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Tokoroa Emission Inventory 2004

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Executive Summary

Air quality monitoring for concentrations of PM_{10} (particles in the air less than 10 microns in diameter) has been carried out in Tokoroa since 1999. Results indicate concentrations exceed the Environment Waikato air quality target and ambient air quality guidelines for PM_{10} of 50 µg m^{-3} each year. In addition, the concentrations are in breach of the National Environment Standard (NES) for PM_{10} of 50 µg m^{-3}. The latter allows for one breach of 50 µg m^{-3} per year. The maximum measured 24-hour average PM_{10} concentration in Tokoroa of 75 µg m^{-3} was recorded during 2001.

This study provides an estimate of sources of emissions of PM_{10} as well as carbon monoxide, sulphur oxides, nitrogen oxides, volatile organic compounds and carbon dioxide. The main focus of the study is on emissions of PM_{10} as existing concentrations are in breach of the NES. Ambient air concentrations of carbon monoxide, sulphur dioxide and nitrogen dioxide are unlikely to breach air quality guidelines or NES in Tokoroa. Sources of PM_{10} included in the inventory are domestic heating, motor vehicles, industrial and commercial activities and outdoor burning.

A survey of domestic home heating was carried out to determine heating methods and fuel use in Tokoroa. Woodburners were found to be the dominant home heating method in Tokoroa, being used to heat the main living area in around 53% of homes. Gas use was also common with around 40% of households using that method. Around 25% of households used electricity heating. Many households used more than one method to heat the main living area of their home.

The main source of PM_{10} and $PM_{2.5}$ emissions in Tokoroa was domestic home heating, which accounted for around 85% and 88% of total emissions respectively. For PM_{10}, the remaining 15% was distributed between motor vehicles (6%), outdoor burning (8%) and industrial emissions (1%). Domestic heating also accounted for 66% of the CO and 79% of the VOCs. Motor vehicles were the main source of NOx and SOx.

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1 Introduction

The main air contaminant of concern in Tokoroa is PM_{10} (particles in the air less than 10 microns in diameter). Air quality monitoring for PM_{10} has been carried out in the town each year since 2001. Concentrations of PM_{10} in Tokoroa have been in breach of the 24-hour ambient air quality guideline and NES of 50 µg m^{-3} for between 15 and 41 days. The NES for PM_{10} allows for one breach of 50 µg m^{-3} per year.

Because of the frequency of guideline exceedences in Tokoroa, an assessment of management measures to achieve the proposed NES is required. This involves an evaluation of sources contributing to existing concentrations as well as likely trends and an assessment of management measures to reduce concentrations. This report assesses sources of emissions in Tokoroa.

Prior to the 2004 emission inventory, studies of sources of PM_{10} emissions in Tokoroa relied on the results of an industrial emissions survey carried out by Noonan in 1997. The latter assessment included estimates of emissions from sources with considerable uncertainty. In particular the estimates of PM_{10} emissions from process emissions at a local sawmill were of concern and are likely to have resulted in an overestimate of the PM_{10} contribution. Closure of the sawmill in 2003 will remove the uncertainty associated with the contribution from that source for the 2004 emission inventory assessment. If this source were a major contributor to PM_{10} concentrations, air quality monitoring data from 2004 should reflect this with a reduction in measured concentrations.

The industrial contribution to PM_{10} concentrations in Tokoroa is further complicated by the presence of the Kinleith Pulp and Paper Mill and the Kinleith Industrial Park, located approximately 5 kilometres to the south-east of Tokoroa. Emissions from these sources are outside of the inventory study area but may contribute to concentrations measured in Tokoroa. An evaluation of the likelihood of emissions from Kinleith contributing to PM_{10} concentrations in Tokoroa on days when the pollution is elevated is included.

2 Inventory design

The inventory has been designed with a focus on emissions of PM_{10}, although it does include estimates of emissions of other contaminants. Actual monitoring of other contaminants has not been carried out in Tokoroa, and it is unlikely, based on monitoring carried out in other areas of New Zealand, that concentrations of other indicator contaminants will exceed the proposed NES values or air quality guidelines. One exception may be the air quality guideline for benzo(a)pyrene (BaP) as concentrations of this contaminant have been found to be high in areas where PM_{10} concentrations are elevated as a result of emissions from domestic home heating. No NES has been proposed for BaP at this stage.

2.1 Selection of sources

The inventory includes detailed estimates of emissions from domestic heating, outdoor burning, motor vehicles and industry. Emissions from lawn mowers, dusts from farming activities and a number of other sources are also discussed in the report.

2.2 Selection of contaminants

The inventory included an assessment of emissions of suspended particles (PM_{10}), carbon monoxide (CO), sulphur oxides (SOx), nitrogen oxides (NOx), volatile organic compounds (VOC), carbon dioxide (CO_2) and fine particles ($PM_{2.5}$).

Emissions of PM_{10}, CO, SOx and NOx are included as these contaminants comprise class one air quality indicators as described by MfE (1994) because of their potential for adverse health impacts. Carbon dioxide is typically included in emission inventory investigations in New Zealand to allow for the assessment of regional greenhouse gas CO_2 emissions. The finer $PM_{2.5}$ size fraction was also included, as a guideline for $PM_{2.5}$ may be considered by MfE within the next few years.

Volatile organic compounds are typically included in emission inventory investigations because of their potential contribution to the formation of photochemical pollution. These have been retained in the inventory to allow an assessment of emissions of precursors to ozone should future monitoring indicate concentrations of concern.

2.3 Selection of areas

The study area was the urban area of Tokoroa based on the census area unit boundaries for the areas of Paraonui, Parkdale, Matarawa, Stanley Park, Tokoroa Central, Aotea, and Strathmore (Figure 2.1). This covers the area of greatest impact and allows subsequent assessments of data relative to census information.

