality associated with PM_{10} concentrations in Te Kuiti for 2004. Baseline mortality statistics for Te Kuiti were based on 1999 data, as these were the most recent data that were available. The latter indicated a mortality rate for Te Kuiti of 47 deaths per year. This was adjusted for an estimated population decrease of 10% to give a baseline mortality rate for 2004.

Estimates of mortality for Te Kuiti based on the Kunzli 4.3% dose-response relationship were:

- 3 deaths per year (based on Kunzli assuming zero threshold)
- 2 deaths per year (based on Kunzli assuming a 7.5 $\mu g\ m^{-3}$ threshold)

In comparison, the time-series approach, assuming no threshold, would result in an estimated 1 death per year for Te Kuiti.

Hospital admissions estimates were made based on an assumed baseline hospital admissions rate of 0.05 per day for respiratory hospital admissions and 1.4 per day for cardiac admissions. These are relatively crude estimates based on the relationship between hospital admissions and mortality in Christchurch and Nelson adjusted for the baseline mortality rate for Te Kuiti.

Health estimates are based on the assumption that measured PM_{10} concentrations in these areas are indicative of average exposure across the urban areas.

5.2 Management options for Te Kuiti

The impact of a range of management options on PM_{10} concentrations in Te Kuiti has been evaluated (Wilton, 2005). Figure 5.1 shows the estimated impact on PM_{10} emissions relative to 2004 for the baseline scenario, the NES for wood burners, an emission standard for multi fuel burners, a ban on open fires and a ban on outdoor burning in Te Kuiti. These estimates are based on the following assumptions:

Heating methods, emission factors and average fuel weights as per the Te Kuiti 2004 household survey carried out for the Ministry for the Environment's "warm homes" project.

- The phase out of solid fuel burners 15 years after installation.
- All phased out wood or multi fuel burners are replaced with either new wood burners (90%) or new or second hand multi fuel burners (10%)[10].
- A decrease in open fires of 10% by 2021[11].
- For an open fire ban, 50% of households replace the open fire with a wood burner or multi fuel burner[7].

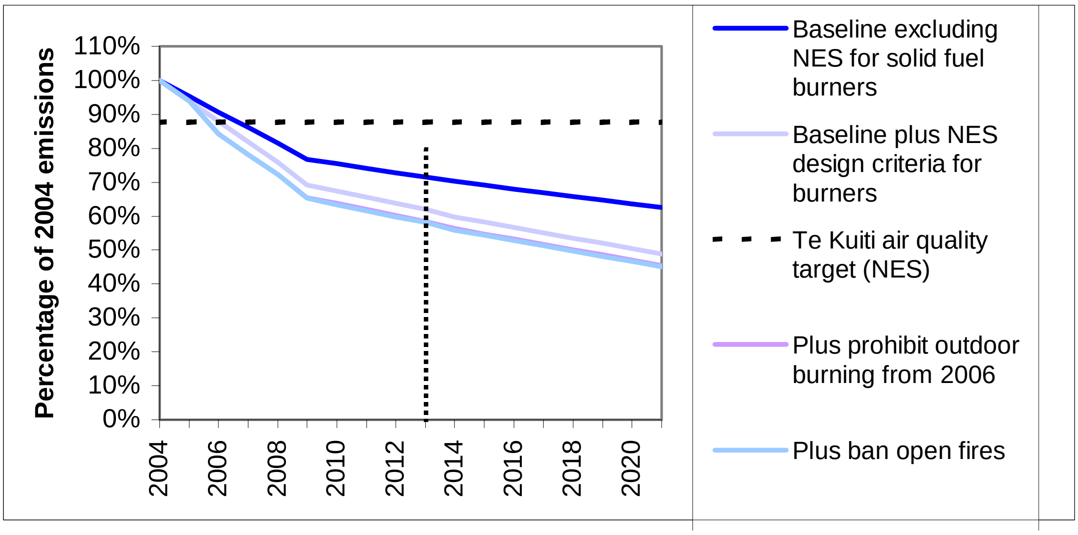

Figure 5-1: Estimates of the impacts of management options for Te Kuiti

5.3 Health impacts of management measures

The impact of management options in reducing PM_{10} in Te Kuiti are based on an evaluation of estimated changes in the 24-hour average wintertime PM_{10} concentrations. In comparison, the mortality impacts assessment methodology is based on annual average concentrations. The impact of management measures to reduce 24-hour average PM_{10} concentrations on annual average concentrations has been estimated based on the following assumptions:

- Inventory estimates of the relative contributions of different sources apply for the months April to September
- Domestic heating emissions during the remaining months (referred to here as summer) are around 5% of the winter values[12]

[10] Except for management options which require all burners, including multi fuel burners to meet the NES criteria for wood burners
[11] Except for management options banning the use of open fires

- Inventory estimates for industry, outdoor burning and motor vehicles apply during the summer months
- Other sources such as wind blown dusts contribute around 15% of the summer emissions

Figure 5.2 shows the estimated health benefits in reduced premature mortality per year for the different management options for Te Kuiti.

