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Mount Maunganui Airshed Emission Inventory 2022

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

EXECUTIVE SUMMARY

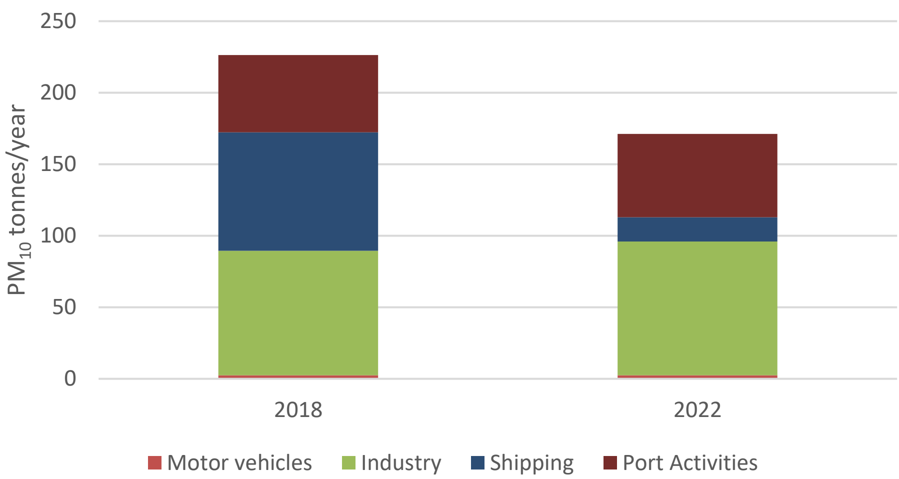
The main air contaminants of interest in the Mount Maunganui Airshed (MMA) are particulate (PM_{10} and $PM_{2.5}$) and sulphur dioxide (SO_2). Concentrations of PM_{10} have regularly exceeded the 24-hour average NESAQ for PM_{10} of 50 µg/m^3 (one allowable exceedance per year) since monitoring commenced in the airshed. Historically SO_2 concentrations have also exceeded guideline values.

Sources of air discharges in the Mount Maunganui Airshed (MMA) include industrial activities, shipping and cargo handling at the Port of Tauranga, fugitive dusts, motor vehicles, aviation and rail as well as domestic sources such as home heating. The airshed contains some large-scale industrial activities including combustion activities, handling of bulk solid material, fertiliser works and several asphalt plants. Fugitive dusts and marine aerosols are not included in the inventory owing to methods for estimating emissions not being robust.

The 2022 air emission inventory estimated that around 174 tonnes of PM_{10}, 74 tonnes of $PM_{2.5}$ and 348 tonnes of SOx (total sulphur oxides) were emitted in the MMA. Industrial and port activities were the main contributors to PM_{10} emissions. The main sources of $PM_{2.5}$ emissions in the MMA were industrial activities (with $PM_{2.5}$ discharges), certain port activities and shipping. The main source of SOx emissions in the MMA is industrial activities (with SOx discharges).

Shipping emissions were compared to a previous assessment (Wilton, 2019) where they were found to be a significant contributor to emissions to air in Tauranga. Since that assessment fuel switching or scrubbers have been a requirement of ocean-going vessels as a result of MARPOL Annexure VI and this has impacted on shipping emissions at the Port. The decrease in PM_{10}, $PM_{2.5}$ and SO_2 emissions as a result has reduced the significance of this source in the MMA. Shipping remains a main contributor towards $PM_{2.5}$ but is not one of the main sources of PM_{10} and SOx.

The reduction in PM_{10} estimated to have occurred in the MMA since 2018 is around 55 tonnes or 24% of the 2018 levels. A 65% reduction in SOx emissions is also estimated to have occurred.



1 INTRODUCTION

Emission inventories are used by Governments and Local Government internationally to provide an estimate of the quantities of contaminants from anthropogenic sources that are emitted into the air. The sources that are included in emissions inventories in New Zealand are generally the domestic heating, motor vehicle, industrial and commercial and outdoor burning sectors. In New Zealand the main air contaminants of concern are $PM_{2.5}$ and PM_{10} as concentrations can exceed the National Environmental Standards for Air Quality (NESAQ) for PM_{10} and the proposed NESAQ for $PM_{2.5}$ (Ministry for the Environment, 2020) in many locations in New Zealand. Emission inventory assessments are based on discharges across an airshed or area and do not include an evaluation of monitoring data at a specific site.

The Bay of Plenty Region contains two gazetted airsheds (Rotorua and Mount Maunganui) within which concentrations of PM_{10} have exceeded the NESAQ. The Mount Maunganui airshed (MMA) was gazetted in October 2019 after measurements showed PM_{10} concentrations in excess of the NESAQ. Previously the Mount Maunganui area was included in the 2018 Tauranga air emission inventory, with emissions aggregated into the wider Tauranga area. This report presents emissions just for the MMA and updates emission estimates for 2022.

The main contaminants of interest in the MMA are particulate (PM_{10} and $PM_{2.5}$), sulphur dioxide (SO_2) and more recently nitrogen dioxide (NO_2). Sulphur oxides and nitrogen dioxide represented in the inventory as total sulphur oxides (SOx) and nitrogen oxides (NOx) respectively. Historically SO_2 concentrations have exceeded guideline values.

Emissions sources in the MMA include industrial activities, shipping and handling of some cargo at the Port of Tauranga, fugitive dusts, motor vehicles, aviation and rail as well as domestic sources such as home heating. The industrial activities discharging to air comprises some large scale activities including combustion activities, handling of bulk solid material, fertiliser works and several asphalt plants. The cargo handling activities that discharge to air include the handling or grains and logs as well as combustion emissions from cargo handling equipment. Port activities include these cargo handling activities as well as emissions from shipping and motor vehicles at the Port of Tauranga. Fugitive dusts and marine aerosols are not included in the inventory owing to methods for estimating emissions not being well defined.

As the MMA includes only around 200 dwellings domestic sources are not a significant source of air contaminants. The airshed contains several large industrial activities including combustion activities, handling of bulk solid material, fertiliser works and several asphalt plants. Key contaminants likely to be of concern include particulate and sulphur dioxide.

It is also noted that shipping emissions will have decreased since the 2018 inventory owing to the implementation of MARPOL Annexure VI which includes specifications around sulphur content of fuels. A revised emission estimate based on full implementation of MARPOL is required for the MMA emissions assessment. It is noted that not all differences between the 2018 shipping emission estimates and the 2022 shipping estimates will occur as a result of MARPOL as variations in ship visits and days at port will also impact on the emission estimates. In particular, a reduction in cruise ships from around 86 in 2018 to none for the year ending June 2022 will result in a decrease in emissions.

This report provides an estimate of emissions of particles (PM_{10} and $PM_{2.5}$), carbon monoxide, nitrogen oxides and sulphur oxides from domestic heating, transportation, aviation, industrial and commercial activities and outdoor burning for MMA for 2022.

2 INVENTORY DESIGN

The key components of inventory design are selection of the study area, selection of sources and the focus/extent of investment in data collection for each, contaminants to be included, the spatial resolution (within the study area what breakdowns might be required) and temporal resolution (e.g., hourly, daily or annual emissions).

2.1 Key issues

The main air quality issue for most urban areas of New Zealand is particles in the air that are typically associated with solid fuel burning for domestic home heating. In the Mount Maunganui Airshed sources are dominated by Port related activities as well as local industry.

2.2 Selection of contaminants

The scope of the inventory with respect to contaminants is:

- particles (PM_{10})
- fine particles ($PM_{2.5}$)
- carbon monoxide (CO)
- sulphur oxides (SOx)
- nitrogen oxides (NOx)

Emissions of PM_{10}, CO, SOx and NOx are included as these contaminants are included in the NESAQ because of their potential for adverse health impacts. $PM_{2.5}$ has been included in the inventory because this size fraction has significance in terms health and because this contaminant is included in the proposed revisions to the NESAQ for $PM_{2.5}$ (Ministry for the Environment, 2020).

2.3 Selection of sources

The inventory will include emission estimates from the following sources:

- Industry including small scale industrial and commercial activities.
- Shipping
- Cargo handling
- Domestic heating
- Motor vehicles
- Outdoor burning
- Small scale domestic sources - lawn mowing, power tool use and solvent use
- Aviation

Marine aerosol emissions and other natural dusts are not well characterized using inventory techniques and are not included in the emissions assessment. Other methods such as receptor modelling and source apportionment will provide a more robust approach for these sources.

2.4 Selection of inventory area

The Mount Maunganui Airshed is shown in Figure 2.1 and is the basis for the 2022 inventory area. An additional three-kilometer radius from the harbour entry was included in the emissions assessment, however, to allow for a more thorough assessment of the discharges from ocean going vessels on approach and departure from the Port. The overland area of the MMA airshed is around 552 hectares.

Figure 2.1: MMA Emission Inventory Area (source Bay of Plenty Regional Council, 2022).

2.5 Temporal distribution

The inventory is based on emission estimates for 2022. Typically, data used are for 2022 or where annual quantities are required for emission estimates the most recent year available (e.g., year ending June 2022).

The temporal distribution of the inventory information is annual, monthly and daily basis where appropriate. Motor vehicle data are based on annualised vehicle movements as seasonal variations are not available.

No differentiation is made for weekday and weekend sources.

3 DOMESTIC HEATING

3.1 Methodology

Home heating methods and fuels for Mount Maunganui Airshed (MMA) were based on home heating data from the 2018 census with average fuel use in these areas assumed to be the same as the 2018 Tauranga emission inventory for Mount Maunganui. As defined by Stats NZ the Statistical Area 1 (SA1) areas identified within the MMA were 7013954, the majority of 7013977, half of 7013955, 7013978, 7013973 and 7013974.

Home heating methods were classified as; electricity (no discharge), open fires, wood burners, pellet fires, multi fuel burners, gas burners and oil burners.

Emission factors were applied to these data to provide an estimate of emissions for each study area. The emission factors used to estimate emissions from domestic heating are shown in Table 3.1. The basis for these is detailed in Appendix A.

Table 3.1: Emission factors for domestic heating methods.

	PM_{10} g/kg	$PM_{2.5}$ g/kg	CO g/kg	NOx g/kg	SO_2 g/kg
Open fire - wood	7.5	7.5	55	1.2	0.2
Open fire - coal	21	18	70	4	8
Pre 2006 burners	10	10	140	0.5	0.2
Post 2006 burners	4.5	4.5	45	0.5	0.2
Pellet burners	2	2	20	0.5	0.2
Multi-fuel[1] - wood	10	10	140	0.5	0.2
Multi-fuel[1] – coal	19	17	110	1.6	8
Oil	0.3	0.22	0.6	2.2	3.8
Gas	0.03	0.03	0.18	1.3	7.56E-09

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

The average fuel use per household was based on the 2018 Tauranga air emission inventory survey data. This indicated around 17 kilograms of wood on average per wood burner after adjusting for frequency of use data.

Emissions for each contaminant were calculated based on the following equation:

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

Where:

CE = contaminant emission

EF = emission factor

FB = fuel burnt

3.2 Home heating methods and fuels

The 2018 census suggests a maximum of 207 households within the MMA airshed, with only a maximum of six reporting the use of wood for home heating. All these households reported to burn wood in a wood burner. The majority of households in the MMA use electricity for heating.

3.3 Domestic heating emissions

Results suggest that around one kilogram of PM_{10} is discharged on a typical winter's day from domestic home heating across MMA. A maximum of 100 kilograms of wood is burnt per typical winter's night in the MMA.

3.4 Other domestic sources of emissions

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. Wilton, (2019) provides an assessment of potential emissions from small domestic appliances such as lawn mowers, chain saws and leaf blowers that which indicates a range of 0.0012 to 0.05 g/household/day for PM_{10}. This indicates less than 0.02 kilograms of PM_{10} per day in MMA. Because of the negligible quantities from these sources, they have not been included in the subsequent emission estimates.

4 MOTOR VEHICLES

4.1 Methodology

Motor vehicle emissions to air include tailpipe emissions of a range of contaminants and particulate emissions occurring as a result of the wear of brakes and tyres. Assessing emissions from motor vehicles involves collecting data on vehicle kilometres travelled (VKT) and the application of emission factors to these data.

Emission factors for motor vehicles are determined using the Vehicle Emission Prediction Model (VEPM 6.0) developed by Auckland Council. Emission factors for PM_{10}, $PM_{2.5}$, CO and NOx for this study have been based on VEPM 6.0. Default settings were used for all variables except for the temperature data and the vehicle fleet profiles which was based on Tauranga vehicle registration data for the year ending December 2021 (Table 4.1). Additionally, emission factors for heavy duty diesel vehicles for 2022 were obtained from the model to separately assess the emission load from the increased prevalence of trucks in this area owing to movements related to Port Activities. Temperature data were based on an average winter temperature for Tauranga of 15 degrees. Resulting emission factors are shown in Table 4.2.

