Auckland Industrial Air Emission Inventory 2011

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Auckland Industrial Air Emission Inventory 2011

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Executive summary

Air emission inventories provide information about the amount of pollutants discharged into air from various pollution sources. They can be used to determine major sources of air pollutants, establish emission trends over time, support air quality policy development, and provide input for air dispersion modeling. This report estimates the emissions to air in the Auckland region from consented industrial sources with emphasis on emissions of five key ambient air pollutants (PM_{10}, $PM_{2.5}$, NO_x, CO and VOCs) for the year 2011. Data were sourced from Auckland Council's consent files and used to populate a database that has been used for two previous inventories (in 2006 and 2009). Data for existing industrial consents were updated. The outputs were compared to the two previous versions to identify industrial emission trends.

The estimated emissions for 2011 within the Auckland region are summarized in Table 1 below. For all pollutants, the emitted mass was dominated by only a few industrial facilities. The metal, non-metal, power, animal and food, waste, and bitumen industries were the greatest emitters for most pollutant categories with the exception of VOCs. Estimated VOC emissions were dominated by the chemical industries.

Table 1. Estimated industrial emissions (T yr^{-1}) in Auckland for 2006, 2009 and 2011.

Pollutant	NO_x	CO	CO_2	SO_2	PM_{10}	$PM_{2.5}$	TSP	VOC
2006	3,169	2,609	4,162,883	1,311	454	321	820	4,105
2009	3,264	2,393	4,021,452	1,245	410	301	699	4,089
2011	3,505	2,042	3,767,319	982	386	300	434	2,363

For all pollutants, with the exception of NO_x, estimated emissions have decreased since 2006 (see the Table). The decreasing trend is due to the closure or decommissioning of some industrial facilities and more stringent consent limits and emission controls for both existing and new industrial facilities. The emissions of VOCs were much lower in 2011 when compared to the previous inventories. This was due to the closure of a large emitter (3M New Zealand limited) and a lower emission estimate for another large emitter (Huhtamaki New Zealand Limited) based on the recent stack testing results. The estimated NO_x emissions were in 2011 higher than in 2009 and 2006. This was due to a higher emission estimate for the Southdown Power Station in 2011 from the recent stack testing results.

1. Introduction

An emission inventory is a tool used for atmospheric pollution management and investigation. Emission inventories estimate the volumes of discharged pollutants within a defined area during a specific time period (U.S. Environmental Protection Agency, 2011a). Emission volumes are calculated by known or estimated pollutant discharge rates for all inventoried discharge sources.

Auckland Council maintains a regional emissions inventory (Xie et al., 2014), as well as a number of emissions inventories for major sources, such as motor vehicles (Sridhar et al., 2014) and home heating (Metcalfe, 2010). This document updates consented industrial emission sources to the end of 2011. All the other emission sources, such as home heating, traffic, and biogenic emissions, are therefore not considered in this inventory.

In Auckland, most inventoried industrial sources are point sources with a small number of area sources. This document also incorporates the documents for the two previous inventories in 2006 and 2009 (Kevern et al., 2009) in an attempt to create one document which is to be used in tandem with the industrial emission inventory database.

2. Background

URS New Zealand Limited (URS) was contracted to produce the database which was used for the Auckland industrial emission inventory (Kevern et al., 2009). The first version of the database was populated with data which was current in 2006. A revision was completed with more recent data in 2009. The third version of the database is what is reported in this document with emission data updated to 31 December 2011.

2.1 Database structure

The Auckland industrial emission inventory is a tabular database in the form of a Microsoft Excel workbook. There are 11 sheets within the workbook with a number of back end calculation sheets and pivot table output sheets (Kevern et al., 2009). Every emission source (generally an industrial facility) has a separate record in the database and contains generic information of the industrial processes such as consent holder codes and names, addresses, and the purpose of the facility as well as the emission information of the discharging processes. Emission data are entered directly into the tabular database. Data is split into different sheets depending on what type of industrial process or pollutant type the emission is. A series of `IF` and `VLOOKUP` functions reads the inputted data to calculate annual emission masses via the back end sheets. The final unit which is presented for emission masses is tonnes per year ($T\ yr^{-1}$).

2.2 Pollutants

Particulate matter, gaseous pollutants, and volatile organic compounds (VOCs) are included in Auckland's industrial emission inventory (Table 2.1). VOCs are managed in a different manner within the database due to their diversity (Section 3.2.1).

Table 2.1. The pollutants included in the Auckland industrial emission inventory.

Pollutant class	Pollutant
Particulates	Total suspended particulates (TSP)
	Particles with a diameter of less than 10 µm (PM_{10})
	Particles with a diameter of less than 2.5 µm ($PM_{2.5}$)
Gases	Oxides of nitrogen (NO_x)
	Carbon monoxide (CO)
	Carbon dioxide (CO_2)
	Sulphur dioxide (SO_2)
VOCs	Hydrocarbons
	Alcohols
	Esters
	Ketones
	Aromatics
	Organochlorides
	Amines
	Aldehydes

2.2.1 Volatile organic compounds (VOCs)

Volatile organic compounds or VOCs are a group of organic chemical compounds that vaporise under normal ambient conditions to enter the atmosphere as gases. Up to 2000 anthropogenic organic compounds can be included within the VOC definition (Vigneron et al., 1994). They can contribute to the formation of ozone in the air at ground level. Ozone is an air pollutant at ground level. Many VOCs are hazardous to human health (e.g., benzene and 1,3 butadiene). Therefore, representing VOCs within emission inventories is a necessity; however, the methods of doing so are varied due to the nature of VOCs' diversity. The Auckland industrial emissions inventory manages eight groups of VOCs which are either based on their functional groups or classed by another common feature. Other inventories have grouped VOCs in a similar way (GEIA data center, 2012; Streets et al., 2003). The eight groups of VOCs are represented by a single representative compound which its molar mass is used to calculate total mass (Table 2.2).

Table 2.2. Volatile organic compound (VOC) speciation in the Auckland industrial emission inventory (Kevern et al., 2009).