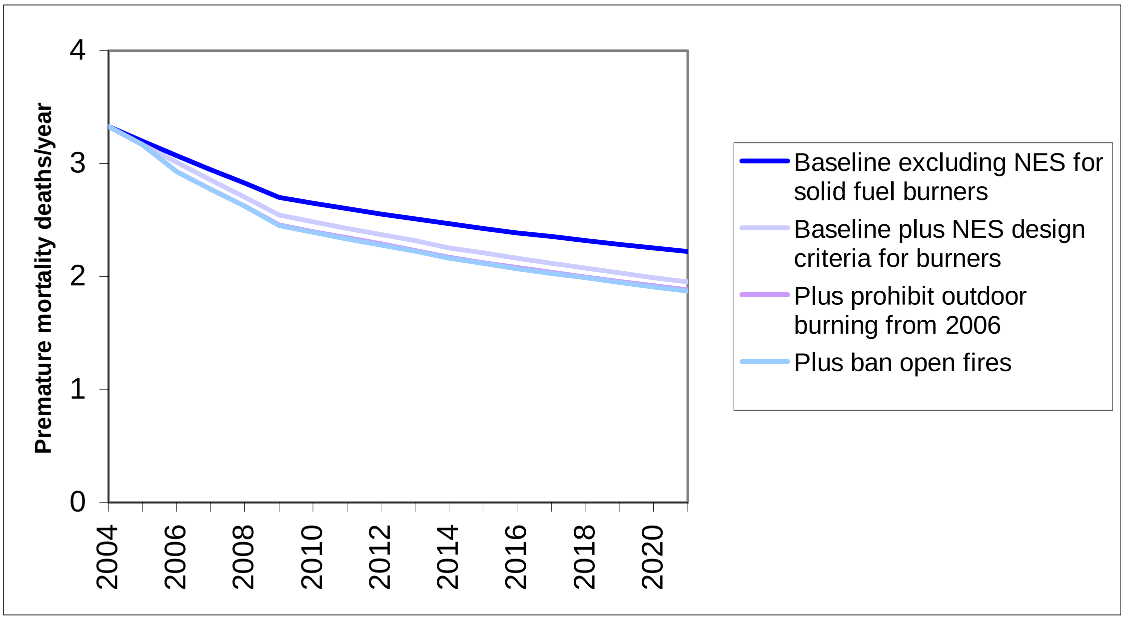

Figure 5-2: Estimates of the impact of management options on mortality in Te Kuiti

Table 5-1: Health benefits of management options to reduce PM10 concentrations in Te Kuiti

Mortality (deaths per year)	**2005**	**2010**	**2015**	**2020**
Baseline excluding NES for solid fuel burners	3	3	2	2
Baseline plus NES design criteria for burners	3	2	2	2
Plus prohibit outdoor burning from 2006	3	2	2	2
Plus ban open fires	3	2	2	2
Hospital admissions (annual)	**2005**	**2010**	**2015**	**2020**
Baseline excluding NES for solid fuel burners	1	1	1	1
Baseline plus NES design criteria for burners	1	1	1	1
Plus prohibit outdoor burning from 2006	1	1	1	1
Plus ban open fires	1	1	1	1
Restricted Activity Days (annual)	**2005**	**2010**	**2015**	**2020**
Baseline excluding NES for solid fuel burners	4070	3337	3043	2773
Baseline plus NES design criteria for burners	4028	3114	2753	2423
Plus prohibit outdoor burning from 2006	4028	3003	2646	2330
Plus ban open fires	4028	2991	2635	2320

[12] This is an estimate based loosely on domestic heating surveys for other areas which indicates a small proportion of households using solid fuel burning for domestic heating during the summer months

6 Health benefits of improving air quality in Taupo

6.1 Health impacts of existing air quality

Health impacts of existing air quality in Taupo were estimated for PM_{10} concentrations measured during 2004.