Emission factors for SOx were estimated for diesel vehicles based on the sulphur content of the fuel (10ppm) and the assumption of 100% conversion to SOx. The g/km emission factor was estimated using VEPM 6.0 using the fuel consumption per VKT for the parameters described above.

The number of vehicle kilometres travelled (VKT) for each area were estimated using two approaches. Firstly, vehicle kilometers travelled were estimated using the New Zealand Transport Authority VKT data for Tauranga for 2021 spatially allocated to the MMA airshed based on the proportion of VKTs in the MMA relative to Tauranga for 2013. Secondly VKT within the Port and associated with heavy vehicle movement from trucks visiting and leaving the Port outside of the Port boundary were estimated using vehicle data provided by the POT (Table 4.3). The latter estimate was subtracted from the former to avoid double counting.

In addition to estimates of tailpipe emissions and brake and tyre emissions using VEPM an estimate of the non-tailpipe emissions (including brake and tyre wear and re-suspended road dusts) was made using the EMEP/EEA air pollutant emission inventory guidebook (2016). The emission factors from this method are shown in Table 4.4. It is noted that emission factors for fugitive sources such as resuspended dusts can have a high level of uncertainty.

Table 4.1: Vehicle registrations for Tauranga for the year ending December 2021.

MMA	Petrol	Diesel	Hybrid	Plug in hybrid	Electric	LPG	Other
Cars	100,906	10,351	2,620	222	594	15	12
LCV	4,419	10,188	6	0	6	12	1
Bus	229	567	0	0	1	1	0
HCV		5,516			13		
Miscellaneous	2396	1141	1	0	82	38	12
Motorcycle	6,374						
Total	114,324	27763	2627	222	696	66	25

Table 4.2: Emission factors (2022).

2022	CO g/VKT	PM_{10} g/VKT	PM brake & tyre g/VKT	NOx g/VKT	NO_2 g/VKT	$PM_{2.5}$ g/VKT	$PM_{2.5}$ brake & tyre g/VKT
Tauranga vehicle fleet	1.5	0.013	0.020	0.469	0.080	0.013	0.011
Heavy duty vehicles	1.0	0.111	0.062	2.983	0.326	0.111	0.034

Table 4.3: VKT daily and annual (NZTA, 2021).

	Total VKT per day	Annual VKT
MMA	162565	59336065.4
Heavy duty vehicles (port related activity outside of port area)	18960	6920400

Emissions were calculated by multiplying the appropriate average emission factor by the VKT:

Emissions (g) = Emission Rate (g/VKT) * VKT

Table 4.4: Road dust TSP emissions (from EMEP/EEA guidebook, EEA, 2016).

	TSP g/KVT
Two wheeled vehicles	0.01
Passenger car	0.02
Light duty trucks	0.02
Heavy duty trucks	0.08
Weighted vehicle fleet factor	0.018
PM_{10} size fraction	0.5
$PM_{2.5}$ size fraction	0.27

4.2 Motor vehicle emissions

Around ten kilograms per day of PM_{10} are estimated to be emitted from motor vehicles daily in MMA.

Around 32% of the PM_{10} and 46% of the $PM_{2.5}$ from motor vehicles is estimated to occur as a result of the tailpipe emissions. Brake and tyre wear are a significant source of PM_{10} from motor vehicles contributing 48% as well as 38% of the $PM_{2.5}$ from motor vehicles (Figure 4.1). Tables 4.5 and 4.6 show the daily and annual estimates of emissions from motor vehicles in MMA.

Table 4.5: Summary of daily motor vehicle emissions (kg/day)

	PM_{10}		CO		NOx		SOx		$PM_{2.5}$	
	kg	g/ha	kg	g/ha	kg	g/ha	kg	g/ha	kg	g/ha
Tailpipe	4	8	239	432	76	138	0.1	0.1	4	8
Brake and tyre	4	8							2	4
Road dust	1	3							1	1
Total	10	18	239	432	76	138	0.1	0.1	7	14

Table 4.6: Summary of daily motor vehicle emissions (tonnes/year)

	PM_{10}		CO		NOx		SOx		$PM_{2.5}$	
	tonnes	kg/ha	tonnes	kg/ha	tonnes	kg/ha	tonnes	kg/ha	tonnes	kg/ha
Tailpipe	1.6	3	87	158	28	50	0.0	0.05	1.6	3
Brake and tyre	1.6	3							0.9	2
Road dust	0.5	1							0.3	1
Total	4	7							3	5

Figure 4.1: Motor vehicle PM_{10} (left) and $PM_{2.5}$ (right) emissions by source.

5 INDUSTRIAL AND COMMERCIAL ACTIVITIES

5.1 Methodology

Industrial and commercial activities to be included in the inventory were identified primarily through the Council's resource consent database. Information on activities with resource consents for discharges to air in the Mount Maunganui Airshed were provided by the Bay of Plenty Regional Council. These included a range of surface coating activities, landfills, combustion activities, cement processing, asphalt manufacture, fertiliser production and chemical industries.

Surface coating activities (e.g., spray painters) were the most predominant consented industrial activity for air discharge across the Bay of Plenty Region. The main discharge from surface coatings is volatile organic compounds (VOC) which is a contaminant not included in the inventory. Particle emissions may occur if coatings are applied using spray guns in an uncontrolled environment. However, they are not typically included in emission inventory assessments as they are comparatively small in relation to those from other sources (Environment Australia, 1999). These activities have been included collectively in the small-scale emission assessment however.

The general approach was to identify activities discharging to air and collect site specific information relevant to the discharge type (activity data) as well as information on seasonal variability and hours of operation where relevant. In a small number of instances resource consents limits were used.

For industries for which relatively recent site-specific emissions data were available from compliance testing or the resource consent application, emissions were estimated based on equation 5.1.

Equation 5.1 Emissions (kg/day) = Emission rate (kg/hr) x hrs per day (hrs)

Where site specific emissions data were not available, emissions were estimated using activity data and emission factor information, as indicated in Equation 5.2. Activity data from industry includes information such as the quantities of fuel used, or in the case of non-combustion activities, materials used or produced. Activity data was collected by direct contact with industry, using data from the resource consents or compliance monitoring or a combination of these methods.

Equation 5.2 Emissions (kg) = Emission factor (kg/tonne) x Fuel/Material use (tonnes)

The emission factors used to estimate the quantity of emissions discharged are shown in Table 5.1. Site specific information was available for a number of sources. The emissions factors used are from the USEPA AP42 database[1] with the exception of the animal cremation factors which are from (EEA, 2016). In addition, AP 42 database was used to assess the proportion of PM_{10} emissions that were likely to be $PM_{2.5}$ for a range of sources. Fugitive dust emissions from industrial and commercial activities were generally not included in the inventory assessment because of difficulties in quantifying the emissions.

Table 5.1: Emission factors for industrial discharges.

AP 42 Chapter	AP 42 Source Category Code	Discharge Type	PM_{10} g/kg	CO g/kg	NOx g/kg	SOx g/kg	$PM_{2.5}$ g/kg
1.1	1-03-013-02	Waste oil combustion	1.40	0.7	2.7	7.8	1.31
9.9.1	3-02-005-55	Grain unloading – shipping	0.019				0.0025
9.9.1	3-02-005-30	Grain handling - general	0.017				0.0028

[1] http://www.epa.gov/ttn/chief/ap42/index.html

9.9.1	3-02-008-16	Grain processing – pellet cooler	0.0375				0.0062
9.9.1	3-02-005-51	Grain unloading - truck	0.0295				0.005
9.9.1	3-02-005-52	Grain unloading – hopper truck	0.0039				0.00065
11.2	3-05-011-17	Cement supplement handling controlled	0.0024				
11.12	3-05-011-04,-21,23	Aggregate loading/ unloading uncontrolled	0.0017				0.0005
11.2	3-05-011-07	Cement handling controlled	0.00017				
13.2.6	3-09-002-04	Abrasive blasting – garnet fabric filter	0.69				0.069
11.1.11,	3-05-002-45	Asphalt - drum mix venturi scrubber	0.0097	0.065	0.28		0.007
			kg/m^3	kg/m^3	kg/m^3	kg/m^3	kg/m^3
1.4	1-01-006-02	Natural gas boilers	0.0001	0.0006	0.0016	0.0000	0.0001
Source							
5.c.1.b	(EEA, 2016)	Crematorium – animal (kg per tonne of material cremated)	0.6				0.5
EEA 2016 5.c.1.v Table 3.1		Crematoria kg/body	0.0347	0.14	0.824	0.113	0.0347

5.2 Small scale activities

An additional assessment of PM_{10} and $PM_{2.5}$ discharges from small scale industry is included in this report based on the methodology described in the Bay of Plenty Regional Council Rotorua Air Emission Inventory (Iremonger & Graham, 2007). The methodology used for this assessment as per Iremonger & Graham, 2007 was to sort small scale activities into category groupings and to apply an across the board hourly emission rate for each activity in each category. The groupings and emission rates from that study and applied here were:

Facilities with highest potential for PM emissions (assumed to emit 0.1 kg/hr)

Joinery factories, heavy engineering, panel beaters, light metal fabrication, metal finishers (powder coating), bakeries, bone/stone/wood grinding or carving.

Facilities with lower potential for PM emissions (0.02 kg/hr)

Light vehicle workshops, printing works, packaging manufacturers, tanneries, paint and other solvents, metal finishers/ electroplating, appliance repairs.

Facilities with very little potential for PM_{10} emissions (no emissions)

Retail facilities, car dealers, food and beverage facilities.

Facilities with the potential for yard emissions (0.1 kg/day)

Wreckers, scrap metal dealers, waste management, timber yards.

The assignment of these emission factors to these groupings was made by Graham, (2006) and reported in (Iremonger & Graham, 2007) based on the emission test data reported in Appendix C. It is noted that these factors will be TSP and the main size fractions of interest are PM_{10} and $PM_{2.5}$. To estimate emissions by size data on size fraction distributions from AP 42 (Appendix B.2, table B2.2 mechanically generated sources for aggregate/ unprocessed ores) were adopted. This indicated PM_{10} at around 51% of TSP and $PM_{2.5}$ at 15% of TSP.

Iremonger & Graham, (2007) note a very high degree of uncertainty in the method to the point of it providing only an indication for the purposes of assessing whether further evaluation is required. We concur with this view because of the very small number of test results available for the different discharge types, no specificity of method associated with the test results (e.g., controlled or uncontrolled) and some significant variations in test results for seemingly the same discharge type (e.g., the two results for spray painting are 0.03 kg/hr and 0.14 kg/hr). In addition, these test data are extrapolated to other industry to provide rough groupings and we have applied an across the board size distribution allocation that does not take into account the different particulate formation processes.

Small scale industrial and commercial activities were identified based on a Regional Council audit database which included around 380 activities. The activity types were compared to those described in Graham (2006) and those consistent with the categories listed were included based on the emission rates specified. Activities not specified in the existing emission categorisation were generally assumed to fall into the "no likely emission" category except in instances where additional information indicated otherwise (e.g., a number of "yard emissions" activities were identified based on comments provided in the audit). A total of 181 small scale industrial and commercial activities were included in the assessment.

5.3 Industrial and commercial emissions

Table 5.2 shows the estimated emissions to air from industrial and commercial activities in MMA. Around 76 tonnes of PM_{10} and 28 tonnes of $PM_{2.5}$ is estimated to be discharged to air per year in MMA. The average daily emissions are 171 kg/day and 70 kg/day for PM_{10} and $PM_{2.5}$ respectively (Table 5.2).

Table 5.2: Industrial and commercial emissions in MMA.

	PM_{10}		CO		NOx		SOx		$PM_{2.5}$	
	kg	g/ha	kg	g/ha	kg	g/ha	kg	g/ha	kg	g/ha
Industrial & commercial activities	171	310	80	144	140	254	688	1246	70	127
	PM_{10}		CO		NOx		SOx		$PM_{2.5}$	
	t/year	kg/ha	t/year	kg/ha	t/year	kg/ha	t/year	kg/ha	t/year	kg/ha
Industrial & commercial activities	76	137	26	47	51	93	231	418	28	50

5.4 Small scale activity emissions

The total estimated emissions from small scale industrial and commercial activities comprising industry for which emission factors are not readily available was 28 kilograms PM_{10} per day and 7.5 tonnes per year. The $PM_{2.5}$ estimates are 8 kilograms per day and 2 tonnes per year. The estimates were based on the assumption that discharges would occur for six hours a day and five days per week at the rates specified for each location.