Name	Representative compound	Representative compound molar mass	Include
Hydrocarbons	Hexane	86.18	Total VOC, Acetylene, Butane, Hexane, Heptane, 2-methyl hexane, 3-methyl hexane, Cyclohexane, Methyl cyclohexane
Alcohols	Ethanol	46.07	Methanol, Ethanol, Methylated spirits, n-propanol, Isopropanol, n-butanol, Iso-butyl alcohol, 2-butoxy ethanol, 2 (dimethyl amino) ethanol, Tripropylene glycol
Esters	Ethyl acetate	88.11	Ethyl acetate, n-propyl acetate, Isopropyl acetate, n-butyl acetate, Ethyl acrylate, Butyl acrylate, Vinyl acrylate, Methyl methacrylate
Ketones	Acetone	58.08	Acetone, Methyl-ethyl ketone, Methyl-isobutyl ketone, Isophorone
Aromatics	Toluene	92.14	Total aromatic hydrocarbons, Benzene, Toluene, Xylene, m-xylene, o-xylene, p-xylene, Ethyl benzene, n-propyl benzene, Isopropyl benzene, sec-butyl benzene, Trimethyl benzene, p-isopropyl toluene, Naphthalene, Styrene, Toluene di-isocyanate, Phenol
Organochlorides	Dichloromethane	84.93	Dichloromethane(methyl chloride), Trichloromethane (chloroform), Tetrachloroethane
Amines	Acrylonitrile	53.06	Acrylonitrile, Methyl isopropylamine, Triethylamine
Aldehydes	Formaldehyde	30.03	Aldehydes, Formaldehyde

2.2.2 Excluded emissions

Fugitive emissions, or emissions leaked from various processes have been excluded from the inventory due to difficulty in quantification. Other pollutants such as hydrochloric acid, metals, dioxins, and unspecific odourous compounds are also not included in the inventory. Furthermore, the inventory does not classify what the composition is of particulate matter.

The inventory does not include all industrial processes, as not all industrial activities discharging to air require consent. Permitted activities or activities which are allowed and are effectively unregulated are therefore not documented in consent files. Notably, cooking is a permitted activity in Auckland. Cooking can be major source of particulates in an urban area in

some countries (Schauer et al., 1996). Because there is no quantification of these permitted emission sources in Auckland, they are not included in the inventory.

2.3 Industrial activity categories

Auckland Council holds consents for more than 260 industrial sites in Auckland which discharge to air. The inventory assigns each site a primary and secondary industry type based on the purpose of the site and the type of work conducted. The primary category classifies the main industry type while the secondary category relates to the actual activity being carried out (Kevern et al., 2009). In total, there are 14 primary categories and 40 secondary categories (Table 2.3).

Table 2.3. Industrial activity categories (Kevern et al., 2009).

Primary category	Secondary category
Aggregate, Bitumen, Chemical, Combustion, Food/Animal Products, Metal, Miscellaneous, Non-metal, Power, Pulp, Paper and Cardboard, Storage, Textiles, Waste, Wood Processing	Abrasive Blasting, Asphalt, Biofilter, Building Products, Chemical, Cleaning chemicals, Coating, Combustion, Composting, Concrete, Concrete crushing, Crematorium, Effluent Treatment, Explosives, Fellmongery, Foundry, Frying, Fumigation, Galvanising, Gases, Generator, Grain Processing, Grease, Joinery, Landfill, Metal, Milk Products, Paint, Pesticide, Plastics, Powder Coating, Quarry, Rendering, Re-sawing, Soldering, Solvent, Solvent coating, Supplies, Timber treatment, Transfer station

2.4 Database modifications

During the preparation of the 2011 industrial emissions inventory, the database created by URS was modified. The following describes the main changes made to the spreadsheets and the reasons behind them.

2.4.1 Renaming of sheets

The database sheets were renamed in the 2011 update. A numerical prefix was added to the sheet names to indicate the recommended order of data input (further information in Section 4.0).

2.4.2 Deletion of obsolete sheets

The Categories, Categories sorted, and General sheets were deleted in the 2011 inventory. These sheets were not updated in the 2009 inventory and contained only redundant information. These sheets were unneeded and removed.

2.4.3 Colour coding changes

An additional colour coding scheme was employed in the 2011 review. The `01_Consent` list sheet became overwhelmingly confusing due to the numerous colours used after the 2009 review. A new colour scheme was employed that simply struck and greyed out all entries were inactive i.e., expired, surrendered, obsolete, superseded, or replaced consents.

2.4.4 Changes to the `06_Summary` sheet

Consents which were inactive were deleted from the sheet. Inactive entries no longer interfere with the inventory's outputs. Additionally, conditional formatting rules were included for the TSP, NO_x, CO, CO_2, and SO_2 fields as a quality control device.

3. Methods

There have been two industrial emission inventories previously done for Auckland with the same database (Kevern et al., 2009): one using data valid in 2006 and the other updated with 2009 data. Both databases have a near-identical structure (apart from the modifications discussed in Section 3.4). The 2011 database consists of the following 11 sheets:

- `Instructions`
- `01_Consent list`
- `02_Particulate`
- `03_Combustion`
- `04_Non-Combustion`
- `05_VOCs`
- `06_Summary`
- `Pivot_Total`
- `Pivot_Percentage`
- `Emission_factors` (hidden)
- `Constant_values` (hidden)

Populating the database with data is done sequentially working from `01_Consent` list to `06_Summary`. Data fields in the database are colour coded to represent various attributes (Table 3.1).

Table 3.1. Colour coding of the database fields.

Completed active sites	
Completed closed sites	
Calculation cell	
Data entered instead of calculated	
Information which needs to be confirmed	
PM_{10} and $PM_{2.5}$ emissions calculated from emission testing	
An estimation	
Values which are inactive and will not need updating again	~~Also struck out~~

3.1 The working calculations

There are a number of methods of how pollutant emissions are either calculated or estimated in the inventory. The calculation framework is shown in Figure 3.1. The final unit which is reported for the inventory is discharged tonnes per year (T yr^{-1}). Because industrial facilities operate at various times and emit different quantities of pollutants, some calculations are needed to determine how much of any particular contaminant is discharged over time.