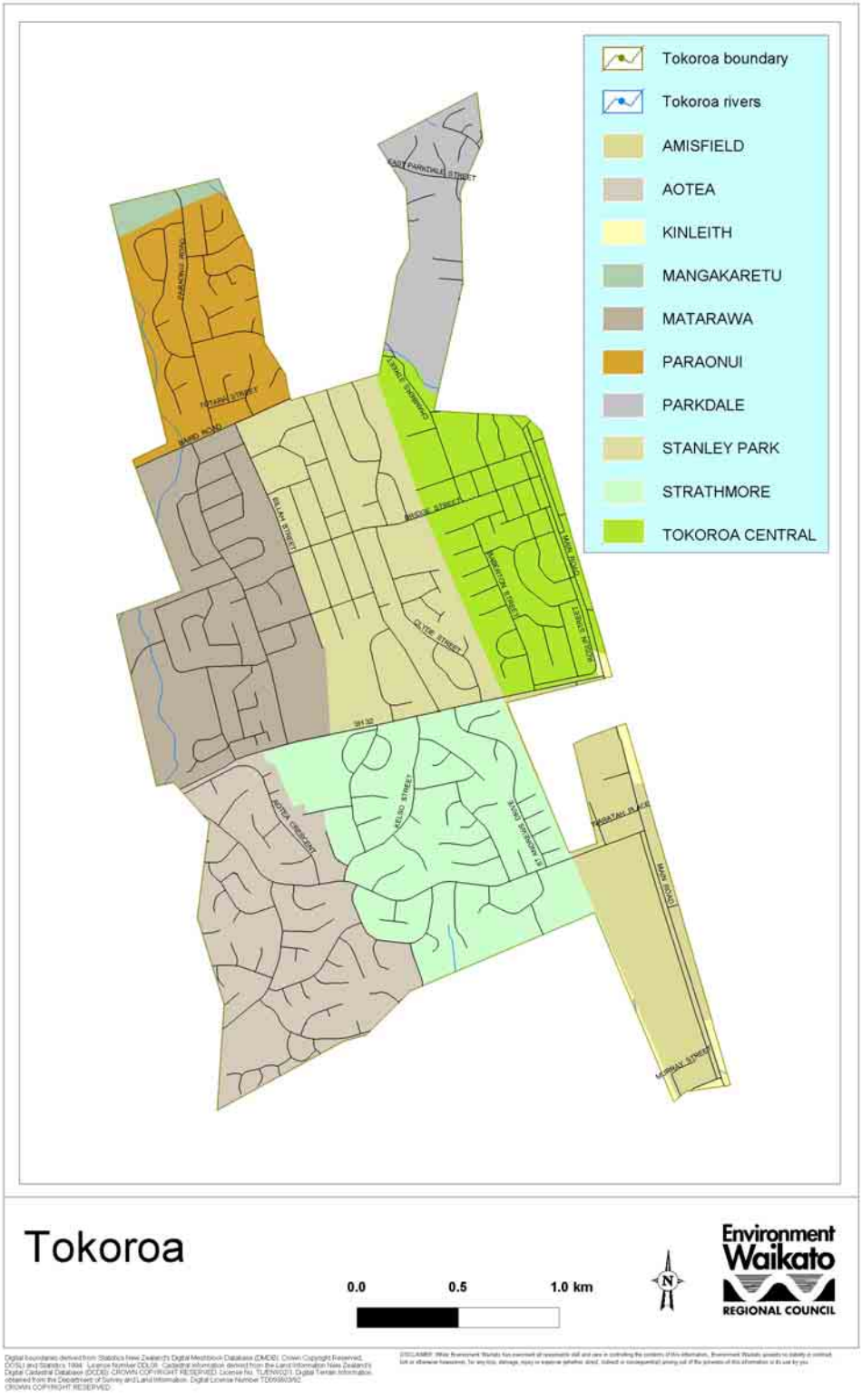

Figure 2-1: Tokoroa study area

2.4 Temporal distribution

Daily data were collected based on average wintertime emissions and were broken down into the following time of day categories:

- 6am to 10am
- 10am to 4pm
- 4pm to 10pm
- 10pm to 6am

These categories have been used in other emission inventory investigations carried out in New Zealand e.g., Christchurch, Nelson, Hamilton, Dunedin, Timaru and Wellington. They were initially selected to coincide with variations in meteorological conditions that occur at different times of the day for high pollution events, and were based on observations of both pollution and meteorological conditions in Christchurch.

The purpose of collecting data for different time of day periods is to allow for subsequent assessments of the contribution of different sources to concentrations, as opposed to emissions. The latter evaluation requires details on the impact of meteorological conditions on contaminants' concentrations at different times of the day.

3 Domestic heating

3.1 Methodology

The domestic heating emission inventory data was collected using a telephone survey of 360 households within the study area during the winter of 2004. The survey was carried out by Digipol during late May and early June 2004 using the emission inventory survey questionnaire shown in Appendix one. Emission factors were then applied to these data to provide an estimate of emissions for the urban areas of Taupo. Summary data for the survey and study area are shown in Table 3.1.

Table 3-1: Home heating survey area and sample details

	Households	Sample size	Area (ha)	Sample error
Tokoroa	4451	368	1185	5%

Home heating methods were classified as electricity, open fires, pre 1994 woodburners, 1994-1999 woodburners, post 1999 woodburners, multi-fuel burners, gas burners and oil burners.

The emission factors used to estimate emissions from domestic heating are shown in Table 3.2. These were reviewed for the Tokoroa 2004 inventory to check that previously used factors were consistent with any more recent testing. As for the 2000 Tokoroa domestic heating assessment, the open fire and multi-fuel burner factors were based on the Christchurch 1999 emission factors. The basis for these is detailed in Wilton (2001a). The woodburner emission rates were derived based on the different age categories in the emission inventory survey. These are consistent with emission factors derived for similar age category appliances for Nelson and Timaru but dissimilar to Christchurch for the more modern burners. This is because regulations in Christchurch restrict the installation of solid fuel burners to burners meeting an emission criterion of 1.5 grams of particulate per kilogram of fuel burnt. The gas and oil PM_{10} emission factors have also been revised as a result of more recent testing in New Zealand.

Table 3-2: Emission factors for domestic heating methods

	PM_{10} g/kg	CO g/kg	NOx g/kg	SO_2 g/kg	VOC g/kg	CO_2 g/kg	$PM_{2.5}$ g/kg
Open fire - wood	10	100	1.6	0.2	30	1600	10
Open fire - coal	21	80	4	5.0	15	2600	12
Pre 1994 burners	13	130	0.5	0.2	39	1700	10.5
1994-1999 burners	8.5	85	0.5	0.2	19.5	1800	6.5
Post 1999 burners	7.2	72	0.5	0.2	18	1800	6
Multi-fuel - wood	13	130	0.5	0.2	39	1600	13
Multi-fuel - coal	28	120	1.2	3.0	15	2600	12
Oil	0.03	0.6	2.2	3.8	0.25	3200	0.7
Gas	0.03	0.18	1.3	7.6E-09	0.2	2500	0.6

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

One of the assumptions underlying the emissions calculations is the average weight for a log of wood. Average log weights used for inventories in New Zealand have included 1.6 kg, 1.4 kg and more recently 1.9 kg. The latter value is based on a survey of 219 households in Christchurch during 2002 and represents the most comprehensive assessment of average fuel weight. There is some potential for fuel size to vary by region although factors such as appliance design should limit these variations. All three average fuel weight values were derived based on measurements carried out in Christchurch. The 1.9 kg average fuel weight value represents a 19% increase over the year 2000 Taupo emission inventory, which used the initial average fuel weight of 1.6 kg. Compared to the 2000 inventory, the 2004 estimates of emissions from domestic heating will therefore be higher by 19%, as a result of a change in methodology.

Emissions for each contaminant and for each time period and season were calculated based on the following equations:

Equation 3.1 **CE (g/day) = EF (g/kg) * FB (kg/day)**

Where:

CE = contaminant emission

EF = emission factor

FB = fuel burnt

Equation 3.2 **CE (g/time period) = EF (g/kg) * FB (kg/time period)**

Where:

CE = contaminant emissions per time period

EF = emission factor

$$FB\ (kg/time\ period) = \frac{\text{no. of hours in time period}}{24hrs} * \text{total daily fuel use}$$

The main assumptions underlying the emissions calculations are as follows:

- The average weight of a log of wood is 1.9 kg. This weight was based on a diary survey carried out in Christchurch during 2002 (Lamb, 2003).
- The average weight of a bucket of coal is 9 kg.
- That the total daily fuel use (kg) is distributed across the different times of the day based on the number of hours in each time period. For example, if a household indicates that it burns 15 kg wood per day and burns during the periods 4pm-10pm and 6am-10am, it is assumed that 9 kg is burnt in the evening period and 6 kg during the morning period.