6 OUTDOOR BURNING EMISSIONS

Outdoor burning of green wastes or household material can contribute to PM_{10} concentrations and also discharge other contaminants to air. 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 burning in a drum, incinerator or open air on residential properties in the study area.

Plan Change 13 (Air Quality) to the Regional Natural Resources Plan (PC 13) bans outdoor burning within 100 metres of a neighbouring dwelling house unless for recreational/ cultural purposes (Rule AIR-R2) or if the activity meets requirements of rules AIR-OBURN-R22 and AIR-OBURN-R23 which provide for fire-fighting, and emergency disposal of diseased carcasses and vegetation. Notwithstanding this, the source has been included in the inventory because of the potential for the activity to be carried out without households realising that it was not a permitted activity.

6.1 Methodology

Outdoor burning emissions for MMA were estimated for all seasons based on data collected during the 2018 domestic home heating survey for the wider Tauranga area. The proportion of households in the MMA that might burn garden waste was determined based on the ratio of households in the MMA airshed relative to those in Tauranga.

Emissions were calculated based on the assumption of an average weight of material per burn of 159 kilograms per cubic metre of material[2] and using the emission factors in Table 6.1 with an average fire size of 0.7 m^3 (size based on survey responses). The AP42 emission factor database includes estimates for a wide range of materials including different tree species, weeds, leaves, vines and other agricultural material. The factors selected are based on a combination of refuse (AP42 table 2.5.1), weeds and prunings (AP42 table 2.5.5). Emission factors for SOx are based on residential wood burning in the absence of emission factors for these contaminants within the AP42 database for outdoor burning. AP42 emission factors were selected in preference to European Environment Agency air pollution emission inventory guidebook (EEA, 2016) tier one assessment emission factors as the latter are based on tree slash for two species and tree pruning for two species only.

Table 6.1: Outdoor burning emission factors (AP42, 2002).

Source AP 42	PM_{10} g/kg	$PM_{2.5}$ g/kg	CO g/kg	NOx g/kg	SOx g/kg
Tables 2.5- 1 and 2.5-5	8	8	42	3	0.5

[2] Based on the average of low and medium densities for garden vegetation from (Victorian EPA, 2016)

6.2 Outdoor burning emissions

Table 6.2 shows that less than one kilogram of PM_{10} from outdoor burning could be expected per day during the winter months on average in the MMA airshed.

It should be noted, however, that there are a number of uncertainties relating to the calculations. In particular it is assumed that burning is carried out evenly throughout each season, whereas in reality it is highly probable that a disproportionate amount of burning is carried out on days more suitable for burning. 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. Outdoor burning emissions include a higher degree of uncertainty relative to domestic heating, motor vehicles and industry owing to uncertainties in the distribution of burning and potential variabilities in material density.

Table 6.2: Outdoor burning emission estimates for MMA.

	PM_{10} kg/ day	CO kg/ day	NOx kg/ day	SOx kg/ day	$PM_{2.5}$ kg/day
Summer (Dec-Feb)	0.2	0.9	0.1	0.0	0.2
Autumn (Mar-May)	0.2	1.2	0.1	0.0	0.2
Winter (June-Aug)	0.3	1.8	0.1	0.0	0.3
Spring (Sept-Nov)	0.2	1.0	0.1	0.0	0.2
	PM_{10} tonnes/ year	CO tonnes/ year	NOx tonnes/ year	SOx tonnes/ year	$PM_{2.5}$ tonnes/ year
Annual emissions	0.1	0.4	0.03	0.01	0.1

7 SHIPPING, PORT, AVIATION AND RAIL

Emissions from non-road transport and associated activities occur in the MMA at the Port, Airport and Rail network. Shipping emissions occur as vessels approach and leave the Port, manoeuvring whilst berthing and as a result of the use of auxiliary engines and boilers whilst docking. Smaller harbour vessels including tugs, coast guard and recreational boats also contribute to shipping emissions, but to a lesser extent (e.g., Peeters, 2018). Other emissions at the Port include particulate (TSP, PM_{10} and $PM_{2.5}$) associated with the loading and unloading of cargo. Combustion emissions also occur as a result of cargo handling equipment and trucks visiting the Port. Other sources of PM_{10} and $PM_{2.5}$ include open storage of material, brake and tyre wear and use of roads.

The use of diesel engines in rail is typically only a minor contributor to urban air pollution in New Zealand. Similarly, aviation is not a major contributor to particulate matter especially at Regional Airports. The Tauranga airport is located in the Mount Maunganui airshed and has a low volume of commercial flights and relatively small aircraft. An emission inventory prepared for Tauranga in 2018 assessed the quantity of PM_{10} and other contaminants from shipping, the port, aviation and rail.

MARPOL Annex VI is the part of the IMO (International Maritime Organization) Marine Pollution Convention and addresses impact of air pollution from shipping activities on human health and the environment including climate change and ozone layer depletion. It specifies a limit of 0.5% sulphur fuels on all ships, or alternative measures such as installation of engine exhaust scrubbers to filter sulphur dioxide emissions. This assessment estimates shipping emissions including the impact of MARPOL fuel specifications and the use of scrubbers in the shipping fleet and with shipping volumes for the year ending 30 June 2022.

7.1 Methodology

7.1.1 Shipping

The methodology for assessing emissions from shipping was taken from the USEPA "Current Methodologies in Preparing Mobile Source Port-Related Emissions Inventories (ICF International, 2009). That report details three approaches for ocean going vessels: a detailed inventory, a mid-tier assessment and a port matching process.

Emissions from ocean going vessels that call at a Port vary depending on vessel size, fuel quality and the time spent at different speeds. A call refers to one entrance and one clearance of a vessel from the Port Authority area. A shift refers to a movement within the Port Authority Area as vessels may move from berth to berth during a call. Hotelling is the time spent stationary at Port during which it uses its auxiliary engine for power. Activity data for shipping includes the number of calls for different vessel sizes, the average number of shifts and the time spent in Port. Speeds are broken down into cruise speed (94% of maximum speed), reduced speed (harbour reduced speed zone – 9-12 knots in most areas) and manoeuvre speed (typically 3-8 knots).

For the purposes of assessing the contribution of shipping and port activities the shipping discharge was limited to emissions assessed at a reduced speed within the harbour area as well as a three kilometre radius from the harbour entry.

Emissions from ocean going vessels were calculated using equation 7.1 which was applied to both the main propulsion engine and the auxiliary engine using the load factor assumptions from Table 7.2.

Equation 7.1 $E = P \times LF \times A \times EF$

Where:

E = Emissions (grams)

P = Maximum continuous rating power (kW)

LF = Load Factor (percent of vessels total power)

A = Activity (hours)

EF = Emission Factor (g/kWh)

A mid-tier assessment approach was undertaken using information on the number of calls by ship type and using the average power rating and load factors for the vessel type.

Data on the number of calls for different vessel types and the time in Port was obtained from the Port of Tauranga (pers comm, Joey McKenzie, 2022). Vessels classified as miscellaneous were assumed to have the same average rating and loadings as the general cargo vessels.

Emission factors for shipping were taken from (ICF International, 2009) and are shown in Table 7.1. Emission factors are considered constant down to loads of 20% and increase for lower loads. Low load adjustment factors from ICF International (Table 2-15, 2009) were used when loads were estimated at less than 20%. ICF International, (2009) indicated that prior to MARPOL implementation most ocean-going vessels operated their main propulsion engines on residual oil (RO)/ heavy fuel oil (HFO). Post MARPOL implementation, the appropriate emission factors are MGO 0.5% sulphur. One complicating variable is that the IMO granted the shipping industry the exception to using 0.5% sulphur fuels if the ship was fitted with SO_2 scrubbers. Whilst the scrubbers remove SO_2 to a greater extent than the 0.5% sulphur fuel, they do not reduce all other contaminants to the same extent and produce sludge containing carcinogens and heavy metals that is dumped overboard in the form of wash-water even with so-called closed loop scrubbers (Comer et al., 2020).

Load factors are 83% for ships at cruise speed and for lower speeds are calculated using propeller law as per Equation 7.2. The maximum speed per vessel type was calculated using equations developed for the Port of Auckland Inventory (table 4, Peeters, 2018).

Equation 7.2: Load Factor = $(\text{Average speed}/\text{Maximum speed})^3$

Figure 7.1: Tauranga Harbour and shipping berths at the Port (source Port of Tauranga).

Emissions from vessels whilst stationary at Port also need to be assessed as the auxiliary engines are used during this time to provide power to the ship unless shore based power is utilised. No shore based power is available to ships from the Port of Tauranga. The load factors used to assess auxiliary emissions whilst stationary at Port (referred to as hoteling) are shown in Table 7.2 along with the average power rating of auxiliary engines for different vessels. Time spent hoteling was calculated using the average time in Port less the approach and manoeuvring times (shown in Table 7.3).

In addition to use of auxiliary to provide power at Port many vessels using heavy oils (those operating with scrubbers) use a boiler when the main engines are shut down to heat residual oil to make it fluid enough to use in diesel engines and to provide hot water. Table 7.3 (from (ICF International, 2009) shows the auxiliary boiler energy default kW ratings for different vessels. Emissions from the boilers have been calculated using the steam turbine emission factors (Table 7.1) as specified in ICF International (2009), the boiler energy ratings (kW) and the time in mode (hours hoteling). The exception is the tankers which are unlikely to contain onboard boilers owing to the likely smaller size of these vessels at the Tauranga Port (Peeters, 2018). The Port of Auckland inventory notes that the smaller tankers used there tend to use hydraulic pumps powered by the auxiliary engines and uses the auxiliary engine manoeuvring power for the emission estimates (Peeters, 2018).

The impact of scrubbers on emissions was estimated using data from Comer et al., (2020). Comer et al., (2020) shows that scrubbers reduced PM_{10} and $PM_{2.5}$ from RO (2.6% S) by 79% relative to RO (2.6% S) without scrubbers and by 98% for SO_2. There was also an 11% reduction in CO and no reduction in NOx. They also note that PM_{10} emission are around 61% higher for a scrubber using RO than for MGO (0.1% S) required by some ports.

Emission factors for shipping for the original assessment (from ICF International, (2009)) and estimates for ships using scrubbers are shown in Table 7.2. It is noted that the 2018 estimates are based primarily of RO (heavy fuel oil) whereas the post MARPOL emission factors are for the MGO (0.5% S) fuels. This shows a reduction in PM_{10} emissions of 76%-78% for the 0.5% sulphur MGO relative to RO and a similar percentage reduction for PM_{10} for RO with scrubbers. Whilst Table 7.2 shows that the impact of using scrubbers in terms of PM_{10} is about the same as fuel switching from 2.7% to 0.5% sulphur, ships using scrubbers will have additional emissions from boiler systems as detailed below. Thus, data on the proportion of ships that have scrubbers installed is required for this assessment. It is noted that the boiler PM_{10} emissions will be significantly less (76%) than prior to MARPOL.

Osipova et al., (2021) identifies 81297 active ships in 2019 and the notes that by the end of 2020 around 4341 ships (5.3%) were to have had scrubbers installed. A breakdown by ship type is also provided in Osipova et al., (2021). This shows that the majority of the scrubbers (74%) are on bulk carriers, container ships and oil tankers. Whilst bulk carriers having the largest number of scrubber outfitted ships (at 1246), this represents only 10% of the bulk carrier fleet. In contrast 34% of cruise ships (but less than 200 ships) are outfitted with scrubbers.

Emissions from recreational vessels and harbour vessels were not included in the assessment. For the Auckland inventory harbour and recreational vessels only comprised a small proportion of the emissions.

Table 7.1: Emission factors for shipping (ICF International, 2009)

	Fuel + S content	PM_{10} g/kWh	CO g/kWh	SOx g/kWh	NOx* g/kWh	$PM_{2.5}$ g/kWh
Slow speed diesel	RO 2.7%	1.42	1.4	10.29	18.1	1.31
	MDO 1%	0.45	1.4	3.62	17	0.42
	MGO 0.5%	0.31	1.4	1.81	17	0.28
	MGO 0.1%	0.19	1.4	0.36	17	0.17
Medium speed diesel	RO 2.7%	1.43	1.1	11.24	14	1.32
	MDO 1%	0.47	1.1	3.97	13.2	0.43
	MGO 0.5%	0.31	1.1	1.98	13.2	0.29

	MGO 0.1%	0.19	1.1	0.40	13.2	0.17
Gas turbine	RO 2.7%	1.47	0.2	16.1	6.1	1.35
	MDO 1%	0.58	0.2	5.67	5.7	0.53
	MGO 0.5%	0.35	0.2	2.83	5.7	0.32
	MGO 0.1%	0.17	0.2	0.57	5.7	0.15
Steam turbine	RO 2.7%	1.47	0.2	16.1	2.1	1.35
	MDO 1%	0.58	0.2	5.67	2.0	0.53
	MGO 0.5%	0.35	0.2	2.83	2.0	0.32
	MGO 0.1%	0.17	0.2	0.57	2.0	0.15
Auxiliary Engine	RO 2.7%	1.44	1.1	11.98	14.7	1.32
	MDO 1%	0.49	1.1	4.24	13.9	0.45
	MGO 0.5%	0.32	1.1	2.12	13.9	0.29
	MGO 0.1%	0.18	1.1	0.42	13.9	0.17

* ICF International, (2009) indicates that an adjustment factor of 0.8 can be applied to NOx emissions for a 2015 assessment to take into account international standards relating to NOx emissions from shipping.