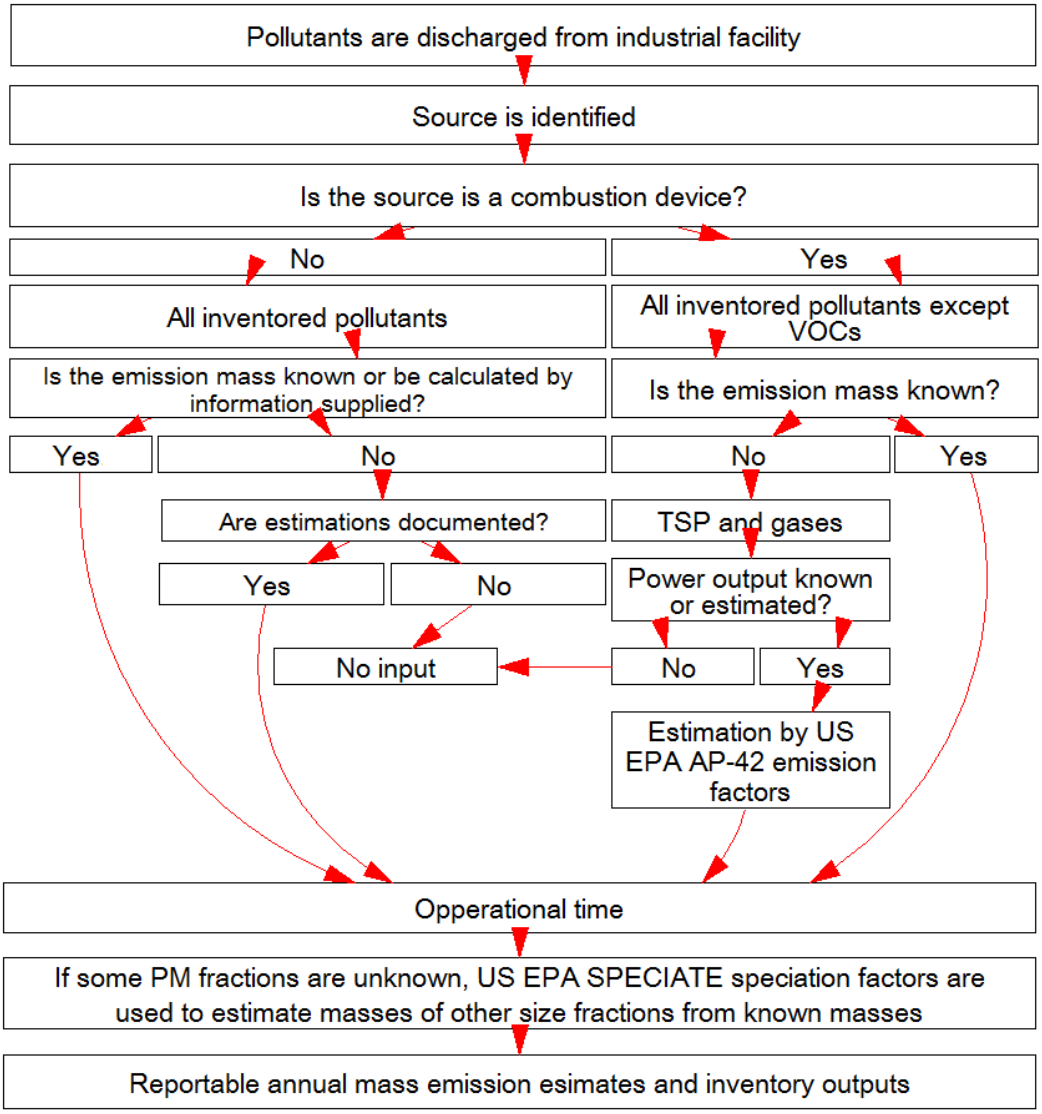


Figure 3.1. Framework of Auckland's industrial emission inventory database calculations and data input (source: Kevern et al. (2009)).

3.1.1 When the emissions of a pollutant have been measured

The emission mass (m) of a pollutant is one of the two parameters used by the inventory to estimate annual emissions (E). m's unit in the inventory is kg h^{-1}. Operational time (t) is managed as hours operating per year. If these parameters are known the annual emission mass (E) can be directly calculated by:

$$E = \frac{m \times t}{1000}$$

Where E is annual emission mass in T y^{-1}, m is in kg h^{-1}, and 1000 is a unit conversion constant (number of kilograms in a tonne). Unfortunately m is unknown in many cases or is not reported due to consent limits generally being

administered as pollutant concentrations (*c*) rather than masses. *m* can be calculated from a known *c* by:

$$m = c \times Q \times 0.0036,$$

where *c* is in mg m^{-3}, *Q* is discharge or volumetric flow rate in m^3 s^{-1}, and 0.0036 is a unit conversion constant (number of seconds in an hour ÷ number of milligrams in a kilogram). If *Q* is unknown, often the stacks' diameter (⌀) and flow velocity (*v*) are known, and therefore can be calculated with:

$$Q = A \times v$$

$$Q = \frac{1}{4} \times \pi \times ⌀ \times \mathrm{v}^2$$

Care must be taken to ensure that moisture content, temperatures, and pressures are reported to correctly determine *Q*.

3.1.2 VOC considerations

VOCs are lumped into eight functional groups which are represented by a common compound (Table 2.2). Because of the lumping methodology, a conversion is needed to correct for the different sub-grouped compounds' masses. The molar masses (*M*; Table 2.2) of the representative and sub-grouped compounds are used to create a functional group emission mass:

$$Er = \frac{Es \times Mr}{Ms}$$

where E_r is hourly emission mass of representative compound in kg h^{-1}, E_s hourly emission mass of sub-grouped compound in kg h^{-1}, *Mr* is the molar mass of representative compound in g mol^{-1}, and M_s is the molar mass of sub-grouped compound also in g mol^{-1}. All sub-grouped compounds (E_s) are summed to get total VOC group mass emission (E_{vh} in kg h^{-1}). Annual emission mass is then calculated with the first equation.

3.1.3 Combustion devices considerations

Many combustion sources such as boilers and heaters are not emission tested. In these situations when emission masses or concentrations are unknown, the US EPA AP-42: Compilation of Air Pollutant Emission Factors are used (Table 3.2).

Table 3.2. US EPA AP-42 emission factors (*EF*) used for the estimation of NO_x , CO, TSP, SO_2 and CO_2 from combustion sources when mass emissions are unknown (kg MW^{-1} or kg T^{-1} for asphalt) (U.S. Environmental Protection Agency, 1995).

Fuel type	NO_x	CO	TSP	SO_2	CO_2
Natural Gas	0.147	0.123	0.011		175.878
Diesel	0.226	0.056	0.023	0.008	251.727
Coal	0.641	0.364	0.656	2.549	350.369
Wood	0.758	0.929	0.464	0.039	301.806
Waste Oil	0.202	0.053	0.680	0.937	233.801
Diesel Generator	4.953	1.316	0.155	0.008	255.374
Landfill Gas Turbine	0.148	0.381	0.037		170.250
Landfill Gas Engine	0.424	0.794	0.082		170.250
Landfill Gas Flare	0.069	1.271	0.029		170.250
Landfill Gas Boiler	0.056	0.010	0.014		175.878
Natural Gas_Asphalt	0.013	0.065			18.500
Diesel_Asphalt	0.028	0.065		0.001	18.500
Waste Oil_Asphalt	0.028	0.065		0.072	18.500

The only two inputs needed for the US EPA AP-42 emission factors are power output (either known or estimated; *P*) of the device in megawatts (MW) and the type of fuel which is combusted. Estimated pollutant concentrations are the output:

$$c = P \times EF$$

m can then be calculated by the first equation.