3.2 Home heating methods

Woodburners (53%) and gas (40%) were the main methods of home heating used in Tokoroa during 2004. Around 25% of households used electricity and 12% used open fires. Just over half of the households using gas used flued gas heating (Figure 3.1). Table 3.3 shows that households rely on more than one method of heating their main living area during the winter months.

Wood burning is the most common fuel for households using solid fuel heating methods in Tokoroa with 68% of households using this fuel. About 69 tonnes of wood is burnt per winter's night. In comparison coal is used by around 3% of Tokoroa households and around one tonne is burnt per night.

Table 3-3: Home heating methods and fuels in Taupo

	Heating methods		Fuel Use	
	HH	%	t/day	%
Electricity	1111	25%		
Open fire	537	12%	5	7%
Open fire - wood	488	11%	4	6%
Open fire - coal	37	1%	1	1%
Total Woodburner	2381	53%	60	86%
Pre 1994 woodburner	73	2%	16	24%
1994-1999 woodburner	46	1%	12	17%
Post 1999 woodburner	103	2%	31	46%
Multi-fuel burner	195	4%	3	5%
Multi-fuel burner-wood	159	4%	3	4%
Multi-fuel burner-coal	98	2%	0.3	0.4%
Gas	1783	40%	1.5	2%
Oil	73	2%	0.2	0%
Total Wood	3028	68%	66.3	96%
Total Coal	134	3%	1.0	1%
Total	4469		69	

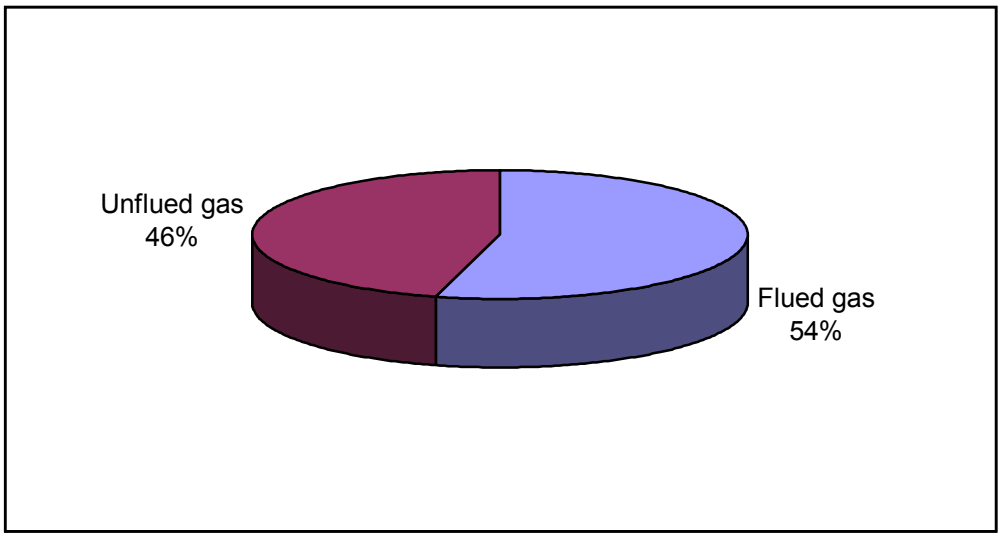

Figure 3-1: Gas use by appliance type

3.3 Emissions from domestic heating

Estimates of emissions from domestic heating in Tokoroa are shown in Tables 3.4 and 3.5 including breakdowns by time of day. These data are also presented in grams per hectare (g/ha) and as a percentage of the total contaminant emissions in Table 3.6. Results indicate the following:

- Just over half a tonne of PM_{10} is discharged from domestic home heating into the air over Tokoroa on a typical winter's night/ day.
- About 98% of the PM_{10} is in the finer $PM_{2.5}$ size fraction.
- About 96% of the PM_{10} emissions come from the burning of wood with around 4% from coal and less than 0.1% from gas and oil.
- Woodburners contribute the majority (82%) of the PM_{10} emissions. Open fires contribute 10% and multifuel burners 8% of the PM_{10} emissions from domestic home heating.
- Wood burning is responsible for the majority of emissions of all contaminants included in the inventory.
- About 46% of the PM_{10} emissions occur during the 4pm – 10pm period coinciding with the time of day when meteorological conditions are most likely to be conducive to high pollution.

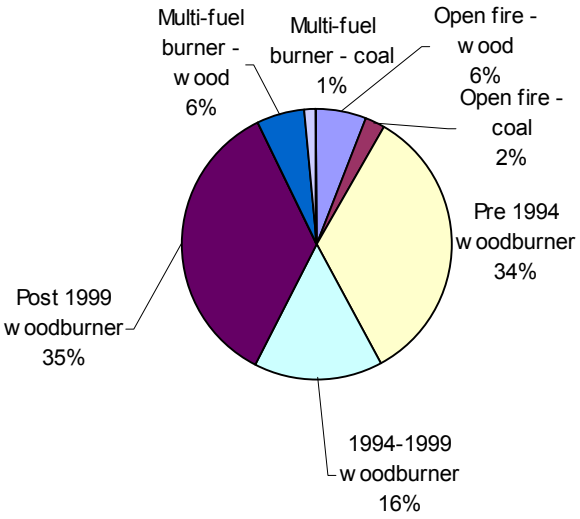

Figure 3-2: PM10 emissions from different heating methods

Table 3-4: Emissions estimates for PM10, CO, NOx and SOx by time of day

	Suspended Particulate					Carbon monoxide					Nitrogen oxides					Sulpher oxides				
	6am-10am	10am-4pm	4pm-10pm	10pm-6am	Total PM_{10} (kg)	6am-10am	10am-4pm	4pm-10pm	10pm-6am	Total CO (kg)	6am-10am	10am-4pm	4pm-10pm	10pm-6am	Total NOx (kg)	6am-10am	10am-4pm	4pm-10pm	10pm-6am	Total SOx (kg)
Open fire - wood	5	5	22	6	39	50	55	222	61	388	1	1	4	1	6	0	0	0	0	1
Open fire - coal	3	1	10	0	14	11	4	38	0	53	1	0	2	0	3	1	0	2	0	3
Pre 1994 wood burner	26	42	97	49	214	256	421	973	495	2145	1	2	4	2	8	0	1	1	1	3
1994 –1999 wood burner	16	16	43	25	99	156	159	431	246	992	1	1	3	1	6	0	0	1	1	2
Post 1999 wood burner	37	40	95	53	224	370	406	954	529	2260	3	3	7	4	16	1	1	3	1	6
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Multi-fuel burner - wood	3	10	21	4	37	26	102	208	37	373	0	0	1	0	1	0	0	0	0	1
Multi-fuel burner - coal	1	2	4	1	8	3	10	16	6	35	0	0	0	0	0	0	0	0	0	1
Total Wood	86	114	278	136	614	858	1142	2788	1368	6157	5	7	17	8	37	2	2	6	3	13
Total Coal	3.6	3.5	13.7	1.3	22.1	13.9	14.3	54.0	5.6	87.9	0.6	0.3	2.0	0.1	3.0	0.7	0.5	2.8	0.1	4.2
Oil	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.2	0.2	0.5	0.2	0.1	0.3	0.3	0.8
Gas	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.1	0.0	0.3	0.4	0.2	1.1	0.2	2.0	0.0	0.0	0.0	0.0	0.0
Total	89	117	292	138	636	872	1157	2843	1374	6246	6	7	21	9	43	3	3	9	3	18