RO = residual oil, MGO = marine gas oil, MDO marine diesel oil

Table 7.2: Emission factors for shipping (ICF International, 2009) and estimated for ships using RO with a scrubber based on (Comer et al., 2020)

	Fuel + S content	PM_{10} g/kWh	% change PM_{10} %	Scrubber PM_{10} g/kWh	% change PM_{10} %	SO_2 g/kWh	% change SO_2 %	Scrubber SO_2 g/kWh	% change SO_2 %
Slow speed diesel	RO 2.7%	1.42	78%	0.3	79%	10.29	82%	0.2	98%
	MGO 0.5%	0.31				1.81			
Medium speed diesel	RO 2.7%	1.43	78%	0.3	79%	11.24	82%	0.2	98%
	MGO 0.5%	0.31				1.98			
Gas turbine	RO 2.7%	1.47	76%	0.31	79%	16.1	82%	0.3	98%
	MGO 0.5%	0.35				2.83			
Steam turbine	RO 2.7%	1.47	76%	0.31	79%	16.1	82%	0.3	98%
	MGO 0.5%	0.35				2.83			
Auxiliary Engine	RO 2.7%	1.44	78%	0.3	79%	11.98	82%	0.2	98%
	MGO 0.5%	0.32				2.12			

RO = residual oil, MGO = marine gas oil,

Table 7.3: Average engine power, speeds, load factors and boiler energy defaults (ICF International, 2009)

Ship Type	Average propulsion engine (kW)	Average Auxiliary Engines			Boiler Energy default – hotel (kW)	LF (Aux hoteling)	LF (Aux reduced speed)	LF (Aux cruise)	LF (Aux manoeuvre)	Cruise speed (knots)
		Number	Power each (kW)	Total Power						
Bulk carrier	8000	2.9	612	1776	371	0.1	0.30	0.15	0.45	14.5
Container ship	30900	3.6	1889	6800	109	0.19	0.27	0.17	0.45	21.6
Cruise ship	39600	4.7	2340	11000	506	0.64	0.25	0.13	0.48	20.9
General cargo	9300	2.9	612	1776	1000	0.22	0.80	0.80	0.80	15.2
Roll on roll off	11000	2.9	983	2850	106	0.26	0.27	0.17	0.45	16.8
Reefer	9600	4	975	3900	109	0.32	0.30	0.15	0.45	19.5
Tanker	9400	2.7	735	1985	464	0.26	0.34	0.20	0.67	14.8

Table 7.4: Activity data for shipping (pers comm, Joey McKenzie, Port of Tauranga, 2022)

Classification	No of calls call/year	Days in Port days/year
Bulk carrier	442	1661
Container ship	638	741
Cruise ship		
General cargo	58	266
Roll on roll off	0	
Reefer	202	281
Tanker	173	475
Miscellaneous	13	42

Estimates of emissions post full implementation of MARPOL are based on the methodology outlined above with the following assumptions:

- The number of ships of each type with scrubbers in MMA are based on the calls/ year multiplied by the estimated percentage with scrubbers (from Comer et al., 2020).
- No auxiliary boiler emissions from ships using 0.5% sulphur fuels (all ships except those with scrubbers).

7.1.2 Cargo Handling

Loading and unloading of bulk dry materials can result in dust emissions including particles in the PM_{10} and $PM_{2.5}$ size fractions. Emissions from cargo loading and unloading were estimated using 2022 product quantities provided by the Port of Tauranga (pers comm, Joey McKenzie, 2022) and AP42 emission factors (Table 7.5). Emission estimates were made for logs, palm kernel, cement, coal and other bulk grains. Where product-specific emission factors were not available, emission factors from other products were used. For ship unloading emission factors for a marine-leg unloading process were used owing to the absence of emission factors for a grab drop to hopper. For palm kernel, a grain-based emission factor was used. The common grains used in developing the emission factors were wheat, corn, oat, rice soyabean and sorghum. The particles within these bulk products may have different size distributions to palm kernel and as palm kernel is finer than many of these grains the emission factor may underestimate PM_{10} and $PM_{2.5}$ emissions.

Loading and unloading of the ships and associated emissions are estimated as cargo handling emissions. The unloading of bulk cargo from these trucks to storage facilities at destinations within the MMA have been included in the industrial and commercial emissions assessment.

Table 7.5: Activity data and emission factors for cargo handling.

Product	AP42 description	SIC	PM_{10} kg/tonne product	$PM_{2.5}$ kg/tonne product
Palm kernel	9.9.1 grain unloading - shipping	SCC 3-02-005-55	0.019	0.0025
Cement – clinker	11.19.2 – truck loading crushed stone	SCC 3-05-020-32	0.0001	n/a
Coal – truck loading	Table 11.9-2		0.01	0.001
Cement	11.12.4 - loading/ unloading	SCC 3-05-011-07	0.0002	0.0002
Other grains/ dry bulk product	9.9.1 grain unloading - shipping	SCC 3-02-005-55	0.019	0.0025
Logs	AP42 memorandum		0.000145 /drop	0.000044 /drop
			Tonne/ha/year	Tonne/ha/year
Log storage	AP 42 memorandum		0.4	0.2

7.1.3 Trucks and off-road vehicles

Around 1600 heavy vehicles deliver or collect goods from the Port each day. Emissions from these vehicles include exhaust emissions, brake and tyre wear and resuspended road dusts. Exhaust and brake and tyre wear emissions from trucks were estimated using emission factors from Table 7.6 and VKT estimated based on the number of trucks per day and average distances travelled within the port of two kilometres for trucks visiting Sulphur Point (20,500 per month for 2022) and 1.6 kilometres for all other trucks (28,500 per month) (pers comm, Joey McKenzie 2022).

Emissions from off road vehicles (e.g., cargo handling equipment) include exhaust emissions and emissions from brake and tyre wear. In 2018 exhaust emissions were estimated using Regional diesel use data for motive power stationary (non-transport) from the EECA energy and emission factors from EEA (2016) (Table 7.5). In more recent years these data are not available at a regional level. Thus, no change to the 2018 volumes were assumed for the 2022 emission estimates. Emissions from brake and tyre wear for off road vehicles were calculated using VFPM brake and tyre emission factors (heavy vehicle fleet average) with VKT estimated from the off-road diesel consumption and the fuel consumption rate for heavy vehicles (kilometres per year = litres per year divided by litres per kilometre).

Table 7.6: Emission factors for diesel consumption by trucks and off road vehicles

		PM_{10}	CO	SOx*	NOx	$PM_{2.5}$
		g/litre	g/litre	g/litre	g/litre	g/litre
Off road vehicles	EEA, (2016) category 1.A.2.g.vii	2.5	13.0	39.3	0.2*	2.5

		g/VKT	g/VKT	g/VKT	g/VKT	g/VKT
Heavy truck	EEA, (2016)					0.00216
road dust		0.04				
Brake and tyre	(Jones, et al., 2011)	0.0145				0.0096

* based on sulphur content of diesel

The resuspension of PM_{10} and $PM_{2.5}$ from the movement of trucks and other port equipment on roads around the Port has been estimated using emission factors from EEA (2016). Activity data for trucks was obtained from the Port (vehicles per day x average distance travelled) and for the cargo handling equipment an estimate of VKT was made based on fuel consumption rates for heavy vehicles (VFPM) and fuel use estimates.

7.1.1 Aviation

The Tauranga Airport operates a small number of commercial scheduled flights and is also used for general aviation. The number of take/off landing cycles per year typically ranges from around 50,000 to 70,000 with around 20% being scheduled flights. The main types of commercial aircraft used at the airport are the smaller turboprop aircraft (e.g., Bombardier Dash 8 and ATR72-500s). Aircraft emissions from turbo prop engines are relatively low for all contaminants and particularly PM_{10} and $PM_{2.5}$. Table 7.7 from EEA (2016) compares the Bombardier Dash 8 emissions to larger aircraft type. Emissions from this source will be minimal owing to the types of aircraft frequenting the airport.

An estimate of aircraft emissions from Tauranga airport was made based on an average of 60,000 TLOs (20% being scheduled flights, and emission factors for the Bombardier Dash 8.

Table 7.7: Emission factors for aircraft take off and landing cycles (source EEA, 2016).

Manufacturer and aircraft	Model[3]	Engine type	Engine ID[4]	Fuel burn (kg)	PM TOTAL kg/LTO	CO kg/LTO	NOx kg/LTO	SOx kg/LTO
De Havilland Canada DHC-8-300 Dash 8 / 8Q	DHC8 314Q	Turboprop	Turboprop	242.08	0	1.54	2.33	0.2
Airbus A320 – 100/200	A320 233	Jet	3CM026	816.7	0.07	8.25	11.28	0.69
Boeing 777-200LR	B777 300ER	Jet	7GE099	3090.84	0.21	47.54	69.79	2.6
B777 300ER	B777 300ER	Jet	7GE099	3090.84	0.21	47.54	69.79	2.6
Boeing 787-8	B787 800	Jet	11GE136	1592.36	0.09	14.51	17.15	1.34
Boeing 787-9	B787 900	Jet	12RR055	1726.66	0.1	6.8	34.52	1.45
Convair CV-580	L188PF	Turboprop	Turboprop	856.47	0	0	0.88	0.72
McDonnell Douglas MD11	MD11ER F	Jet	2GE049	2627.91	0.17	18.28	38.17	2.21
Saab SF340A/B	SF340A	Turboprop	Turboprop	145.06	0	0.95	0.89	0.12
Fairchild (Swearingen) SA26 / SA226	SA 226TC METRO II	Turboprop	Turboprop	86.48	0	1.23	0.62	0.07

7.1.2 Rail

The KiwiRail rail network for Tauranga is for freight only with a southern link from Kawerau and a northern link from Waharoa Junction and includes a number of branches within the port area (Figure 7.2). KiwiRail operates New Zealand DL class (diesel-electric) locomotives.

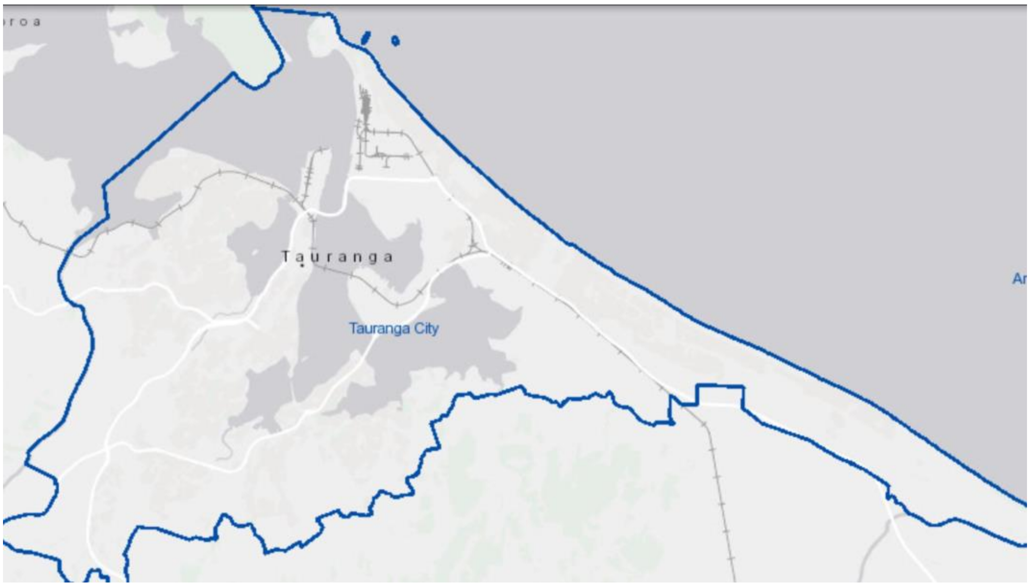


Figure 7.2: Tauranga rail network (source Stats Maps, 2018)

Emissions from rail are calculated using emission factors and fuel consumption as follows:

Emissions = fuel consumption (tonnes of diesel per day) x emission factor (kg pollutant/ tonne of diesel)

The fuel consumption for the area within the Tauranga City boundary was estimated using data on the gross tonne kilometres (GTK) within the TCC boundary. Diesel consumption was estimated by multiplying the GTK by the average diesel consumption rate per GTK across the national rail network (litres per GTK).