3.1.4 PM_{10} and $PM_{2.5}$ considerations

PM_{10} and $PM_{2.5}$ concentrations and masses are increasingly being tested and reported. TSP is however generally the pollutant which has consent limits and is reported by stack testing. Furthermore, PM_{10} and $PM_{2.5}$ are not estimated by the US EPA AP-42 emission factors used for combustion sources. If PM_{10} and/or $PM_{2.5}$ masses are unknown, the TSP mass of the source is used to estimate the fraction of coarse and fine particulates, PM_{10}-$PM_{2.5}$ and $PM_{2.5}$ respectively. The US EPA SPECIATE speciation factors are used (Table 3.3). Speciated particulate estimations (E_p) are calculated by TSP mass (TSP_m) and the speciation factor of course and fine particulate fractions:

$$E = TSP_m \times SF$$

Table 3.3. US EPA SPECIATE speciation factors (*SF*) for course and fine particulate fractions for sources when emissions are unknown (U.S. Environmental Protection Agency, 2011b).

Code	Description	PM_{10}	$PM_{2.5}$
0	Default	0.976	0.6881
1130	Utility boilers - residual	0.97	0.7321
1170	Vehicular sources - gasoline	0.994	0.992
1200	Gaseous material combustion	1	1
1300	Solid material combustion	0.9971	0.6563
1310	Coke/coal combustion	0.4	0.15
1340	Other waste combustion	0.9971	0.6563
1620	Incineration - gaseous fuel	0.9999	0.8502
3110	Chemical manufacturing	0.8998	0.4666
3460	Clay and products	0.5592	0.2743
3480	Glass melting furnace	0.98	0.8212
3510	Steel heat treating salt quench	0.96	0.86
3520	Steel sinter plant	0.98	0.6472
3530	Steel abrasive blasting	0.8594	0.4296
3560	Electric arc furnace	0.83	0.6
3580	Aluminum Foundry	0.95	0.903
3620	Wood-operation (re-sawing)	0.4	0.283
3710	Mineral process loss	0.5	0.146
3730	Rock crushers	0.1	0.03
3740	Rock screening and handling	0.5	0.146

3.2 The updating procedure

Data used to populate the emission inventory database was sourced by reviewing Auckland Council's consent files. Populating the database with data was done sequentially from moving from the `01_Consentlist` to `06_Summary` sheets within the database. First file numbers, consent numbers, site names, addresses, purpose classifications, and consent expiry dates were entered into the database. Individual sources within a facility were then identified. For example, if there are six stacks and four baghouses, they were all represented separately. Different stacks generally represent a discrete activity and therefore often have different emissions and parameters. This separation allowed the inventory to represent this complexity. A list of the 90 consents processed is shown in Table 3.4.

Table 3.4. Files and site information which were updated in the 2011 industrial emissions inventory.

File	Consent	Site name	Notes
7983	35886	VISY Beverage	
8000	34671	3M New Zealand - Glenfield	Closed
8002	37305	O-I New Zealand	
8012	35378	Osmose	
8018	30971	East Tamaki Galvanising Ltd	
8026	39521	Laminex Group - Hunua Road	
8028	28133	Fulton Hogan asphalt plant	
8029	35960	Galvanizing Services	
8031	34683	Hayes Metal Refineries	

File	Consent	Site name	Notes
8035	32021	Masport foundry	
8039	21954	Morris and Watson	
8041	11211	NCI Packaging	
8044	30216	Tasman Insulation	
8046	14317	Glenbrook Steel Mill	
8049	23597	NuplexOnehunga	
8050	22533	Nuplex Penrose	
8052	39314	Pacific Coilcoaters	
8053	36362	Pacific Steel	
8057	36234	VIP Steel Packaging	
8058	27103	Rohm and Haas	
8069	36140	Winstone Wallboard	
8070	14330	Vita	
8076	29828	Webprint Colour Ltd	Closed
8211	31894	Glucina Smelter	
8557	38519	Transit New Zealand Auckland Harbour Bridge	
8877	35738	Comprint Limited	
9264	36738	Fletcher Aluminium Limited	
9309	38004	Affco	
9556	37982	Bascands Limited	
9781	30109	Southdown Power Station	
16864	28175	Southdown Power Station	
10002	33547	Redvale Landfill	
10850	14820	Mangere WWTP	
10930	39114	Ottogi	
11052	32643	Asphalt Plant Silverdale	
11175	34892	Otahuhu B	
11175	34892	Otahuhu B	
11534	26762	Amcor Beverage Cans	
11584	39980	PVL Proteins	
11746	16147	Tegal Foods	
11836	39272	Flat Top Quarry	
12108	37423	PMP Print Limited	Closed
12604	36283	W. Stevensons Quarry	
12969	37227	Consolidated Alloys	
13005	34396	Puketutu Island Quarry	
14027	36656	Huhtamaki	
14362	37527	Kaiparaseptage treatment	
14590	36952	Pets @ Rest	
14798	38783	Chemcolour Industries	
14846	31949	Envirowaste - WiriTfr Station	
14849	37659	Higgins Contractors	
14931	38221	Perry Metal Protection Ltd	
15099	30175	Otahuhu C	
15156	36600	Rheem	
15496	35661	Warkworth WWTP	
15497	34098	Snells-Algies WWTP	
16018	31717	Chelsea Sugar Refinery	
17090	36833	Holcim Avondale	
17092	32346	BSN Medical Limited	
17096	37340	Mulford Plastics	

File	Consent	Site name	Notes
17098	31492	MethvenTapware	
17101	36755	Lion Breweries	
17105	37542	National Radiators	
17106	37252	Carter Holt Harvey Penrose Paper Mill	
17123	29467	Orica	
17127	39569	Duroid	
17131	28644	New Zealand Starch	
17133	29478	Auckland Hospital	
17135	35529	Sanitarium Health Foods	
17529	37936	Adam's Landscapes	
17569	29400	Firth Industries - Crosbie Rd	
17605	39238	Brookby Quarries	
17618	37042	Meadow Lea Foods	
17720	36736	Sims Pacific Metals	
17723	38694	Henkel	
17739	37691	Status Produce	
17741	37039	Nestle NZ	
17755	36740	Cerebros Gregg's coffee roastery	
17762	36971	Coca Cola Amatil ltd	
17777	37018	Irvines Quality Bakers	
17791	35607	Hi Tech Security Disposal	
17795	39078	Jack Links	
17797	38304	Firth Industries, 27 Smales Rd	
17797	37458	Firth Industries, 27 Smales Rd	
19084	32599	North Shore Memorial Park	
21210	36739	James Hardie Building Products	
17115	35782	BOC	
20032	34752	New Zealand Steel Limited - Glenbrook	
20536	38393	Flo-Dry Engineering Limited	

Industrial discharges are often discretionary activities and therefore assessment of environmental effects or AEEs are required as part of the consent process. For many facilities, especially large sites, stack or emission testing every six-monthly, annually, or very two years is a condition for the granting of the discharge to air consent. These testing data are the preferable data type and were used in any situation where they were present. A confidence ranking system (from A to H) to rate the accuracy of the emission estimate, with A being the most accurate and H representing the least accurate (Table 3.5).