Table 3-5: Emissions estimates for VOCs, CO2, and PM2.5 by time of day

	VOCs					Carbon dioxide					$PM_{2.5}$				
	6am-10am	10am-4pm	4pm-10pm	10pm-6am	Total VOC (kg)	6am-10am	10am-4pm	4pm-10pm	10pm-6am	Total CO_2 (t)	6am-10am	10am-4pm	4pm-10pm	10pm-6am	$PM_{2.5}$ (kg)
Open fire - wood	15	16	66	18	116	1	1	4	1	6	5	5	22	6	39
Open fire - coal	2	1	7	0	10	0	0	1	0	2	2	1	6	0	8
Pre 1994 wood burner	77	126	292	148	643	3	5	12	6	26	26	42	97	49	214
1994 –1999 wood burner	48	49	132	75	303	3	3	8	5	19	16	16	43	25	99
Post 1999 wood burner	110	121	284	158	673	8	9	21	12	50	37	40	95	53	224
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Multi-fuel burner - wood	8	30	62	11	112	0	1	3	0	5	3	10	21	4	37
Multi-fuel burner - coal	0	1	2	1	4	0	0	0	0	1	0	1	2	1	5
Total Wood	258	343	837	411	1848	15	19	47	24	106	86	114	278	136	614
Total Coal	2.4	2.1	9.1	0.7	14.3	0.4	0.4	1.6	0.1	2.5	2.0	2.0	7.8	0.7	12.6
Oil	0.0	0.0	0.0	0.0	0.1	0.2	0.1	0.2	0.2	0.7	0.0	0.0	0.0	0.0	0.0
Gas	0.0	0.0	0.0	0.0	0.0	0.8	0.5	2.0	0.3	3.6	0.0	0.0	0.0	0.0	0.0
Total	260	345	846	412	1863	17	20	51	25	113	88	116	286	137	627

Table 3-6: Tokoroa summary emissions by appliance type

	Fuel Use		PM_{10}			CO			NO_x			SO_x			VOC			CO_2			$PM_{2.5}$		
	t/day	%	kg	g/ha	%	kg	g/ha	%	kg	g/ha	%	kg	g/ha	%	kg	g/ha	%	t	kg/ha	%	kg	g/ha	%
Open fire	4.5	7%	53	44	8%	441	372	7%	9	7	21%	4	3	22%	126	107	7%	8	7	7%	47	39	7%
Open fire - wood	3.9	6%	39	33	6%	388	327	6%	6	5	14%	1	1	4%	116	98	6%	6	5	5%	39	33	6%
Open fire - coal	0.7	1%	14	12	2%	53	45	1%	3	2	6%	3	3	18%	10	8	1%	2	1	2%	8	7	1%
Total woodburner	59.6	86%	538	454	85%	5397	4555	86%	30	25	70%	12	10	65%	1620	1367	87%	95	80	84%	538	454	86%
Pre 1994 wood burner	16.5	24%	214	181	34%	2145	1810	34%	8	7	19%	3	3	18%	643	543	35%	26	22	23%	214	181	34%
1994 –1999 wood burner	11.7	17%	99	84	16%	992	837	16%	6	5	14%	2	2	13%	303	256	16%	19	16	17%	99	84	16%
Post 1999 wood burner	31.4	46%	224	189	35%	2260	1907	36%	16	13	37%	6	5	34%	673	568	36%	50	42	44%	224	189	36%
Total multi-fuel burner	3.2	5%	46	38	7%	408	345	7%	2	1	4%	1	1	8%	116	98	6%	5	5	5%	42	35	7%
Multi-fuel burner-wood	2.9	4%	37	31	6%	373	315	6%	1	1	3%	1	0	3%	112	94	6%	5	4	4%	37	31	6%
Multi-fuel burner-coal	0.3	0%	8	7	1%	35	30	1%	0	0	1%	1	1	5%	4	4	0%	1	1	1%	5	4	1%
Gas	1.5	2%	0	0	0%	0	0	0%	2	2	5%	0	0	0%	0	0	0%	4	3	3%	0	0	0%
Oil	0.2	0%	0	0	0%	0	0	0%	0	0	1%	1	1	5%	0	0	0%	1	1	1%	0	0	0%
Total wood	66	96%	614	518	97%	6157	5197	99%	37	32	87%	13	11	73%	1848	1560	99%	106	90	94%	614	518	98%
Total coal	1	1%	22	19	3%	88	74	1%	3	3	7%	4	4	23%	14	12	1%	2	2	2%	13	11	2%
Total	69		636	537		6246	5271		43	36		18	15		1863	1572		113	95		627	529	0%

4 Motor vehicles

4.1 Methodology

Assessing emissions from motor vehicles involves collecting data on vehicle kilometres travelled (VKT) under different levels of congestion, and the application of emission factors to these data. For emission inventory assessments, this is typically done via a road network model. In most areas of New Zealand where emission inventories have been carried out, the territorial local authorities or consulting traffic engineers have had traffic models, which have been used. No traffic model currently exists for Tokoroa. The establishment of one for the purposes of the inventory was considered. However, screening methods indicated that motor vehicles were unlikely to be a significant contributor to contaminant emissions, particularly the main contaminant of concern, PM_{10}. Because of this, and because of the significant resources required to establish and maintain a road network model, an alternative method of estimating VKTs was used.

4.1.1 Vehicle kilometres travelled (VKT)

An estimate of VKTs travelled in Tokoroa was made based on the ratio of VKTs to households for urban areas of New Zealand for which VKT data from road network models were available. These ranged from 64 VKTs per household in Taupo to 33 VKTs per household in Timaru (excluding the Washdyke area). An average of 52 VKTs per household was used. Although the potential range in VKTs is significant, emission estimates (section 4.2) are low in comparison to other sources. Thus the relative contributions of different sources and the total emissions estimates are not particularly sensitive to variations in VKTs.

Table 4.1 shows an estimate of the number of VKT for each of the different time periods, for 2004. The time of day breakdown and proportion of data in each level of service (LOS) category is based on data for Taupo. The LOS categories are A-B, C-D and E-F representing free-flowing, interrupted and congested vehicle movements, respectively.