The Tauranga air emission inventory estimated around 110,000,000 Gross Tonne kilometres (GTKs) occur across the Tauranga area. Around one quarter of this (28,000,000) was assumed to occur within the MMA airshed based on the location of the rail network. The diesel consumption rate per GTK was provided by KiwiRail (pers com J, Jones, 2018) as 5.7 litres per 1000 GTK (average for New Zealand rail fleet).

Emission factors for rail are shown in Table 7.8 and are from the European Inventory Guidebook (EEA/EMEP, 2016).

Table 7.8: Emission factors for rail (source EEA, 2016).

	PM_{10}	CO	SOx*	NOx	$PM_{2.5}$
	kg/tonne fuel	kg/tonne fuel	kg/tonne fuel	kg/tonne fuel	kg/tonne fuel
Line-haul rail	1.2	18	0.02	63	1.1
Upper CI (95%)	3	21		93	3
Lower CI (95%)	0.45	5		29	0.42

*SOx emissions calculated based on the sulphur content of diesel in New Zealand

7.2 Aviation, shipping, rail and port emissions

Table 7.9 shows the estimated emissions from shipping, cargo handling, off road vehicles, aviation and rail. Shipping is the largest non-road transport contributor to $PM_{2.5}$, SOx and NOx emissions with around 17, 113 and 749 tonnes per year respectively. The handling of cargo (primarily grains and logs) is the main source of PM_{10} contributing 50 tonnes per year.

Table 7.10 shows total shipping emissions by vessel type and Tables 7.11 and 7.12 show emissions for approach/ departure and hoteling by ship type. Most emissions occur whilst at berth as a result of running of auxiliary engines for providing power to the ship. Container ships were the largest contributors to discharges to air from shipping in 2022. Seasonal variability in the daily shipping emissions are shown in Table 7.13.

Table 7.9: Aviation, rail, shipping and port emissions in kilograms per day (winter) and tonnes per year

	PM_{10} kg/day	CO kg/day	NOx kg/day	SOx kg/day	$PM_{2.5}$ kg/day
Port Activities					
- shipping	59	198	2510	382	56
- cargo handling	131	0	0	0	32
- trucks/ off road vehicles/handling equipment - exhaust	29	155	469	0.2	29
- trucks/ off road vehicles - brake & tyre wear	0.4				0.2
- trucks/ off road vehicles – road dust	1.1				0.1
Total Port	221	353	2979	382	117
Aviation	0	51	77	7	0
Rail	0	7	23	0	0
Total non-road transportation	222	410	3079	389	117
	PM_{10} tonnes/year	CO tonnes/year	NOx tonnes/year	SOx tonnes/year	$PM_{2.5}$ tonnes/year
Port Activities					
- shipping	17	59	749	113	17
- cargo handling	50	0	0	0	12
- trucks/ off road vehicles/handling equipment - exhaust	11	57	171	0.1	11
- trucks/ off road vehicles - brake & tyre wear	0.1				0.3
- trucks/ off road vehicles – road dust	0.4				0.1
Total Port	78	116	920	113	40
Aviation	0	18	28	2	0
Rail	0.2	2	8	0	0
Total other-transportation	78	136	957	116	40

Table 7.10: Shipping emissions by ship type

	PM_{10} tonnes/year	CO tonnes/year	NOx tonnes/year	SOx tonnes/year	$PM_{2.5}$ tonnes/year
Bulk carrier	2.7	8.9	112.8	16.8	2.5
Container ship	9.3	30.8	389.0	55.6	8.4
Cruise ship	0.0	0.0	0.0	0.0	0.0
General cargo	0.8	2.9	36.9	5.6	0.8
Roll on roll off	0.0	0.0	0.0	0.0	0.0
Reefer	2.8	9.5	120.3	18.4	2.5

Tanker	2.2	7.4	93.1	18.6	2.5
Miscellaneous	0.1	0.0	6.0	0.1	0.1
Total	18	60	758	115	17

Table 7.11: Shipping emissions in transit by vessels type – cruise/ reduced speed and manoeuvring

	PM_{10} tonnes/year	CO tonnes/year	NOx tonnes/year	SOx tonnes/year	$PM_{2.5}$ tonnes/year
Bulk carrier	0.3	1.2	14.0	2.0	0.3
Container ship	1.6	6.1	71.7	10.1	1.5
Cruise ship	-	-	-	-	-
General cargo	0.1	0.2	2.3	0.3	0.0
Roll on roll off	-	-	-	-	-
Reefer	0.1	0.3	4.2	0.6	0.1
Tanker	0.2	0.6	7.8	1.1	0.2
Miscellaneous	0.0	0.0	0.5	0.1	0.0
Total	2.0	7.5	91.7	12.5	1.8

Table 7.12: Auxiliary hoteling emissions by vessel type

	PM_{10} tonnes/year	CO tonnes/year	NOx tonnes/year	SOx tonnes/year	$PM_{2.5}$ tonnes/year
Bulk carrier	2.3	7.7	98.0	13.6	2.0
Container ship	7.2	24.5	314.8	42.1	6.6
Cruise ship	-	-	-	-	-
General cargo	0.8	2.7	34.6	5.2	0.7
Roll on roll off	-	-	-	-	-
Reefer	2.7	9.2	116.1	17.7	2.4
Tanker	1.9	6.4	81.2	11.7	1.7
Miscellaneous	0.1	-	5.5	-	0.1
Total	15	51	650	90	14

Table 7.13: Seasonal variability in emissions from ocean going vessels

	PM_{10} kg/day	CO kg/day	NOx kg/day	SOx kg/day	$PM_{2.5}$ kg/day
January	36	120	1519	228	34
February	40	132	1682	257	37
March	52	172	2181	330	48
April	49	164	2080	316	46
May	52	173	2193	334	49
June	55	181	2301	348	51
July	59	198	2510	382	56
August	52	173	2196	333	49
September	47	155	1963	297	44
October	46	154	1957	298	43
November	47	156	1986	302	44
December	45	149	1889	288	42

8 UNCERTAINTY

The uncertainties associated with the input variables for domestic heating include the emission factors for each appliance type, the fuel quantities used and the number of households using different heating methods. The sampling uncertainty for the household survey of 5% was used for the latter variable (assuming no systemic bias) and expert judgement for emission factors (30%) and fuel quantities (25%).

The emissions from domestic home heating were estimated to have a medium level of uncertainty based on the above assessment

There are several areas of uncertainty around the emissions estimates from motor vehicles. The fleet weighted average emission factors contain assumptions around average speeds, cold starts and the distribution of diesel and petrol vehicles as well as the allocation of vehicles to different engine capacity or weight classes. The NZTA VKT data provide another source of potential uncertainty.

The authors of VEPM provide an expert judgement on the uncertainty being in the range of 20-100% depending on the make-up of the fleet being investigated. In particular it notes that *"It is anticipated that if the fleet consisted entirely of European vehicles uncertainty would be close to 20%. Conversely, if the fleet was predominantly of Japanese origin with a high proportion of HDVs then the uncertainty could be as high as 100%"* (EFRU, 2008).

An estimate of the uncertainty of the PM_{10} motor vehicle tailpipe emissions was made based on the following uncertainties: fleet weighted average emissions – exhaust 40% and brake and tyre wear 60% and VKT estimates 20%. Road dust PM_{10} estimates were assumed to contain an uncertainty of 50%.

The emissions for motor vehicle exhaust, brake and tyre wear emissions and road dust were estimated to have a medium level of uncertainty based on the above assessment.

The uncertainty for the industrial and commercial emissions was estimated for PM_{10} based on the kg/day emissions for the months of July. The emission estimates include a range of uncertainties. The uncertainty has been quantified based on the statistical approach outlined in Appendix B. Because of some limitations in the assumptions underpinning this approach the resulting calculation has been categorised as either low (less than 20%), medium (20-40%) or high (more than 40%). The uncertainties used varied depending on the nature of the industrial information available. Lower uncertainties were assigned (15%) for continuous emission sampling compared with 40%- 100% for emission factors depending on AP42 rating. Activity data uncertainty ranged from 10% to 30% depending on the source of the information. Smaller industrial contributors were collated and allocated an emission uncertainty estimate of 40%.

The PM_{10} uncertainties from industrial and commercial activities collectively were estimated to be medium.

The small-scale activity emissions have been treated as a separate source for the purposes of assessing uncertainty. The uncertainty has been estimated to be high based on expert judgement.

The key areas of uncertainty regarding emissions estimates from outdoor burning are the quantities of material burnt per day and the emission factors. The uncertainty around the quantities has been estimated at around 80% because of potential errors in householder estimates of quantities burnt and the potential for burning not to be spread evenly across the seasons (i.e., more emissions on some days and less on others). The uncertainty around emission factors of 50% was assumed.

The combined uncertainty around outdoor burning emissions was estimated to be high.

The uncertainties were assessed for shipping and cargo handling as the key contributors to emissions from the non-road transportation.

There are a number of uncertainties in the calculations of emissions from shipping. The mid-tier methodology assumes average kW ratings based on ship classifications rather than using individual vessel data. Emission factors, load assumptions and speed assumptions are other sources of uncertainty.

The uncertainty for shipping was estimated at low to medium based on estimated uncertainties of 40% emission factors, 30% load factors, 40% kW ratings and 30% average speeds.

Cargo handling emission estimates collectively had individual source estimates and collective emission estimates with a high level of uncertainty. The main area of uncertainty is the emission factors as these require the best matching of materials or processes at times. The assessment was based on activity data uncertainty of 20% and emission factor uncertainties ranging from 40% to 100%.

9 TOTAL EMISSIONS FOR THE MMA

The total PM_{10} and $PM_{2.5}$ emissions per year for the MMA for 2022 was 174 and 74 tonnes respectively. Industry, port activities and shipping were all significant contributors to annual and daily winter PM_{10} (Figure 9.1).

The main sources of annual and winter $PM_{2.5}$ are industrial activities, shipping and port activities (Figure 9.2).

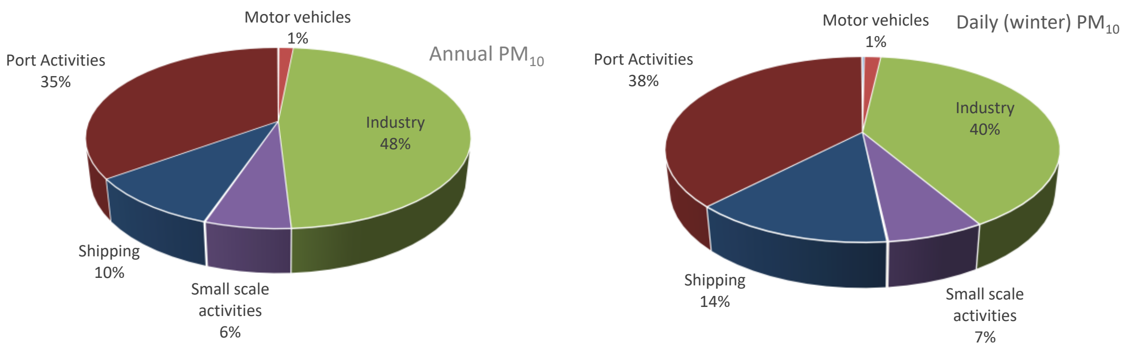


Figure 9.1: Relative contribution of sources to annual PM_{10} and daily winter PM_{10} emissions in MMA.

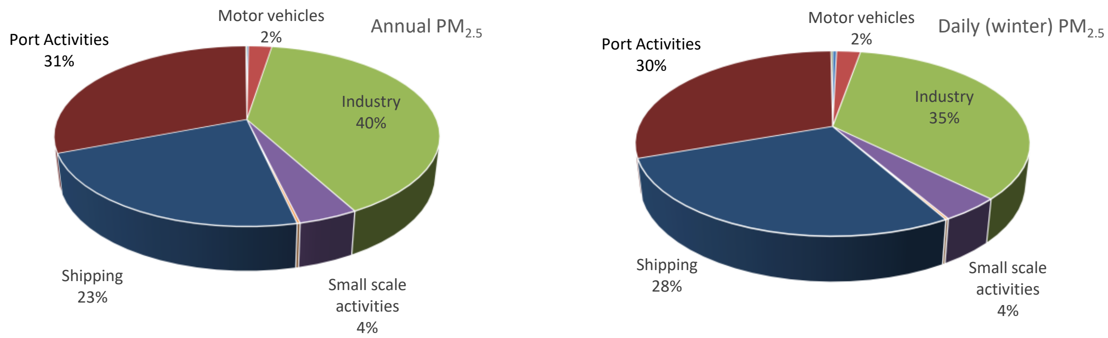


Figure 9.2: Relative contribution of sources to annual $PM_{2.5}$ and daily winter $PM_{2.5}$ in MMA.