Table 3.5. The confidence codes for the different methods of calculating or estimating different facilities' emissions (Kevern et al., 2009).

Confidence code	Information source
A	Stack emission testing
B	Recent AEE (2003 – present)
C	Contacting consent holder
D	US EPA AP42 Emission factors
E	Old AEE (up to 1999)
F	Consent limit
G	URS judgment
H	Other/unknown

3.3 A software note

The database in a Microsoft Excel workbook saved in the `.xlsx` file format. It is highly recommended that a Microsoft Excel version at least as recent as 2007 is used to open and work with the database. The database contains filtering functions, conditional formatting rules, pivot tables, and additional functions which are only implemented correctly in Excel 2007 and newer. Older Excel versions such as 2003 should be avoided, especially if data is to be entered.

3.4 A working example: O-I New Zealand

O-I New Zealand is a large industrial facility in Penrose, Auckland. O-I recycle glass and operate 24 hours a day, seven days a week (8760 hours a year). There are three stacks named AK2, AK3, and AK4 (Figure 3.2) which discharge pollutants into the atmosphere. These stacks emit combustion products from natural gas powered furnaces and waste from the actual glass processing. O-I is a large source of particulates, NO_x and SO_2 in Auckland and therefore, the three stacks undergo six-monthly emission testing. The properties of the three O-I stacks are shown in Table 3.6. The latest stack testing results are shown in Table 3.7.

Table 3.6. Properties of the three O-I New Zealand glass recycling facility's stacks.

Stack	h	⌀	V	Q	P
	m	m	$m\ s^{-1}$	$m^3 s^{-1}$	MW
AK2	40	1.54	9.5	7.06	2
AK3	40	1.57	9.4	7.12	2
AK4	50	2.2	6.5	18.75	17.4

Table 3.7. Emissions from the three O-I New Zealand glass recycling facility's stacks (kg h^{-1}).

Stack	TSP	PM_{10}	$PM_{2.5}$	NO_x	CO	CO_2	SO_2
AK2	1.3	1.25	1.25	0.3	0.6	3290	2.4
AK3	1.8	1.78	1.78	18.6	0.1	3190	3.1
AK4	0.2	0.2	0.2	2.55	2.1	3060	0

Figure 1.2. O-I New Zealand's AK4 50 metre high stack in Penrose, Auckland. Photograph by Stuart Grange.

TSP, PM_{10}, NO_x and SO_2 mass emission rates are known from recent emission testing for some or all of O-I New Zealand's stacks. Almost all of the emitted TSP is PM_{10} and the inventory assumes also that all PM_{10} is $PM_{2.5}$. As the furnaces' combustion products exit via the stacks, the stacks with NO_x and SO_2 testing (AK2 and AK3) do not need additional non-combustion pollutant estimates. Because the combustion of natural gas has negligible SO_2 emissions, the emitted SO_2 mainly come from glass processing. The AK4 stack's lower emission concentrations and masses demonstrate the effectiveness of the electrostatic precipitator as an emission control device. The inventory's outputs for O-I New Zealand are in Table 3.8.

Table 3.8. Industrial emission outputs for the O-I facility in Penrose, Auckland (T yr^{-1}).

Pollutant	TSP	PM_{10}	$PM_{2.5}$	NO_x	CO	CO_2	SO_2
Emission	29	28	28	188	25	83,580	48

4. Results and discussion

4.1 Total emissions

The total emissions from consented industrial sources for 2011 are summarized in Table 4.1. For comparison, the emissions for 2006 and 2009 are included in the table.

Table 4.1. Estimated industrial emissions in Auckland for 2006, 2009 and 2011 (T yr^{-1}).

Pollutant	NO_x	CO	CO_2	SO_2	PM_{10}	$PM_{2.5}$	TSP	VOC
2006	3,169	2,609	4,162,883	1,311	454	321	820	4,105
2009	3,264	2,393	4,021,452	1,245	410	301	699	4,089
2011	3,505	2,042	3,767,319	982	386	300	434	2,363

4.2 Emission trends since 2006

Estimated annual emissions of VOCs, CO, SO_2, all particulate classes and CO_2 decreased in 2011 when compared to 2006 (Table 4.1 and Figure 4.1). This is because of the gradual closure of a number industrial facilities or sections or parts of their activities or processes and more stringent consent conditions in recent years. Many individual industrial facilities are therefore less polluting than they once were.

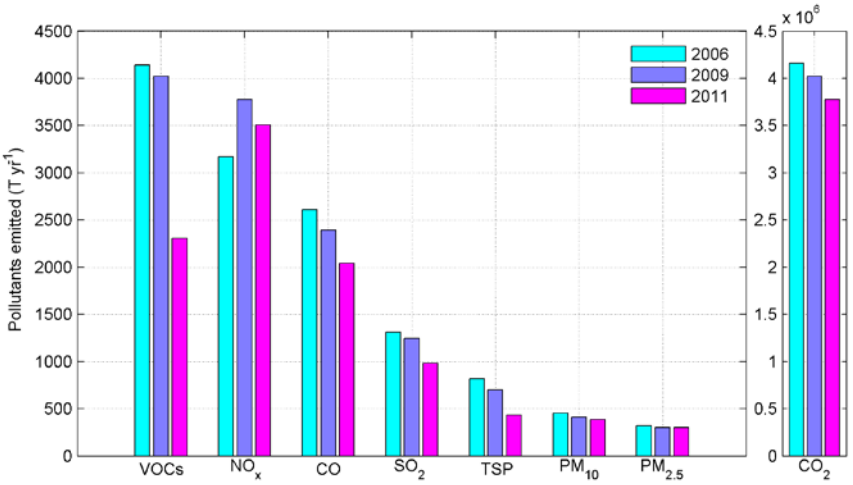


Figure 4.1. Estimated annual industrial pollutant emissions for the three inventories. NOx emissions for 2009 here (Kevern, et al. 2009) included those from the Otahuhu C Power Station which is not yet in operation. The updated total NOx emissions for 2009 without those from the Otahuhu C Power Station are listed in Table 4.1.

Annual estimated VOC emissions in 2011 decreased by over a third since 2006 and 2009. This is due to the change of emissions for two major sources.

Firstly, The 3M adhesive manufacturing facility is now closed and was a large emitter of hexane, heptane, cyclohexane, methyl cyclohexane, ethanol, ethyl acetate, and toluene.