Table 4.1: VKT breakdown by time of day and LOS for Tokoroa for 2004

	Total VKT	Time of day			
2004		**6am-10am**	**10am-4pm**	**4pm-10pm**	**10pm-6am**
A-B	233,863	43,717	98,747	75,602	15,798
C-D	9,615	1,941	3,064	4,610	-
E-F					
Total	243,478	45,658	101,810	80,212	15,798

4.1.2 Emission factors

The emission factors used to estimate motor vehicle emissions for PM_{10}, CO, NOx and VOC were taken from the New Zealand Traffic Emission Rates (NZTER) database based on the national vehicle fleet profile for 1998, described in the Ministry of Transport's Vehicle Fleet Emission Control Strategy (Table 4.2). The NZTER database was developed by the Ministry of Transport (MOT) based on measured emissions rates from actual vehicle emissions tests on New Zealand vehicles under various road/traffic conditions. Emission rates for SOx and CO_2 are not included in the NZTER database and were selected based on emission rates derived by the Fuel and Energy Group for the national vehicle fleet profile.

The emission factors for $PM_{2.5}$ were based on estimates of PM_{10} emissions using data from the British Colombia Lower Fraser Valley adjusted for the New Zealand vehicle fleet profile. This indicated that around 64% of the PM_{10} tailpipe emissions would be in

the $PM_{2.5}$ size fraction. In addition to tailpipe emissions, PM_{10} from the wearing of brakes and tyres were also included in the emissions assessments. Emission factors for PM_{10} and $PM_{2.5}$ from these sources were also derived from the British Colombia Lower Fraser Valley data adjusted for the New Zealand vehicle fleet profile. However, the extent to which these conversions based on overseas data are applicable to New Zealand vehicle emissions is uncertain. Consequently emission estimates for $PM_{2.5}$ from motor vehicles and PM_{10} from the wearing of tyre and brakes should be treated with caution.

Table 4.2: New Zealand vehicle fleet profile from MOT (1998)[1]

	Petrol	Diesel	CNG	LPG	Electric	Total
Cars	1798000	103100	280	640		1902020
LCV	212000	148600	130	230		360960
Bus	600	6600	80	170	1200	8650
Heavy truck	3200	68000	280	330		71810
Miscellaneous	6200	18600				24800
Motorcycle	79000					79000
Total	2099000	344900	770	1370	1200	2447240
Total percentage	85.8%	14.1%	0.0%	0.1%	0.0%	100.0%

Emission factors were selected based on “suburban” type driving and for the three different levels of service (LOS).

The emission factors for each contaminant and each LOS category for 2004 are shown in Table 4.3. Emission rates are based on 30% of the VKTs occurring under cold start conditions.

Table 4.3: Emission factors for 2004 based on a suburban driving regime

	CO g/km	VOC g/km	NOx g/km	PM_{10} g/km	SOx g/km	CO_2 g/km
Congested (E-F)	476	2.81	2.61	0.215	0.282	19.76
Interrupted (C-D)	407	2.16	2.50	0.175	0.236	15.53
Free-flow (A-B)	366	1.99	2.33	0.155	0.216	12.21

Emissions for the year 2004 were estimated by multiplying the VKT estimates in Table 4.1 by the emission factors shown in Table 4.3. Equation 4.1 shows the calculation used to determine the amount of emissions for each time period.

*Equation 4.1 Emissions(g)=Emission Factor (g/km) * VKT (km)*

The emissions over a 24-hour period were calculated by totalling the emissions calculated during the four emission inventory time-periods.

4.2 Motor vehicle emissions

Total VKTs in Tokoroa are estimated to be around 243,000 per day during 2004. Traffic conditions are assumed to be relatively free flowing and the majority of the VKTs are assumed to occur during the 10am to 10pm periods.

[1] Ministry of Transport, 1998, Vehicle fleet emission control strategy – final report. Ministry of Transport.

Around 42 kilograms of PM_{10} is estimated to be produced as a result of vehicle emissions in Tokoroa. Of this 38 kg is estimated tailpipe emissions with 3kg from brake wear and 4kg from tyres (Figure 4.1).

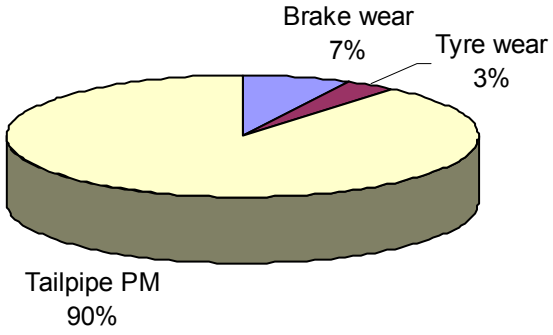

Figure 4.1: Breakdown of PM_{10} and $PM_{2.5}$ emissions from motor vehicles

Other contaminant emissions from motor vehicles in Tokoroa include around 3 tonnes of CO, 568kg of NOx and 53kg of SOx. In comparison, in Christchurch, where CO concentrations exceed ambient air quality guidelines at least once during most winters, motor vehicles emit around 109 tonnes of CO within the main urban area.

Tables 4.6 and 4.7 show emissions from motor vehicles in Tokoroa by time of day and by weight and grams per hectare respectively.

Table 4.6: Emissions from motor vehicles by time of day

	PM_{10}					CO					NOx					SOx				
	6am-10am	10am-4pm	4pm-10pm	10pm-6am	PM_{10} (kg)	6am-10am	10am-4pm	4pm-10pm	10pm-6am	CO (kg)	6am-10am	10am-4pm	4pm-10pm	10pm-6am	NOx (kg)	6am-10am	10am-4pm	4pm-10pm	10pm-6am	SOx (kg)
Tokoroa	8	18	14	3	42	564	1253	995	193	3005	107	237	187	37	568	10	22	17	3	53

	VOC					CO_2					$PM_{2.5}$				
	6am-10am	10am-4pm	4pm-10pm	10pm-6am	VOC (kg)	6am-10am	10am-4pm	4pm-10pm	10pm-6am	CO_2 (t)	6am-10am	10am-4pm	4pm-10pm	10pm-6am	$PM_{2.5}$ (kg)
Tokoroa	91	203	160	31	486	17	37	30	6	90	5	12	10	2	29

Table 4.7: Summary of motor vehicle emissions in Tokoroa

		PM_{10}		CO		NOx		SOx	
	Hectares	kg	g/ha	kg	g/ha	kg	g/ha	kg	g/ha
Tokoroa	1185	42	36	3005	2536	568	480	53	45

		VOC		CO_2		$PM_{2.5}$	
	Hectares	kg	g/ha	t	kg/ha	kg	g/ha
Tokoroa	1185	486	410	90	76	29	24

5 Industrial and commercial

5.1 Methodology

Industrial and commercial activities that discharge to air are few within the urban areas of Tokoroa. Since the closure of the Carter Holt Harvey timber mill in 2004, no activities hold resource consents for air discharges in the urban areas of Tokoroa. The Kinleith pulp and paper mill and Kinleith industrial park are located approximately five kilometres to the southeast of Tokoroa. Emissions from these have not been included in the inventory assessment as they are well outside the study area.