Figures 9.3 and 9.4 show motor vehicles and shipping are the main sources of CO and shipping is the main source of NOx emissions in MMA. Industry is the largest contributor to SOx emissions contributing around 232 of the 348 tonnes per year discharged in the MMA (Figure 9.5).

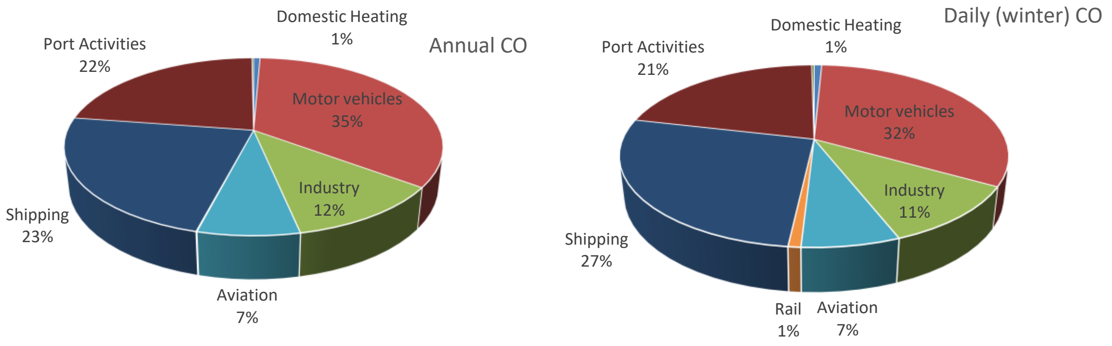


Figure 9.3: Relative contribution of sources to daily winter and annual average CO emissions in MMA

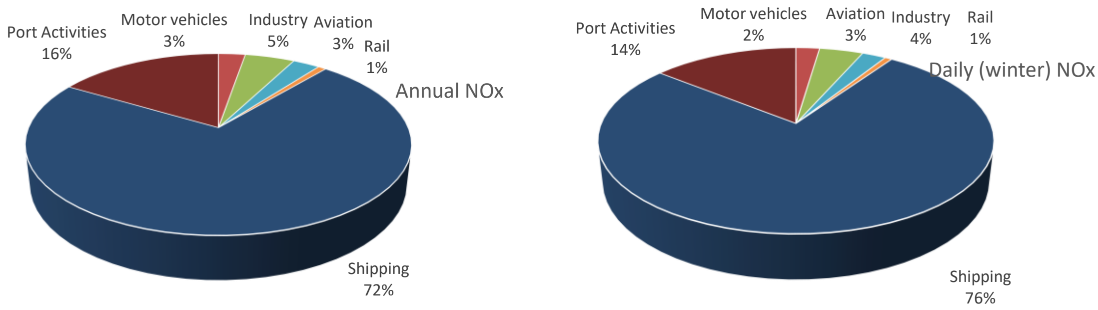


Figure 9.4: Relative contribution of sources to annual (left) and daily winter (right) NOx emissions in MMA.

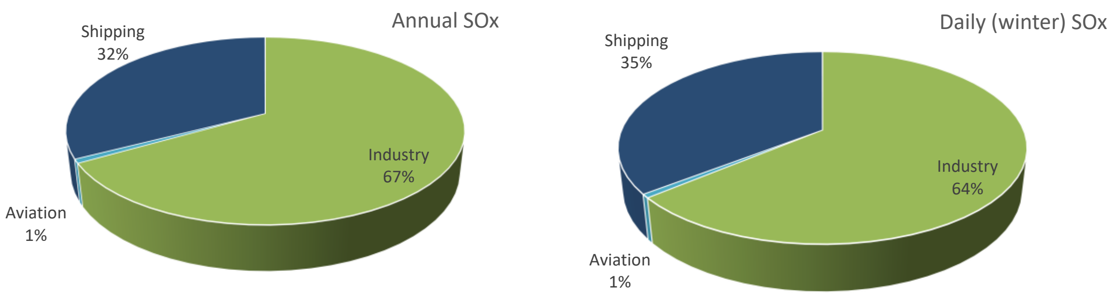


Figure 9.5: Relative contribution of sources to daily winter and annual average SOx emissions in MMA

Seasonal variations in PM_{10} and other contaminant emissions are shown in Tables 9.3 to 9.7

Table 9.1: Annual average emissions in MMA by source and contaminant (tonnes/year)

	PM_{10} tonnes/year	CO tonnes/year	Nox tonnes/year	Sox tonnes/year	$PM_{2.5}$ tonnes/year
Domestic Heating	<1	2	<1	<1	<1
Motor vehicles	3	87	28	<1	2
Industry	83	29	51	232	29
Small scale activities	11				3
Aviation	<1	18	28	2	<1
Rail	<1	<1	8	<1	<1
Shipping	17	59	749	113	17
Port Activities	61	57	171	0	23
Outdoor burning	<1	<1	<1	<1	<1
Total	174	253	1036	348	74

Table 9.2: Daily (winter) average emissions in MMA by source and contaminant (kg/day)

	PM_{10} kg/day	CO kg/day	Nox kg/day	Sox kg/day	$PM_{2.5}$ kg/day
Domestic Heating	1	15	<1	<1	1
Motor vehicles	7	239	76	<1	5
Industry	171	80	140	688	71
Small scale activities	29			<1	8
Aviation	<1	51	77	7	<1
Rail	<1	<1	23	<1	<1
Shipping	59	198	2510	382	56
Port Activities	162	155	469	0	61
Outdoor burning	<1	2	<1	<1	<1
Total	430	739	3295	1077	203

Table 9.3: Monthly variations in PM_{10} emissions in MMA by source (kg/day)

	Domestic Heating kg/day	Motor vehicles kg/day	Industry kg/day	Small scale activities kg/day	Aviation kg/day	Rail kg/day	Shipping kg/day	Port Activities kg/day	Outdoor burning kg/day	Total kg/day
January	<1	7	242	29	<1	<1	36	153	<1	468
February	<1	7	260	29	<1	<1	40	173	<1	508
March	<1	7	242	29	<1	<1	52	170	<1	501
April	<1	7	248	29	<1	<1	49	139	<1	472
May	<1	7	242	29	<1	<1	52	173	<1	504
June	1	7	174	29	<1	<1	55	177	<1	443
July	1	7	171	29	<1	<1	59	162	<1	430
August	1	7	171	29	<1	<1	52	185	<1	445
September	<1	7	248	29	<1	<1	47	171	<1	502
October	<1	7	242	29	<1	<1	46	157	<1	482
November	<1	7	248	29	<1	<1	47	144	<1	476
December	<1	7	242	29	<1	<1	45	201	<1	524

Table 9.4: Monthly variations in CO emissions in MMA by source (kg/day)

	Domestic Heating	Motor vehicles	Industry	Small scale activities	Aviation	Rail	Shipping	Port Activities	Outdoor burning	Total
	kg/day	kg/day	kg/day	kg/day	kg/day	kg/day	kg/day	kg/day	kg/day	kg/day
January	<1	239	80		51	<1	120	155	1	646
February	<1	239	81		51	<1	132	155	1	659
March	<1	239	80		51	<1	172	155	1	698
April	1	239	80		51	<1	164	155	1	691
May	7	239	80		51	<1	173	155	1	706
June	13	239	80		51	<1	181	155	2	722
July	15	239	80		51	<1	198	155	2	739
August	12	239	80		51	<1	173	155	2	712
September	4	239	80		51	<1	155	155	1	685
October	1	239	80		51	<1	154	155	1	681
November	<1	239	80		51	<1	156	155	1	683
December	<1	239	80		51	<1	149	155	1	674

Table 9.5: Monthly variations in NOx emissions in MMA by source (kg/day)

	Domestic Heating	Motor vehicles	Industry	Small scale activities	Aviation	Rail	Shipping	Port Activities	Outdoor burning	Total
	kg/day	kg/day	kg/day	kg/day	kg/day	kg/day	kg/day	kg/day	kg/day	kg/day
January	<1	76	140		77	23	1519	469	<1	2304
February	<1	76	143		77	23	1682	469	<1	2470
March	<1	76	140		77	23	2181	469	<1	2966
April	<1	76	141		77	23	2080	469	<1	2866
May	<1	76	140		77	23	2193	469	<1	2978
June	<1	76	141		77	23	2301	469	<1	3087
July	<1	76	140		77	23	2510	469	<1	3295
August	<1	76	140		77	23	2196	469	<1	2981
September	<1	76	141		77	23	1963	469	<1	2748
October	<1	76	140		77	23	1957	469	<1	2742
November	<1	76	141		77	23	1986	469	<1	2772
December	<1	76	140		77	23	1889	469	<1	2673

Table 9.6: Monthly variations in SOx emissions in MMA by source (kg/day)

	Domestic Heating	Motor vehicles	Industry	Small scale activities	Aviation	Rail	Shipping	Port Activities	Outdoor burning	Total
	kg/day	kg/day	kg/day	kg/day	kg/day	kg/day	kg/day	kg/day	kg/day	kg/day
January	<1	<1	824		7	<1	228	0.2	<1	1059
February	<1	<1	859		7	<1	257	0.2	<1	1123
March	<1	<1	780		7	<1	330	0.2	<1	1117
April	<1	<1	876		7	<1	316	0.2	<1	1199
May	<1	<1	354		7	<1	334	0.2	<1	696
June	<1	<1	464		7	<1	348	0.2	<1	819
July	<1	<1	688		7	<1	382	0.2	<1	1077
August	<1	<1	381		7	<1	333	0.2	<1	720
September	<1	<1	500		7	<1	297	0.2	<1	804
October	<1	<1	871		7	<1	298	0.2	<1	1175
November	<1	<1	399		7	<1	302	0.2	<1	708
December	<1	<1	645		7	<1	288	0.2	<1	939

Table 9.7: Monthly variations in $PM_{2.5}$ emissions in MMA by source (kg/day)

	Domestic Heating	Motor vehicles	Industry	Small scale activities	Aviation	Rail	Shipping	Port Activities	Outdoor burning	Total
	kg/day	kg/day	kg/day	kg/day	kg/day	kg/day	kg/day	kg/day	kg/day	kg/day
January	<1	5	82	8	<1	<1	34	60	<1	190
February	<1	5	86	8	<1	<1	37	64	<1	201
March	<1	5	82	8	<1	<1	48	62	<1	207
April	<1	5	83	8	<1	<1	46	59	<1	202
May	<1	5	82	8	<1	<1	49	63	<1	208
June	1	5	71	8	<1	<1	51	64	<1	200
July	1	5	70	8	<1	<1	56	61	<1	202
August	1	5	70	8	<1	<1	49	64	<1	198
September	<1	5	83	8	<1	<1	44	63	<1	204
October	<1	5	82	8	<1	<1	43	60	<1	200
November	<1	5	83	8	<1	<1	44	59	<1	201
December	<1	5	82	8	<1	<1	42	66	<1	204

9.1.1 Uncertainty

The uncertainty for the total PM_{10} emission estimate was assessed by combining the individual source uncertainties addition as per Appendix B. The total uncertainty for the inventory PM_{10} emission estimate for MMA is around 28% (uncertainty rating of medium).

9.2 Trends in PM_{10} since 2018

A comparison of the 2018 and 2022 PM_{10} emission in the MMA airshed are shown in Figure 9.6. This excludes negligible sources such as domestic heating, outdoor burning, aviation and rail PM_{10}. Figure 9.6 indicates a 24% reduction in annual PM_{10} emissions in the MMA since 2018. This occurs primarily as a result of MARPOL Annex VI as well as the absence of cruise ships in the harbour. An additional two tonnes per year of PM_{10} is anticipated if cruise ships return to 2018 levels. With the return of cruise ships the reduction in PM_{10} emissions in the airshed since 2018 reduces to 23%.

Figure 9.6 also indicates a slight increase in emissions from industrial discharges (7%) and Port Activities (8%) in the MMA since 2018. This occurs as a result of increase in the bulk solid materials handling volumes through the Port, which also impact on industrial emissions as these products are stored and handled locally. The extent to which the estimated increase reflects actual discharges is unclear as management practices may have improved in the MMA as a result of increased regulatory attention. The emission factor database relied upon for emission estimates typically provides only improved emission factors for larger scale emission control approaches such as the implementation of technologies (for example fabric filters or emission scrubbing systems.

In the absence of these increases the reduction in the MMA occurring primarily as a result of MARPOL and the absence of cruise ships would be around 29%.