The second factor which contributed to this change was emission testing results from the flexible plastic manufacturing facility, Huhtamaki. Previous to 2011, VOC emissions from Huhtamaki were estimated by solvent consumption and emission factors. Emission testing conducted in 2008 for a modelling study, reported that the VOC emission estimates were overestimated in the 2009 inventory. These changes of these two large emitters had a big influence on the final estimated VOC mass for the 2011 inventory (Figure 4.1).

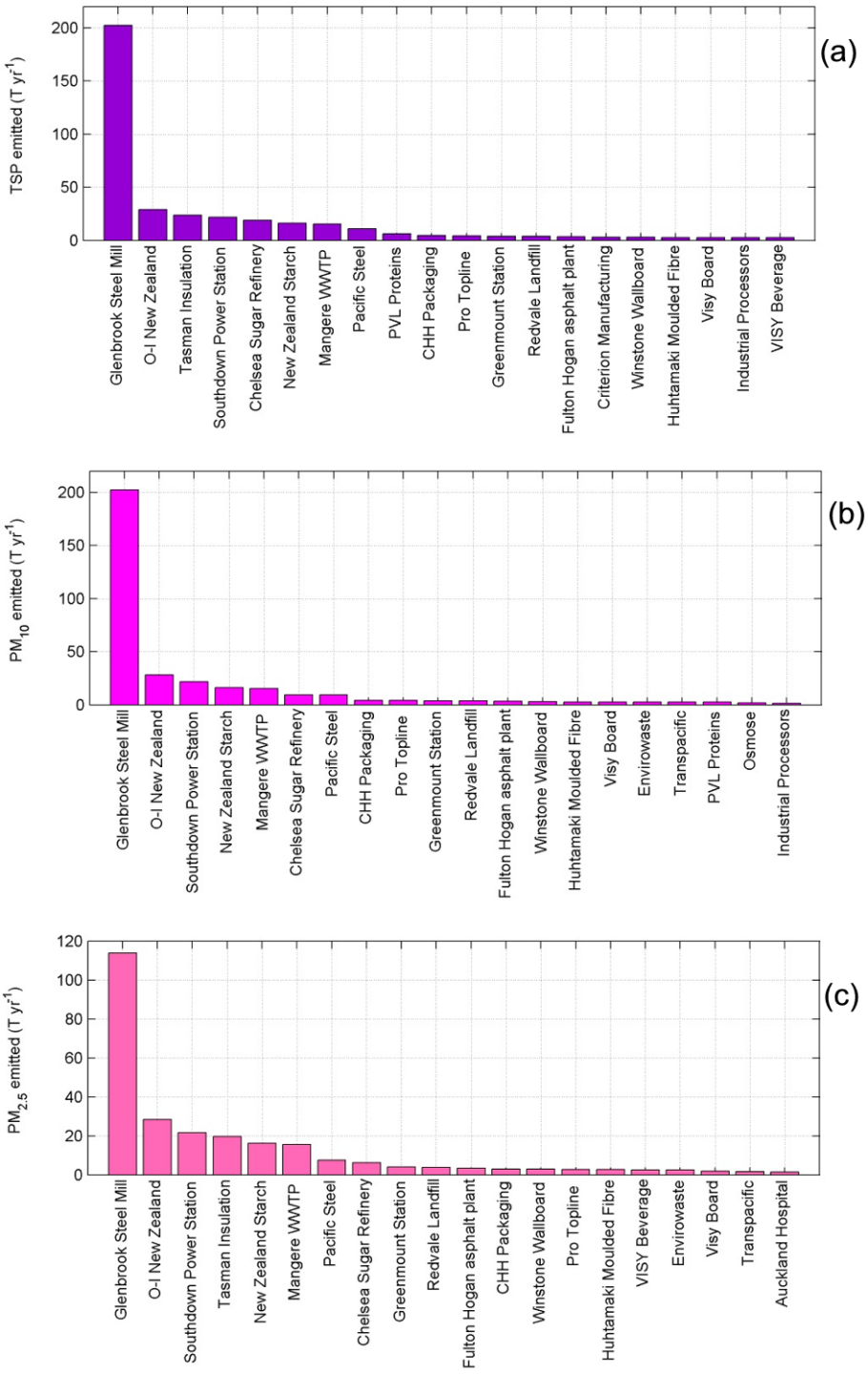
Estimated NO_x emissions from the Otahuhu C Power Station were included in the previous 2009 inventory (Kevern, et al. 2009). Since the station is not yet in operation, the emissions of the Otahuhu C Power Station are removed and the updated total NO_x emissions are listed in Table 4.1. The estimated total NO_x emissions for 2011 were higher than for 2009 and 2006. This was due to a higher emission estimate for the Southdown Power Station in 2011 from the recent stack testing results.