Emissions from 11 non-consented industrial/commercial activities were included in the assessment. The types of discharges included one site with a coal burner, one school incinerator and nine gas-fired boilers.

The combustion emissions were estimated using emission factor data as indicated in Equation 5.1.

Equation 5.1 Emissions (kg) = Emission factor (kg/tonne) x Fuel use (tonnes)

The emission factors used to estimate the quantity of emissions discharged are shown in Table 5.1. The coal fired boiler emission factors for PM_{10} are based on Coal Research Limited emission factors. Other emission factors for $PM_{2.5,}$ CO, NOx, SOx and benzene are based on AP42, as are emission factors for PM_{10} from wood fired boilers and diesels. The VOC and CO_2 emission factors are based on factors derived by NIWA for the Christchurch 1996 emission inventory.

Table 5-1: Emission factors for industrial discharges

	PM_{10} g/kg	$PM_{2.5}$ g/kg	CO g/kg	NOx g/kg	SO_2 g/kg	VOC g/kg	CO_2 g/kg
Coal boiler (underfeed stoker)	3.1	1.9	5.5	4.8	13.5	0.1	2400
Diesel boiler	0.47	0.11	0.67	3.24	10.5	0.2	3194
Wood fired boiler	3.2	2.7	6.8	0.8	0.0	0.1	1069
	g/m^3	g/m^3	g/m^3	g/m^3	g/m^3	g/m^3	g/m^3
Natural gas boiler	0.1216	0.1216	1.344	1.6	0.0096	0.088	1920

5.2 Industrial and commercial emissions

Table 5.2 shows an estimated 5-6 kilograms of PM_{10} from industry in the urban areas of Tokoroa per day during the winter months. The main source is the hospital boiler which is coal fired and operates 24-hours a day during the winter months.

Table 5.2: Summary of Tokoroa industrial/ commercial emissions

		PM_{10}		CO		NOx		SOx	
	Hectares	Kg	g/ha	kg	g/ha	kg	g/ha	kg	g/ha
		6	5	5	4	9	8	32	27
		VOC		CO_2				$PM_{2.5}$	
	Hectares	Kg	g/ha	kg	g/ha			kg	g/ha
		0	**0**	5	**4**			2	**2**

Table 5-2: Industrial/commercial emissions for Tokoroa by time of day

	Suspended Particulate – PM_{10}					Suspended Particulate - $PM_{2.5}$					Carbon monoxide					Nitrogen oxides				
	6am-10am	10am-4pm	4pm-10pm	10pm-6am	PM_{10} (kg)	6am-10am	10am-4pm	4pm-10pm	10pm-6am	$PM_{2.5}$ (kg)	6am-10am	10am-4pm	4pm-10pm	10pm-6am	CO (kg)	6am-10am	10am-4pm	4pm-10pm	10pm-6am	NOx (kg)
	1	1	1	2	6	0	0	0	1	2	1	1	1	1	5	2	2	2	3	9
	Sulphur oxides					Volatile organic compounds					Carbon dioxide									
	6am-10am	10am-4pm	4pm-10pm	10pm-6am	SOx (kg)	6am-10am	10am-4pm	4pm-10pm	10pm-6am	VOC (kg)	6am-10am	10am-4pm	4pm-10pm	10pm-6am	CO_2 (t)					
	5	8	8	11	32	0	0	0	0	0	1	1	1	1	5					

6 Outdoor burning

Emissions from outdoor burning can contribute to PM_{10} and $PM_{2.5}$ concentrations. In some urban areas of New Zealand outdoor burning is prohibited because of the adverse health and nuisance effects associated with these emissions. Outdoor burning includes any backyard burning of household or garden wastes in a drum, incinerator or open air. Presently there are no regulations restricting outdoor burning in Tokoroa, although section 17 of the Resource Management Act (1991) or section 29 of the Health Act could be used to control these emissions if individual discharges were causing adverse effects.

6.1 Methodology

Outdoor burning emissions for the winter months were estimated for Tokoroa based on data collected for the 2004 Tokoroa domestic home heating emission survey. The survey showed 11% of households in Tokoroa burnt rubbish in the outdoors during the winter, burning an average of around 4 fires per winter per household. The proportion of green waste (60%) versus household rubbish burnt (40%) was based on data collected in Otago. Emissions were calculated based on the assumption of an average weight of material per burn of 290kg and using the emission factors in Table 6.1.

Table 6-1: Outdoor burning emission factors (AP42, 2002)

	$PM_{2.5}$ g/kg	PM_{10} g/kg	CO g/kg	NOx g/kg	SOx g/kg	VOC g/kg	CO_2 g/kg
Garden rubbish	8	8	42	3	0.5	4	1470
Household rubbish	17	19	42	3	0.5	4.278	1470
Emission factor	11.7	12.5	42.0	3.0	0.5	4.3	1470

6.2 Emissions from outdoor burning

Outdoor burning emission estimates for Tokoroa (Table 6.2) indicate that around 17 kg of PM_{10} from outdoor burning could be expected per day during the winter months. Of this, the majority (93%) is within the finer, $PM_{2.5}$ size fraction. Outdoor burning also produces around 58 kg of carbon monoxide and around 2031 tonnes of carbon dioxide per day during winter.

It should be noted, however, that there are a number of uncertainties relating to this estimation. In particular it is assumed that burning is carried out evenly throughout the winter, whereas in reality it is highly probable that a disproportionate amount of burning is carried out during weekend days. Thus on some days no PM_{10} from outdoor burning may occur and on other days it might be many times the amount estimated in this assessment.

Table 6-2: Outdoor burning emission estimates for Tokoroa by time of day

	$PM_{2.5}$ kg	PM_{10} kg	CO kg	NOx kg	SOx kg	VOC kg	CO_2 kg
6am-10am	4	4	15	1	0	1	4
10am-4pm	12	13	44	3	1	4	12
4pm-10pm							
10pm-6am							
Tokoroa - total							

7 Other sources of emissions

The major sources of PM_{10} and other contaminants during the winter months when PM_{10} concentrations are high in Tokoroa are likely to result from domestic home heating, outdoor burning, motor vehicles and industry.

Other sources of emissions not included in the inventory include vegetation, which can emit VOC and NOx. Neither of these contaminants is likely to be an air quality concern in Tokoroa and vegetation is unlikely to be a significant source in the predominantly urban area of Tokoroa, although it may be significant in the surrounding rural areas. A separate study of emissions from natural sources in the Waikato was carried out in 1996 (NIWA, 1996).

Emissions of PM_{10} from wind blown dusts from the erosion of soils and from the tilling of land are also potential contributors. Some contribution from the more rural areas surrounding Tokoroa is possible. Limited emission data available for tilling suggests around 1.26 kg PM_{10} and 0.6 kg $PM_{2.5}$ is produced per hectare tilled (GVRD, 1998). Thus if 10 hectares were being tilled in or near to the Tokoroa area, emissions might be in the order of 12 kilograms of PM_{10} and 6 kg of $PM_{2.5}$.

Lawn mowers, leaf blowers and chainsaws can also contribute small amounts of particulate. These are not typically included in emission inventory studies owing to the relatively small contribution, particularly in areas where solid fuel burning is a common method of home heating. Based on data for other areas, PM_{10} emissions from lawn mowing in Tokoroa are likely to be much less than 5 kg per day.