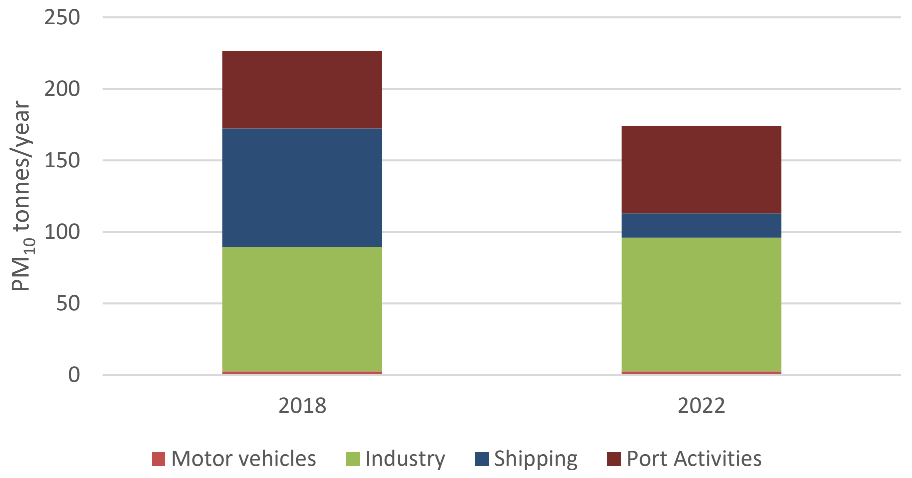


Figure 9.6: Impact of MARPOL and other changes in activities on PM_{10} in the MMA from 2018 to 2022

9.3 Trends in SOx since 2018

The estimated change in SOx emissions from 2018 to 2022 are shown in Figure 9.7. This suggests a 65% reduction in SOx which occurs as a result of shipping emissions. Whilst the majority relates to the impact of MARPOL a small reduction is also estimated as a result of the absence of cruise ships. The return of cruise ships to 2018 volumes would likely see an increase in SOx of around 12 tonnes per year, reducing the improvement in SOx emissions to around 63%.

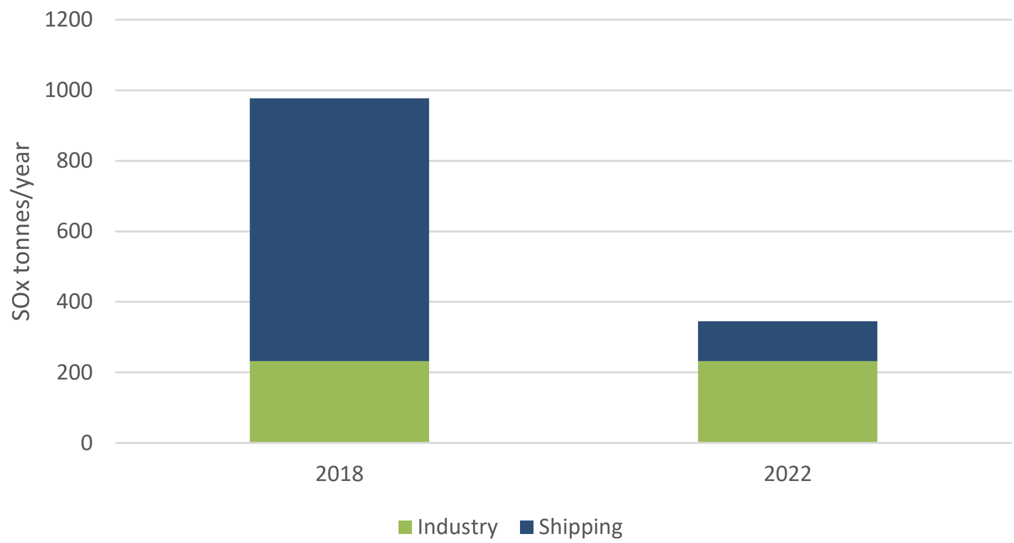


Figure 9.7: Impact of MARPOL and other activities (including a reduction in cruise ships) on SOx in the MMA from 2018 to 2022

It is also noted that whilst the industrial SOx contribution remains unchanged from 2018 to 2022 the distribution of these emissions between activities has changed. Figure 9.8 shows the relative contribution of the main industrial SOx sources in the MMA for 2018 and 2022.

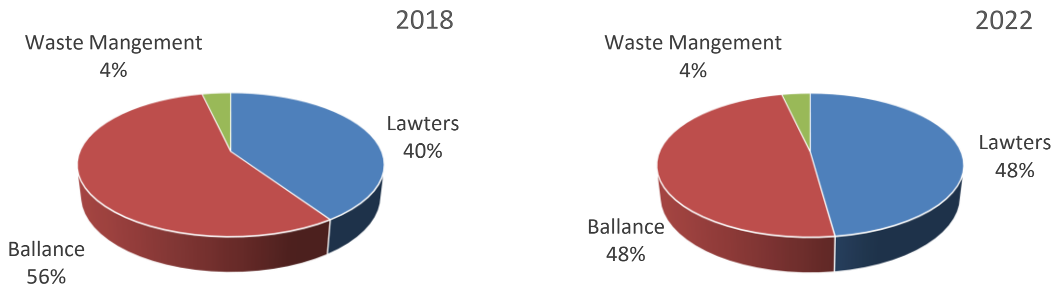


Figure 9.8: Relative contribution of industrial sources of SOx to MMA discharges in 2018 and in 2022

9.4 Spatial distribution in emissions across Mount Maunganui

The spatial distribution of contaminant emissions (as tonnes/km^2/year) across the Mount Maunganui Airshed is shown in Figures 9.9 to 9.12 .

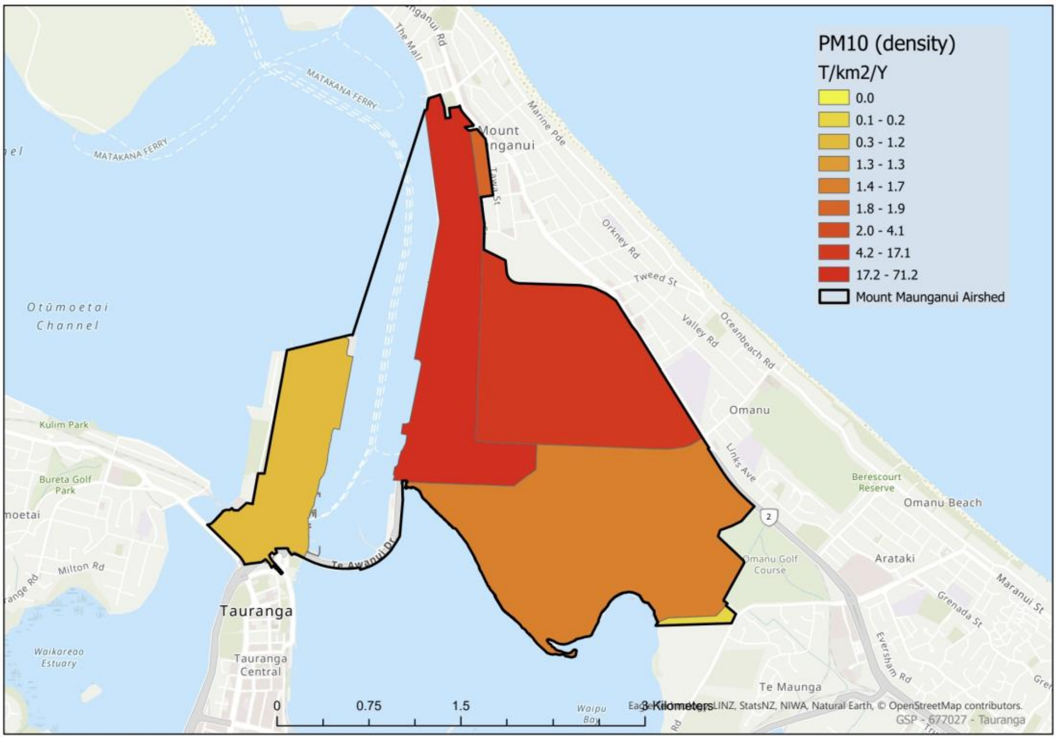


Figure 9.9: Spatial distribution in PM_{10} emissions for Mount Maunganui - 2022

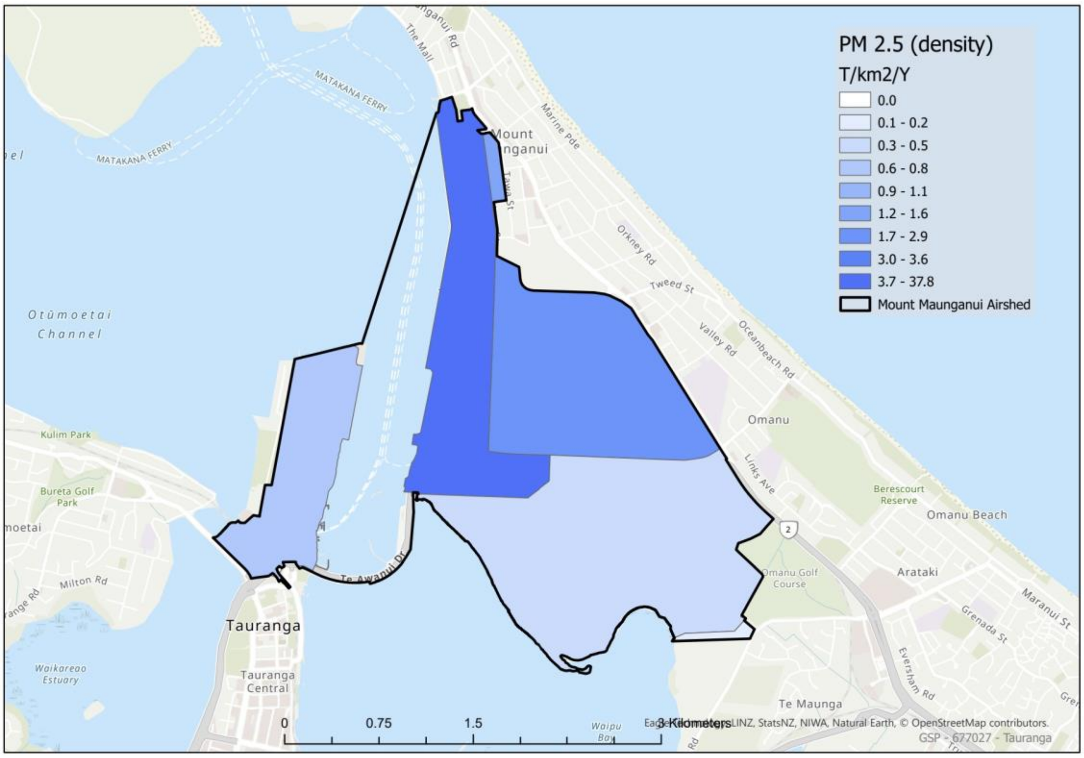


Figure 9.10: Spatial distribution in $PM_{2.5}$ emissions for Mount Maunganui - 2022