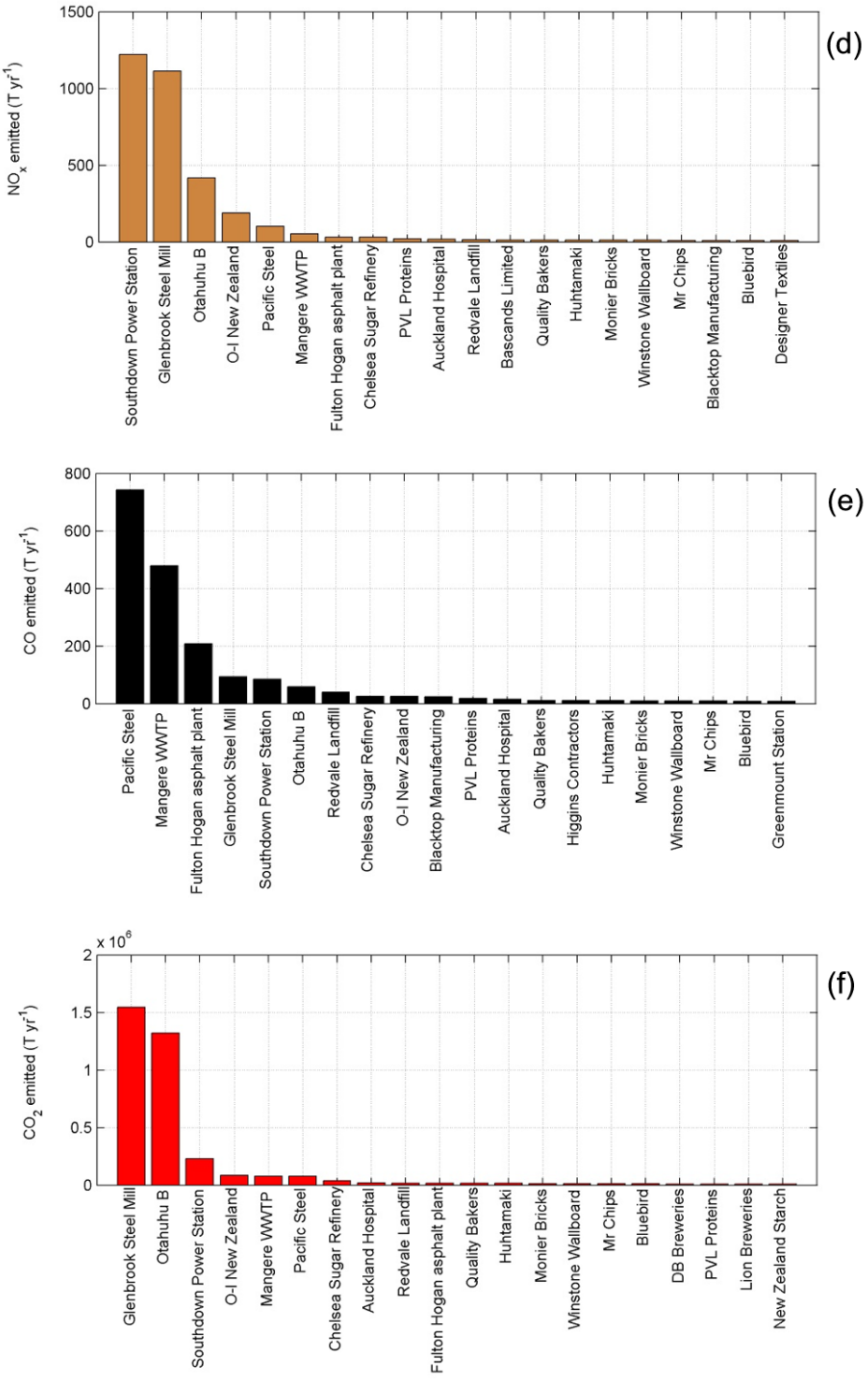
4.3 The gross emitters

Auckland's estimated industrial mass emissions of all pollutants are dominated by a handful of emitters (Figure 4.2). These priority facilities are listed in Table 4.2. The large emitters are facilities which consume large volumes of fossil fuels, such as natural gas and coal. The steel mill operated by New Zealand Steel in Glenbrook (outside Auckland's urban area and urban Airshed) consumes 0.8 million T yr^{-1} of sub-bituminous Huntley coal (Green and Batchelor, 2008). Therefore, the emissions of NO_x, particulates, SO_2, and CO_2, especially the latter two are very large (Figures 4.2 and 4.4). Two thermal power stations, a steel recycling foundry (Pacific Steel) and a glass recycling facility (O-I New Zealand), are the other major sources of particulates and most gaseous pollutants inventoried. Other large industrial sources include the Chelsea Sugar Refinery (for particulates and NO_x), Tasman Insulation (particulates), and the Mangere wastewater treatment plant (particulates, NO_x, CO and CO_2).

Table 4.2. The gross industrial emitters in Auckland

Site name	Purpose	File number	Consent number	Pollutant
Glenbrook Steel Mill	Foundry	8046	14317	Particulates, NO_x, SO_2, CO, CO_2
O-I New Zealand	Glass recycling	8002	37305	Particulates, NO_x, CO_2, SO_2
Otahuhu B	Thermal power station	11175	34892	Particulates, NO_x, CO, CO_2
Pacific Steel	Recycling foundry	8053	36362	NO_x, CO, CO_2, SO_2
Southdown Power Station	Thermal power station	9781 and 16864	30109 and 28175	Particulates, NO_x, CO, CO_2
Huhtamaki	Plastics manufacture	14027	36656	VOCs: Alcohols and esters


(a)
TSP emitted (T yr-1)
0
50
100
150
200
Glenbrook Steel Mill
O-I New Zealand
Tasman Insulation
Southdown Power Station
Chelsea Sugar Refinery
New Zealand Starch
Mangere WWTP
Pacific Steel
PVL Proteins
CHH Packaging
Pro Topline
Greenmount Station
Redvale Landfill
Fulton Hogan asphalt plant
Criterion Manufacturing
Winstone Wallboard
Huhtamaki Moulded Fibre
Visy Board
Industrial Processors
VISY Beverage
(b)
PM10 emitted (T yr-1)
0
50
100
150
200
Glenbrook Steel Mill
O-I New Zealand
Southdown Power Station
New Zealand Starch
Mangere WWTP
Chelsea Sugar Refinery
Pacific Steel
CHH Packaging
Pro Topline
Greenmount Station
Redvale Landfill
Fulton Hogan asphalt plant
Winstone Wallboard
Huhtamaki Moulded Fibre
Visy Board
Envirowaste
Transpacific
PVL Proteins
Osmose
Industrial Processors
(c)
PM2.5 emitted (T yr-1)
0
20
40
60
80
100
120
Glenbrook Steel Mill
O-I New Zealand
Southdown Power Station
Tasman Insulation
New Zealand Starch
Mangere WWTP
Pacific Steel
Chelsea Sugar Refinery
Greenmount Station
Redvale Landfill
Fulton Hogan asphalt plant
CHH Packaging
Winstone Wallboard
Pro Topline
Huhtamaki Moulded Fibre
VISY Beverage
Envirowaste
Visy Board
Transpacific
Auckland Hospital


(d)
NO_x emitted (T yr^{-1})
1500
1000
500
0
Southdown Power Station
Glenbrook Steel Mill
Otahuhu B
O-I New Zealand
Pacific Steel
Mangere WWTP
Fulton Hogan asphalt plant
Chelsea Sugar Refinery
PVL Proteins
Auckland Hospital
Redvale Landfill
Bascands Limited
Quality Bakers
Huhtamaki
Monier Bricks
Winstone Wallboard
Mr Chips
Blacktop Manufacturing
Bluebird
Designer Textiles
(e)
CO emitted (T yr^{-1})
800
600
400
200
0
Pacific Steel
Mangere WWTP
Fulton Hogan asphalt plant
Glenbrook Steel Mill
Southdown Power Station
Otahuhu B
Redvale Landfill
Chelsea Sugar Refinery
O-I New Zealand
Blacktop Manufacturing
PVL Proteins
Auckland Hospital
Quality Bakers
Higgins Contractors
Huhtamaki
Monier Bricks
Winstone Wallboard
Mr Chips
Bluebird
Greenmount Station
(f)
x 10^6
CO_2 emitted (T yr^{-1})
2
1.5
1
0.5
0
Glenbrook Steel Mill
Otahuhu B
Southdown Power Station
O-I New Zealand
Mangere WWTP
Pacific Steel
Chelsea Sugar Refinery
Auckland Hospital
Redvale Landfill
Fulton Hogan asphalt plant
Quality Bakers
Huhtamaki
Monier Bricks
Winstone Wallboard
Mr Chips
Bluebird
DB Breweries
PVL Proteins
Lion Breweries
New Zealand Starch