8 Total emissions

Domestic heating is the main source of PM_{10} and $PM_{2.5}$ emissions in Tokoroa during the winter months, contributing around 85% of PM_{10} and 88% of the $PM_{2.5}$. Of the domestic PM_{10} emissions, older (pre 1994) woodburners contribute around 34% of the emissions, with open fires and multifuel burners producing around 8% and 7% of the emissions respectively. Figure 8.1 shows that the other 15% of the total PM_{10} emissions come from a combination of motor vehicles (6%), outdoor burning (8%) and industry (1%).

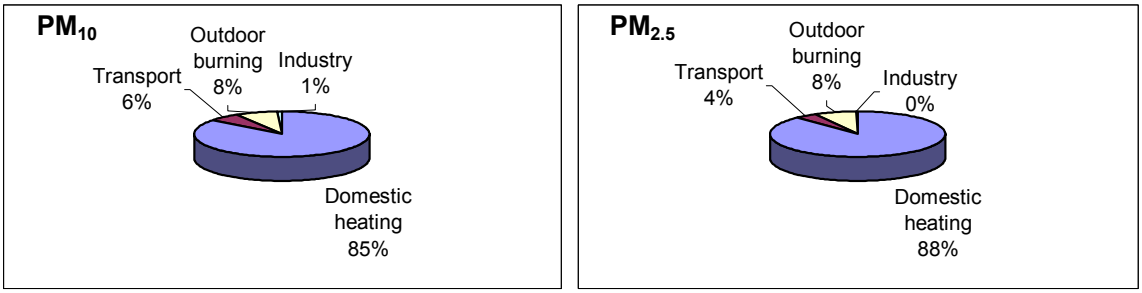

Figure 8-1: Relative contribution of sources to PM10 and PM2.5 emissions in Tokoroa

The majority of the PM_{10} emissions occur during the evening (4pm to 10pm) time period (Figure 8.2). This is likely to coincide with the time of day when meteorological conditions are most conducive to elevated pollution levels as temperature inversions and low wind speeds typically occur during the evening period. Emissions that occur during times when meteorological conditions are conducive to elevated pollution will have a greater impact on 24-hour average concentrations than emissions that occur when wind speeds are elevated.

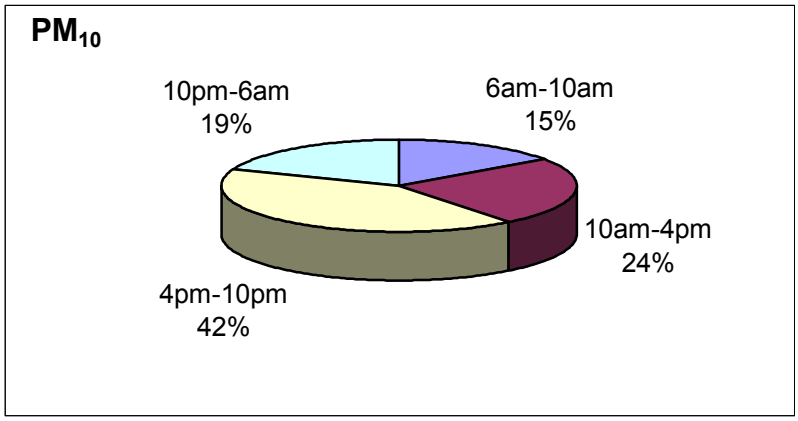

Figure 8-2: Estimated PM10 emissions by time of day

The total quantities of emissions for each contaminant and the breakdown of emissions by time of day are shown in Tables 8.2 and 8.3.

Around 700 kilograms of PM_{10} and $PM_{2.5}$ are estimated to be discharged into the air per day in Tokoroa during winter. This is less than the 800 kilograms estimated for Taupo, largely because of the greater industrial presence in Taupo. Domestic heating emissions are estimated to be slightly higher in Tokoroa, mostly because of the age of the burner and because of the installations of second hand burners. Outdoor burning emissions are estimated to be about three times higher in Tokoroa than in Taupo. Motor vehicles are the main source of NOx and SOx and contribute about a third of the benzene emissions (Table 8.1).

Table 8-1: Relative contribution of different sources to contaminant emissions

	PM_{10}	$PM_{2.5}$	CO	NOx	SOx	VOC	CO_2
Domestic heating	86%	88%	66%	7%	17%	79%	53%
Motor vehicle	6%	4%	32%	90%	50%	21%	42%
Outdoor burning	8%	8%	2%	2%	2%	1%	3%
Industry	1%	0%	0%	1%	30%	0%	2%

Table 8.2: Total emissions by time of day for Tokoroa

Total emissions (kg)	6am-10am	10am-4pm	4pm-10pm	10pm-6am	Total PM_{10} kg	6am-10am	10am-4pm	4pm-10pm	10pm-6am	Total $PM_{2.5}$ kg	6am-10am	10am-4pm	4pm-10pm	10pm-6am	Total CO (kg)	6am-10am	10am-4pm	4pm-10pm	10pm-6am	Total NOx (kg)
Domestic heating	89	117	292	138	636	88	116	286	137	627	872	1157	2843	1374	6246	6	7	21	9	43
Motor vehicle	8	18	14	3	42	5	12	10	2	29	564	1253	995	193	3005	107	237	187	37	568
Outdoor burning	15	45			59	14	42			56	50	150			200	4	11			14
Industry	1	1	1	2	6	0	0	0	1	2	1	1	1	1	5	2	2	2	3	9
Total	113	181	307	142	744	107	170	296	140	713	1487	2561	3838	1568	9455	119	258	210	48	635

Total emissions (kg)	6am-10am	10am-4pm	4pm-10pm	10pm-6am	Total SOx (kg)	6am-10am	10am-4pm	4pm-10pm	10pm-6am	Total VOC (kg)	6am-10am	10am-4pm	4pm-10pm	10pm-6am	Total CO_2 (t)
Domestic heating	3	3	9	3	18	260	345	846	412	1863	17	20	51	25	113
Motor vehicle	10	22	17	3	53	91	203	160	31	486	17	37	30	6	90
Outdoor burning	1	2			2	5	15			20	2	5			7
Industry	5	8	8	11	32	0	0	0	0	0	1	1	1	1	5
Total	19	35	34	18	106	356	563	1007	443	2369	37	64	82	32	214

Table 8-2: Total emissions by time of day per hectare for Tokoroa

	6am-10am	10am-4pm	4pm-10pm	10pm-6am	Total PM_{10} g/ha	6am-10am	10am-4pm	4pm-10pm	10pm-6am	Total $PM_{2.5}$ g/ha	6am-10am	10am-4pm	4pm-10pm	10pm-6am	Total CO g/ha	6am-10am	10am-4pm	4pm-10pm	10pm-6am	Total NOx g/ha
Domestic heating	75	99	246	116	537	74	98	241	116	529	736	976	2399	1160	5271	5	6	17	7	36
Motor vehicle	7	15	12	2	36	5	10	8	2	24	476	1058	840	163	2536	90	200	158	31	480
Outdoor burning	13	38	0	0	50	12	35	0	0	47	42	126	0	0	169	3	9	0	0	12
Industry	1	1	1	2	5	0	0	0	1	2	1	1	1	1	4	2	2	2	3	8
Total	95	153	259	120	628	91	144	250	118	602	1255	2162	3240	1324	7980	100	218	177	41	536