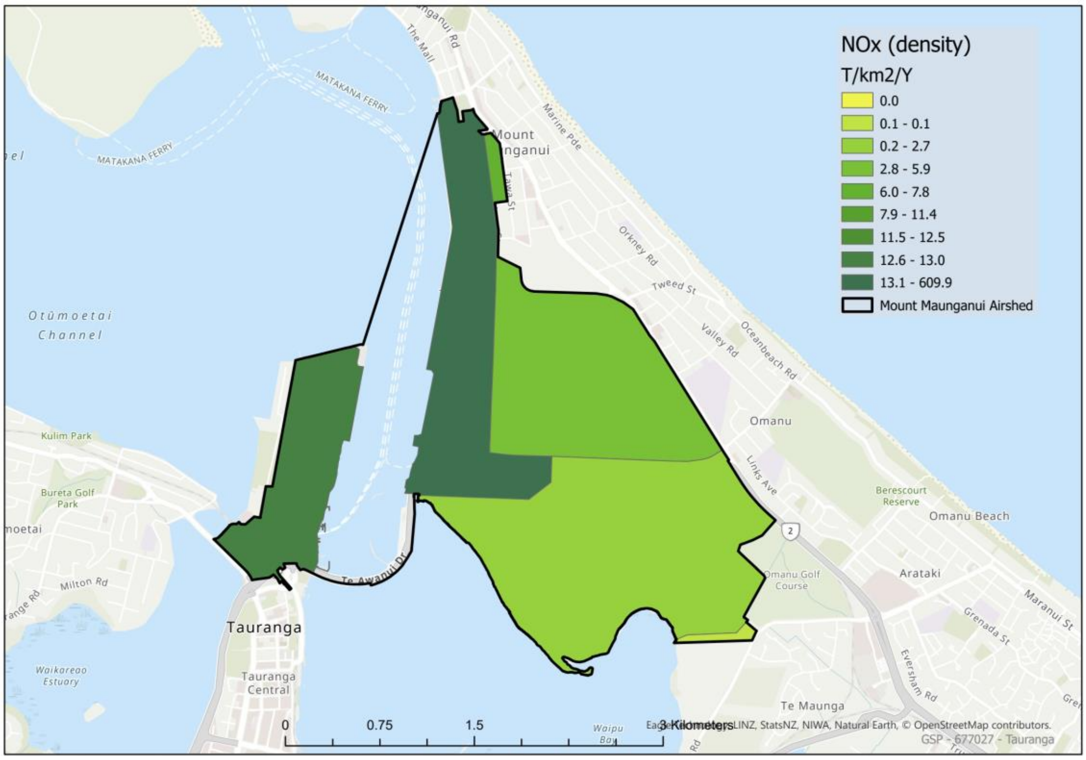


Figure 9.11: Spatial distribution in NOx emissions for Mount Maunganui - 2022

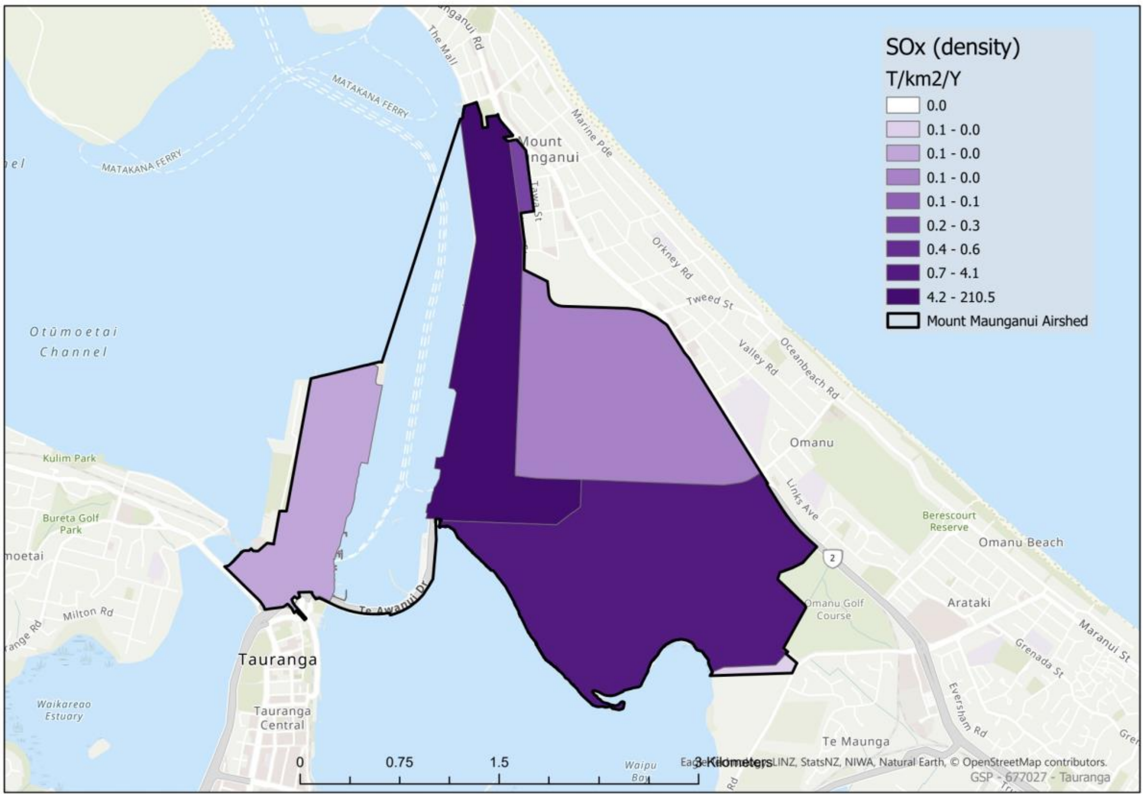


Figure 9.12: Spatial distribution in SOx emissions for Mount Maunganui - 2022

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APPENDIX A: EMISSION FACTORS FOR DOMESTIC HEATING.

Emission factors were based on the review of New Zealand emission rates carried out by Wilton et al., (2015) for the Ministry for the Environments air quality indicators programme. This review evaluated emission factors used by different agencies in New Zealand and where relevant compared these to overseas emission factors and information. Preference was given to New Zealand based data where available including real life testing of pre 1994 and NESAQ compliant wood burners (Wilton & Smith, 2006; Smith, et. al., 2008) and burners meeting the NESAQ design criteria for wood burners (Bluett et al., 2009; Smith et al., 2009).

The PM_{10} open fire emission factor was reduced in the review relative to previous factors. Some very limited New Zealand testing was done on open fires during the late 1990s. Two tests gave emissions of around 7.2 and 7.6 g/kg which at the time was a lot lower than the proposed AP42 emission factors (http://www.rumford.com/ap42firepl.pdf) for open fires and the factors used in New Zealand at the time (15 g/kg). An evaluation of emission factors for the 1999 Christchurch emission inventory revised the open fire emission factor down from 15 g/kg to 10 g/kg based on the testing of Stern, Jaasma, Shelton, & Satterfield, (1992) in conjunction with the results observed for New Zealand (as reported in Wilton, 2014). The proposed AP42 emission factors (11.1 g/kg dry) now suggest that the open fire emission factor may be lower still and closer to the result of the limited testing carried out in New Zealand. Consequently a factor of 7.5 g/kg for PM_{10} (wet weight) is proposed to be used for open fires in New Zealand based on the likelihood of the Stern et al., (1992) data being dry weight (indicating a lower emission factor), the data supporting a proposed revised AP 42 factor and the results of the New Zealand testing being around this value. It is proposed that other contaminant emissions for open fires be based on the proposed AP42 emission factors adjusted for wet weight.

The emission factor for wood use on a multi fuel burner was also reduced from 13 g/kg (used in down to the same value as the pre 2004 wood burner emission factor (10 g/kg). The basis for this was that there was no evidence to suggest that multi fuel burners burning wood will produce more emissions than an older wood burner burning wood.

Emission factors for coal use on a multi fuel burner are based on limited data, mostly local testing. Smithson, (2011) combines these data with some further local testing to give a lower emission factor for coal use on multi fuel burners. While these additional data have not been viewed, and it uncertain whether bituminous and subbituminous coals are considered, the value used by Smithson has been selected. The Smithson, (2011) values for coal burning on a multi fuel burner have also been used for PM_{10}, CO and NOx as it is our view that many of the more polluting older coal burner (such as the Juno) will have been replaced over time with more modern coal burners.

No revision to the coal open fire particulate emission factor was proposed as two evaluations (Smithson, (2011) and Wilton 2002) resulted in the same emission factor using different studies. Emissions of sulphur oxides will vary depending on the sulphur content of the fuel, which will vary by location. A value of 8 g/kg is proposed for SOx based on an assumed average sulphur content of 0.5 g/kg and relationships described in AP42 for handfed coal fired boilers (15.5 x sulphur content).

Emission factors for $PM_{2.5}$ are based on 100% of the particulate from wood burning being in the $PM_{2.5}$ size fraction and 88% of the PM_{10} from domestic coal burning. The $PM_{2.5}$ component of PM_{10} is typically expressed as a proportion. The AP42 wood stove and open fire proportion is based on 1998 data and given as 93% of the PM_{10} being $PM_{2.5}$ (http://www.epa.gov/ttnchie1/efdocs/rwc_pm25.pdf). Smithson, (2011) uses a proportion of 97% which is more consistent with current scientific understanding that virtually all the particulate from wood burning in New Zealand is less than 2.5 microns in diameter (Perry Davy, pers comm, 2014). Literature review of the proportion of PM_{10} that was $PM_{2.5}$ returns minimal information for domestic scale wood use. The technical advisory group to the Ministry for the Environment (2014) air quality indicators project on emissions advised their preference for a value of 100% and we have opted for this value for subsequent work because information is indicative of a value nearing 100%. Further investigations into this may be warranted in the future given the focus towards $PM_{2.5}$. A value of 88% from Ehrlich & Kalkoff, (2007) was used for the proportion of PM_{10} in the $PM_{2.5}$ size fraction for small scale coal burning.

An emission factor of 0.5 g/kg was proposed for NOx from wood burners based on the AP42 data because the non-catalytic burner measurements were below the detection limit but the catalytic converter estimates (and conventional burner estimates) weren't. This value is half of the catalytic burner NOx estimate.

A ratio of 14 x PM_{10} values was used for CO emission estimates as per the AP42 emissions table for wood stoves. This is selected without reference to any New Zealand data owing to the latter not being in any publically available form.

APPENDIX B: ASSESSMENT OF UNCERTAINTY

Statistical methods can be used to quantify the uncertainty associated with the emission estimates. Typically, this involves the collating of base uncertainties on variables in the emission calculation (e.g., emission factors or activity data) although EMEP/EEA also give the option of a more sophisticated stochastic simulation (Monte Carlo) analysis.

The uncertainties on variables may have been quantitatively determined (through testing) or based on expert judgement. A 95% confidence interval is used.

Formulae given in the EMEP/EEA guidebook (EEA, 2016) for carrying out a tier one statistical assessment of uncertainty are shown below. These gave the same uncertainty estimates as the equations used previously by the author (e.g., Wilton, 1998) and detailed in Topping, (1971).

Tier one statistical uncertainty from EMEP/EEA guidebook

Calculation of uncertainty when quantities are combined by adding:

$$U_{total} = \frac{\sqrt{(U_1 \times x_1)^2 + (U_2 \times x_2)^2 + \cdots + (U_n \times x_n)^2}}{x_1 + x_1 + \cdots + x_n}$$

Where:

x_i are the quantities.

U_i are the percentage uncertainties associated with the quantities (half the 95% confidence interval). And

U_{total} is the percentage uncertainty in the sum of the quantities (half the 95% confidence interval divided by the total (i.e. mean) and expressed as a percentage).

Calculation of uncertainty when quantities are combined by multiplication

$$U_{total} = \sqrt{U_1^2 + U_2^2 + \cdots + U_n^2}$$

U_i are the percentage uncertainties associated with the quantities (half the 95% confidence interval). and

U_{total} is the percentage uncertainty in the product of the quantities (half the 95% confidence interval divided by the total and expressed as a percentage)

These rules are based on the assumptions that variables are uncorrelated with a standard deviation of less than about 30% of the mean. The guidebook recognises that in practice these assumptions are often not valid, but states that under these circumstances the rules may still be used to obtain an approximate result.

Statistical uncertainty estimates

Where quantitative uncertainty data were not available uncertainty was estimated using the following table from in EEA (2016) as guidance.

Rating	Description	Typical Range
A	An estimate base on a large number of measurements made at a large number of facilities that fully represent this sector.	10-30%
B	An estimate based on a number of measurements made at a large number of facilities that represent a large part of the sector	20-60%

C	An estimate based on a number of measurements made at a small number of representative facilities, or an engineering judgement based on a number of relevant facts.	50-200%
D	An estimate based on single measurement, or an engineering calculation derived from a number of relevant facts.	100-300%
E	An estimate based on an engineering calculation derived from assumptions only.	Order of magnitude

APPENDIX C: EMISSION TEST DATA SMALL SCALE ACTIVITIES

The following tables summaries the test data used by Graham (2006) to derive emission estimates for small scale activities.

Industry type	kg/hr
timber & joinery, good control	0.07, 0.07
timber & joinery, poor control	1.8, 3.6
spray painting	0.14, 0.03
abrasive blasting	0.05, 0.04
metal fabrication, etc	0.04, 0.07, 0.14, 0.01
printing	0.05
packaging	0.36, 0.72
coffee roasting	0.11
coffee drying	1.37
bakeries	0.04
tyre retreads	0.01
sand dryer	1.08
concrete plant	0.11
roofing tiles	0.02
coal-fired boiler	2.16

Facilities with the highest potential for PM emissions:	assigned a rate of 0.1 kg/hr
Heavy engineering/maintenance Joinery factories Panel beaters Light metal fabrication	Metal finishers – powder coating Bakeries Stone/bone/wood grinding or carving
Facilities with lower potential for PM emissions:	assigned a rate of 0.02 kg/hr
Light vehicle workshops Printing works Packaging manufacturers Tanneries (small specialty products)	Paint and other solvents Metal finishers – electroplating Appliance repairs
Facilities with very little potential for PM emissions:	assigned a rate of 0.0 kg/hr
Abattoirs	Photographic developing/printing
Facilities with the potential for 'yard' emissions:	assigned a rate of 0.1 kg/hr
Wreckers Scrap metal dealers	Waste management Timber yards