An annual average PM_{10} concentration of 17 $\mu g\ m^{-3}$ was used to estimate premature mortality associated with PM_{10} concentrations in Taupo during 2004. Baseline mortality statistics for Taupo were based on 1999 data, as these were the most recent data that were available. The latter indicated a mortality rate for Taupo of 132 deaths per year. This was adjusted for changes in the population based on a projected increase of 11% from 2001 to 2021 (as detailed in Wilton, 2004).

Estimates of mortality for Taupo based on the Kunzli 4.3% dose-response relationship were:

- 9 deaths per year (based on Kunzli assuming zero threshold)
- 5 deaths per year (based on Kunzli assuming a 7.5 $\mu g\ m^{-3}$ threshold)

In comparison, the time-series approach, assuming no threshold, would result in an estimated 2 deaths per year for Taupo.

Hospital admissions estimates were made based on an assumed baseline hospital admissions rate of 0.1 per day for respiratory hospital admissions and 0.4 per day for cardiac admissions. These are relatively crude estimates based on the relationship between hospital admissions and mortality in Christchurch and Nelson, adjusted for the baseline mortality rate for Taupo.

Health estimates are based on the assumption that measured PM_{10} concentrations in these areas are indicative of average exposure across the urban areas.

6.2 Management options for Taupo

The impact of a range of management options on PM_{10} concentrations in Taupo has been evaluated (Wilton, 2004). Figure 6.1 shows the estimated impact on PM_{10} emissions relative to 2004 for the baseline scenario, the NES for wood burners, an emission standard for multi fuel burners, a ban on open fires and a ban on outdoor burning in Taupo. These estimates are based on the following assumptions:

- Emission factors and average fuel weights as per the Taupo 2004 emission inventory
- The phase out of all solid fuel burners 15 years after installation
- All phased out wood or multi fuel burners are replaced with either new wood burners (85%) or new or second hand multi fuel burners (15%)[13]
- A decrease in open fires of 10% by 2021[14]
- For an open fire ban, 43% of households replace the open fire with a wood burner or multi fuel burner[15]
- Emission factors and average fuel use rates as per the Taupo 2004 emission inventory (Wilton, 2004)

[13] Except for management options which requires all burners, including multi fuel burners to meet the NES criteria for wood burners
[14] Except for management options banning the use of open fires
[15] Survey data for Taupo indicates that 57% of households with open fires also currently use either gas or wood burners in their main living area

- Heating methods for 2004 as per the Taupo 2004 emission inventory (Wilton, 2004)

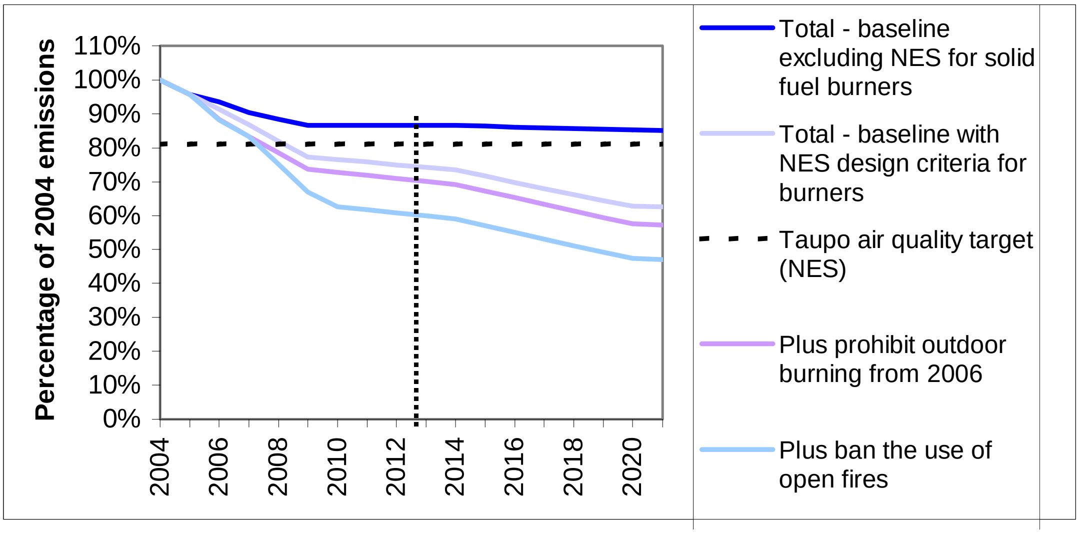

Figure 6-1: Estimates of the impacts of management options for Taupo

6.3 Health impacts of management measures

The impact of management options in reducing PM_{10} in Taupo are based on an evaluation of estimated changes in the 24-hour average wintertime PM_{10} concentrations. In comparison, the mortality impacts assessment methodology is based on annual average concentrations. The impact of management measures to reduce 24-hour average PM_{10} concentrations on annual average concentrations has been estimated based on the following assumptions:

- Inventory estimates of the relative contributions of different sources apply for the months April to September.
- Domestic heating emissions during the remaining months (referred to here as summer) are around 5% of the winter values[16].
- Inventory estimates for industry, outdoor burning and motor vehicles apply during the summer months.
- In the absence of controls on outdoor burning, emissions from this source increase in proportion with population projections (11% by 2021).

Emissions from motor vehicles decrease according to assumptions detailed in Wilton (2004). The magnitude of this reduction for Taupo is assumed to be 66% by 2021.
Other sources such as wind blown dusts contribute around 15% of the 2004 summer emissions. Emissions from this source remain constant with time.
Figure 6.2 shows the estimated health benefits in reduced premature mortality per year for the different management options for Taupo. The escalation of premature mortality associated with the baseline projection occurs because increases in projected population (and consequent increases of number of people affected) outweigh estimated reductions in PM_{10} concentrations.

Achievement of the NES for PM_{10} in Taupo would reduce 2004 mortality estimates from 9 deaths per year (assuming no threshold) to 7 deaths per year.

[16] This is an estimate based loosely on domestic heating surveys for other areas which indicates a small proportion of households using solid fuel burning for domestic heating during the summer months

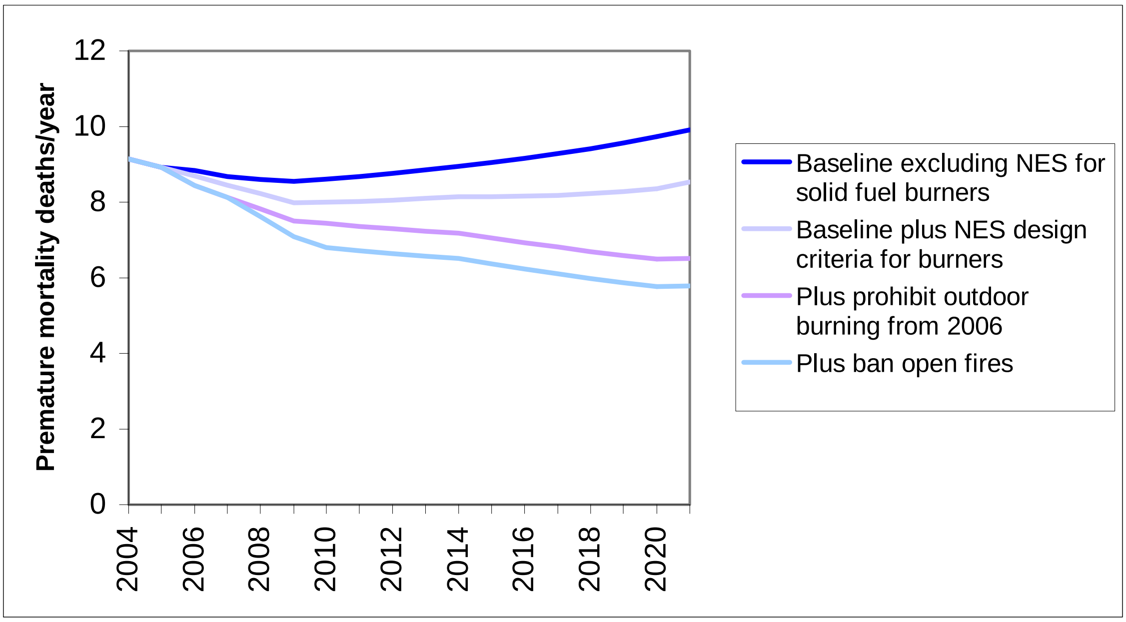

Figure 6-2: Estimates of the impact of management options on mortality in Taupo

Table 6-1: Health benefits of management options to reduce PM10 concentrations in Taupo