	6am-10am	10am-4pm	4pm-10pm	10pm-6am	Total SOx g/ha	6am-10am	10am-4pm	4pm-10pm	10pm-6am	Total VOC g/ha	6am-10am	10am-4pm	4pm-10pm	10pm-6am	Total CO_2 kg/ha
Domestic heating	2	3	8	3	15	220	291	714	347	1572	14	17	43	21	95
Motor vehicle	8	19	15	3	45	77	171	135	27	410	14	32	25	5	76
Outdoor burning	1	2	0	0	2	4	13	0	0	17	1	4	0	0	6
Industry	5	7	7	9	27	0	0	0	0	0	1	1	1	1	4
Total	16	29	29	15	89	301	475	850	374	2000	31	54	69	27	181

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Appendix One: Home Heating Questionnaire

1. (a) Do you use an **OPEN FIRE** in your house on a TYPICAL Winter's day or night?
YES ( ) NO ( ) ***If* NO *GO TO Question* 3**.

   (b) Do you use it:
   - i. In the morning (between 6am and 10 am) **YES ( ) NO ( )**
   - ii. Day time (between 10am and 4pm) **YES ( ) NO ( )**
   - iii. Evening (between 4pm and 10pm) **YES ( ) NO ( )**
   - iv. Overnight (between 10pm and 6am) **YES ( ) NO ( )**

   (c) Do you use wood on your open fire? **YES () NO *If NO GO TO Part (f)***

   (d) How much wood do you use per day? ***(ask them how many pieces*** of ***wood (logs) they use on an average Winter's day. Better would be KG/DAY):*** _____

   (e) Do you buy your wood from a wood merchant or collect it yourself? **BUY IT ( )**
COLLECT IT ( ) BOTH ( ) */f* **BOTH ask %Collected _____ % Bought _____**

   (f) Do you use coal on your open fire? **YES ( ) NO ( )** *If* NO ***GO TO Question*** 2.

   (g) How much coal do you use per day? ***(ask them how many buckets*** of ***coal they use on an average Winter's day. Better would be KG/DAY):*** _____

   (h) What type of coal do you use? _____

2. (a) Do you use any type of **ELECTRICAL HEATING** in your house on a TYPICAL winter's day or night? **YES ( ) NO ( )** ***If*** NO ***GO TO Question 3.***

   (b) Do you use it
   - i. In the morning (between 6am and 10 am) **YES ( ) NO ( )**
   - ii. Day time (between 10 am and 4pm) **YES ( ) NO ( )**
   - v. Evening (between 4pm and 10 pm) **YES ( ) NO ( )**
   - vi. Overnight (between 10 pm and 6am) **YES ( ) NO ( )**

3. (a) Do you use any type of **GAS HEATING** in your house on a TYPICAL winter's day or night?
YES ( ) NO ( ) *If NO GO TO Question 4***.**

   (b) Is it flued or unflued gas heating? **FLUED ( ) UNFLUED ( ) BOTH ( )**

   (c) Do you use it:
   - i. In the morning (between 6am and 10 am) **YES ( ) NO ( )**
   - ii. Day time (between 10 am and 4pm) **YES ( ) NO ( )**
   - vii. Evening (between 4pm and 10pm) **YES ( ) NO ( )**
   - viii. Overnight (between 10pm and 6am) **YES ( ) NO ( )**

   (d) How much gas do you use ***?(ask them for the size of the gas bottle(s) and how often they would refill them*** -(sizes are 2kg, 2.5kg, 3kg, 4.5kg, 9kg, 18kg, 20kg, 45k, 90kg)

   Size#*1* _____ Freq# 1 _____
   Size#2 _____ Freq# 2 _____

4. (a) Do you use a **LOG BURNER**? ***(This is not a multifuel burner ie does not burn coal)*** in your house on a TYPICAL Winter's day or night. **YES ( ) NO ( )** */f* ***NO GO TO Question 5.***

   (b) How old is your log burner? 10 yrs+ ( ) 5- 10 yrs old ( ) Less than 5 yrs ( )

   (c) What type of wood burner:

   Make: _____

   Model: _____

(d) Do you use it:

i. In the morning (between 6am and 10 am) **YES ( ) NO ( )**
ii. Day time (between 10 am and 4pm) **YES ( ) NO ( )**
ix. Evening (between 4pm and 10 pm) **YES ( ) NO ( )**
x. Overnight (between 10 pm and 6am) **YES ( ) NO ( )**

(e) How much wood do you use per day? ***(ask them how many pieces of wood (logs) they use on an average winter's day. Better would be KG/DAY):*** _____

(f) Do you buy your wood from a wood merchant or collect it yourself? **BUY IT ( )**
COLLECT IT ( ) BOTH ( ) *If* **BOTH ask %Collected _____ % Bought _____**

5. (a) Do you use a burner which burns coal as well as wood - ie a **MULTI FUEL BURNER** ***(This includes incinerators, pot belly stoves, McKay space heaters etc.)*** in your house on a TYPICAL winter's day or night? **YES ( ) NO ( )** ***If*** NO ***GO TO Question 6***

(b) How old is your multi fuel burner? 10 yrs+ ( ) 5- 10 yrs old ( ) Less than 5 yrs ( )

(c) What type of multi fuel burner is it? _____

(d) Do you use it

i. In the morning (between 6am and 10 am) **YES ( ) NO ( )**
ii. Day time (between 10am and 4pm) **YES () NO ( )**
xi. Evening (between 4pm and 10pm) **YES () NO ( )**
xii. Overnight (between 10pm and 6am) **YES ( ) NO ( )**

(e) How much wood do you use per day? ***(ask them how many pieces of wood (logs) they use on an average winters day. Better would be KG/DAY):*** _____

(f) Do you buy your wood from a wood merchant or collect it yourself? **BUY IT ( )**
COLLECT IT ( )
BOTH ( ) *If* **BOTH ask %Collected _____% Bought _____**

(g) Do you use coal on your multi fuel burner? **YES () NO ( )** *If NO GO TO Question 6.*

(h) How much coal do you use per day? ***(ask them how many buckets of coal they use on an average Winter's day. Better would be KG/DAY):*** _____

(i) What type of coal do you use?

6. (a) Do you use an **OIL FIRED HEATING** system in your house on a TYPICAL Winter's day or night? **YES ( ) NO( )** ***If*** NO ***GO TO*** END.

(b) Do you use it:

i. In the morning (between 6am and 10 am) **YES ( ) NO ( )**
ii. Day time (between 10am and 4pm) **YES () NO ( )**
xiii. Evening (between 4pm and 10pm) **YES () NO ( )**
xiv. Overnight (between 10pm and 6am) **YES ( ) NO ( )**

(c) How much oil do you use? _____(litres)