Mortality (deaths per year)	**2005**	**2010**	**2015**	**2020**
Baseline excluding NES for solid fuel burners	9	9	9	10
Baseline plus NES design criteria for burners	9	8	8	9
Plus prohibit outdoor burning from 2006	9	7	7	7
Plus ban open fires	9	7	6	6
Hospital admissions (annual)	**2005**	**2010**	**2015**	**2020**
Baseline excluding NES for solid fuel burners	4	4	4	5
Baseline plus NES design criteria for burners	4	4	4	4
Plus prohibit outdoor burning from 2006	4	3	3	3
Plus ban open fires	4	3	3	3
Restricted Activity Days (annual)	**2005**	**2010**	**2015**	**2020**
Baseline excluding NES for solid fuel burners	16375	15741	16577	18223
Baseline plus NES design criteria for burners	16380	14567	14829	15554
Plus prohibit outdoor burning from 2006	16383	13471	12720	11676
Plus ban open fires	16380	12247	11433	10331

Because of the reliance on the time-series studies for dose-response relationships for hospital admissions, it is likely that these estimates under predict the size of the effect.

7 Summary

Estimates of mortality, hospital admissions and restricted activity days (RAD) that may occur as a result of exposure to PM_{10} concentrations in Hamilton, Tokoroa, Taupo and Te Kuiti were made for the following scenarios:

1. existing PM10 concentrations
2. achievement of the NES for PM_{10}
3. baseline scenario excluding the NES design standard for wood fuel burners
4. baseline scenario including the NES design standard for wood burners (assumed to be the status quo)
5. status quo plus a ban on outdoor burning
6. status quo plus a ban on outdoor burning and a ban on the use of open fires

Table 7.1 shows the estimated mortality, hospital admissions and RAD for each scenario.

Table 7-1:Estimated health impacts for Hamilton, Tokoroa, Taupo and Te Kuiti

Scenario	**1**	**2**	**3**	**4**	**5**	**6**
Mortality	**2004**	**2013**	**2020**	**2020**	**2020**	**2020**
Hamilton	52	51	61	56	44	42
Tokoroa	10	7	9	8	7	7
Taupo	9	7	10	9	7	6
Te Kuiti	3	3	2	2	2	2
Hospital Admissions						
Hamilton	24	23	28	26	20	19
Tokoroa	5	3	4	4	3	3
Taupo	4	3	5	4	3	3
Te Kuiti	1		1	1	1	1
RAD						
Hamilton	111000	107000	128000	118000	91000	88000
Tokoroa	23000	16000	21000	17000	16000	16000
Taupo	16000	14000	18000	16000	12000	10000
Te Kuiti	4000	3000	3000	2400	2300	2300

Air quality monitoring shows that the people of Tokoroa are likely to be exposed to the worst PM_{10} concentrations in the Waikato Region. However, the greatest health impact of PM_{10} concentrations is estimated to occur in Hamilton, as this is the area where the greatest numbers of people are exposed. The actual health impact is greater than illustrated in Table 7.1 because of the effect of the predicted population increase. The implementation of management options to improve air quality will therefore have the greatest health benefits in Hamilton, although the costs of achieving reductions in concentrations are also likely to be greater.

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Appendix A: Projections and uncertainty

As outlined in the body of the report, the estimates of projections in PM_{10} emissions for different management options are based on a number of assumptions. The uncertainty surrounding each of these assumptions can combined statistically to give an overall uncertainty indication for the projections.

Figure A1 shows the estimated PM_{10} projections based on a combination of management options for Tokoroa with additional estimates of the uncertainty surrounding the projections. The uncertainty estimates are a statistical extrapolation based on the formulae described in Topping (1971) or a 95% confidence interval. Uncertainty estimates are based on the following assumptions:

- 100% uncertainty associated with emission factors for solid fuel burning.
- 50% uncertainty associated with fuel use factors for solid fuel burning.
- Varying uncertainty associated with estimated household numbers starting at 20% for 2002 and increasing to 56% for 2021.
- 6% variability associated with the assumptions relating to the impact of meteorology.
- Varying uncertainty associated with estimates of emissions from motor vehicles and industry starting at 20% in 2002 and increasing to 40% by 2021.

Depending on the management options selected, the uncertainties of the projections can change significantly with time. For example, if a management option prohibits the installation of burners in new dwellings and existing dwellings currently using other heating methods then the uncertainty associated with projected heating methods will decrease.

Figure A2 shows the uncertainty estimates for Taupo for the management options described as the assumptions relating to the uncertainty listed above. Uncertainty analyses for Hamilton and Te Kuiti are contained within the management options report for those areas (Wilton, 2005).

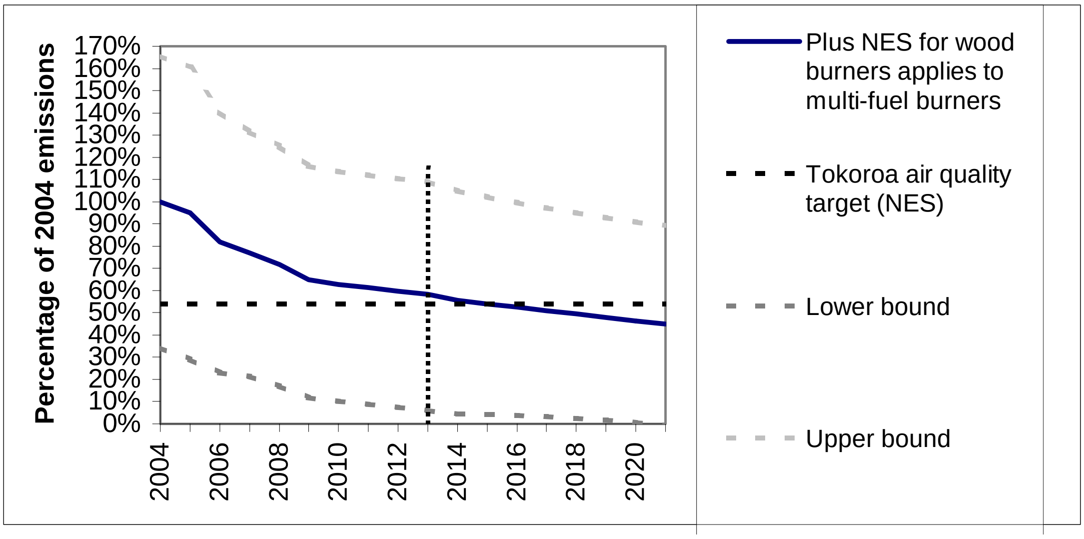

Figure A1: Uncertainty estimates for ban on open fires, outdoor burning, and application of the NES design standard for wood burners to multi-fuel burners in Tokoroa (based on the assumptions described in section 3.2)

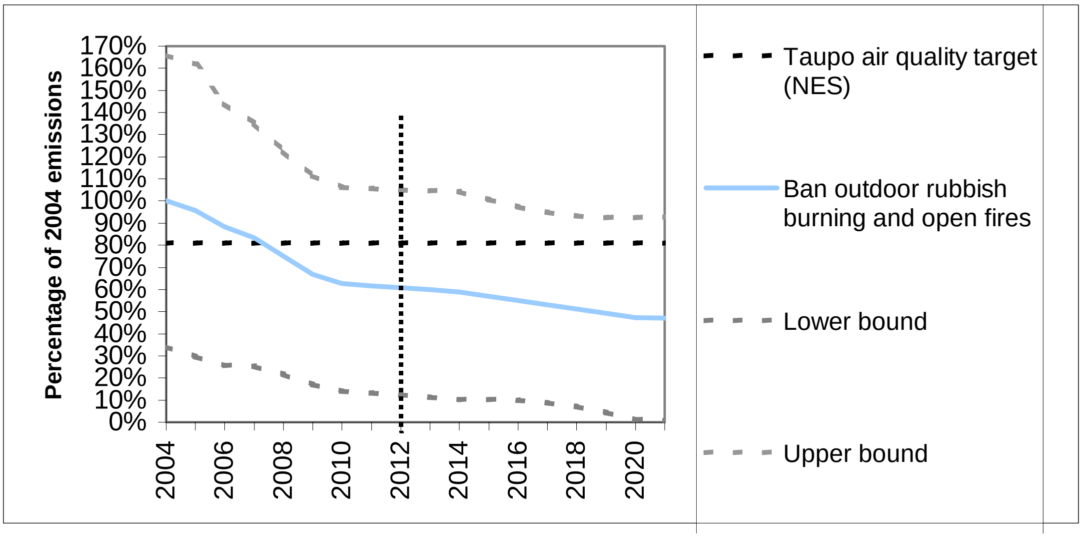

Figure A2: Uncertainty estimates for management options that prohibit the use of open fires and outdoor burning in Taupo (based on assumptions described in section 6.2)