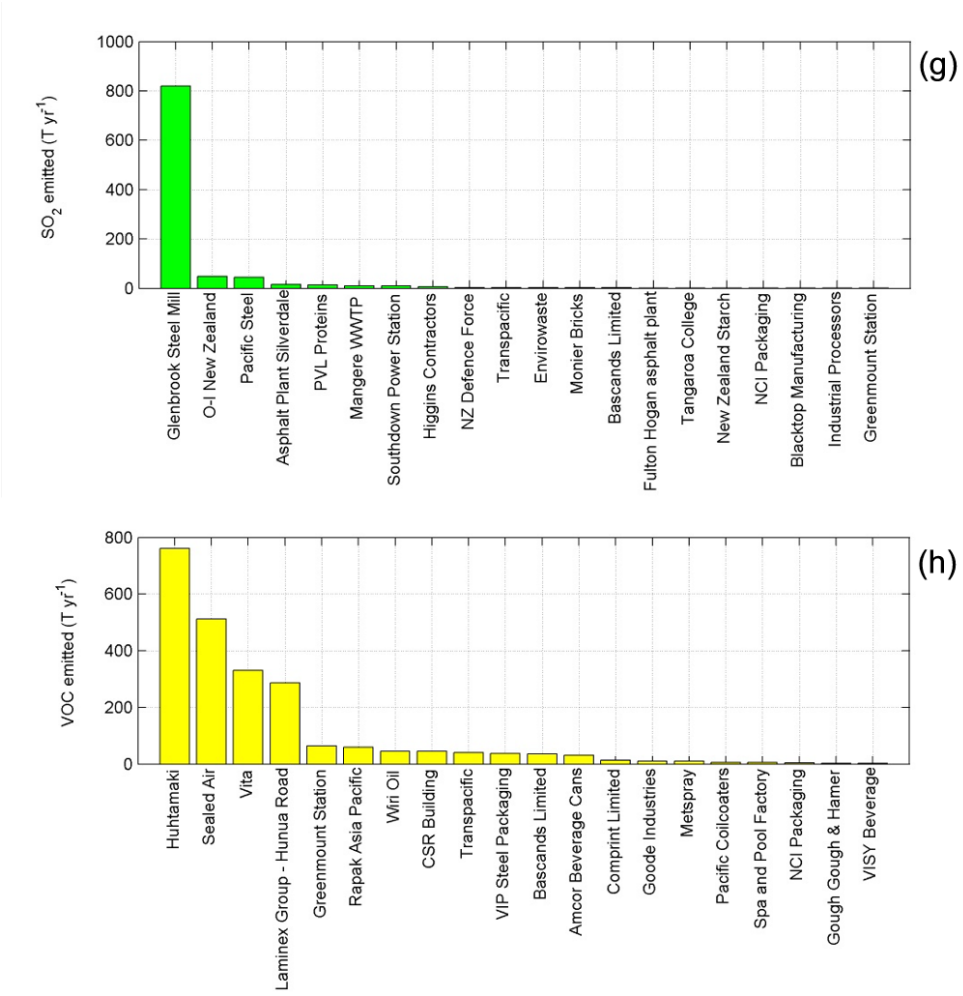


Figure 4.2. The top twenty emitters (by pollutant) in Auckland as estimated by the emission inventory in 2011.

4.3.1 Trends of the gross emitters

As discussed earlier, Auckland's industrial emissions of all pollutants are dominated by a handful of emitters. Understanding the emissions trends of these gross emitters helps us understand the trends of regional industrial emissions.

4.3.1.1 O-I New Zealand

The estimates for gaseous pollutants from the O-I New Zealand glass recycling facility in 2009 are generally higher than in 2011 and 2006 (Figure 4.3). NO_x emissions were much greater in 2009 because of estimates being used for the AK4 stack. These estimates were considered as either errors or gross overestimates and therefore, in the 2011 review, US EPA AP-42 emission factors were used. SO_2 emissions in 2009 were possibly overestimated. All particulate size class estimates have changed by small amounts due to small changes in emission testing results. CO_2 emissions are greater in 2009 and 2011 compared to 2006 because of the commissioning of a third 17 MW natural gas furnace used to process glass products.

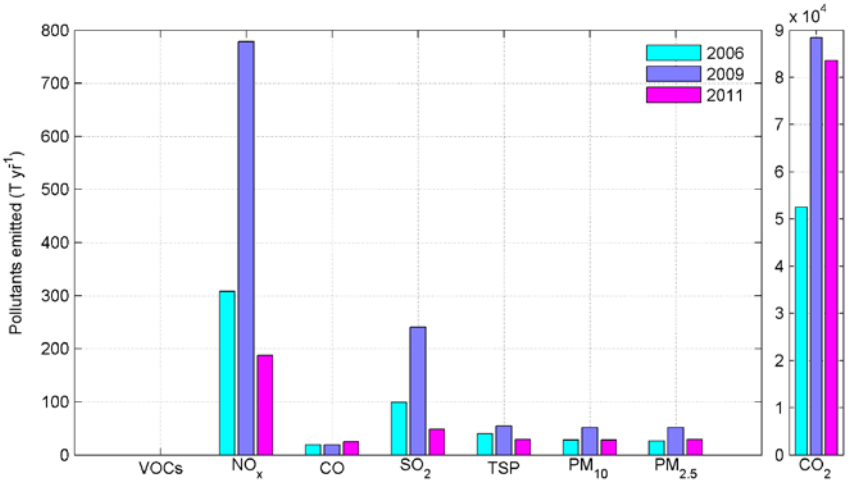


Figure 4.3. Emission trends of O-I New Zealand for the three inventories.

4.3.1.2 New Zealand Steel: Glenbrook Steel Mill

In this inventory, information from several reports (Beca, 2009, 2011a, b; Engineering and Technical Services, 2009; Simpson, 2009) were used for the input of New Zealand Steel emission data. The future may see a consolidation of the emission testing data for the Glenbrook Steel Mill and will be an important information source for the next versions of the inventory.

The New Zealand Steel's Glenbrook Steel Mill emission estimates are showing no clear trends for the three versions of the inventory (Figure 4.4). Many of the 85 stacks at the facility are poorly represented because the major sources from the iron and steel plants are the greatest emitters and little attention is paid to

the smaller emitters. The four multi-heath furnaces, the four rotary kilns, melter stacks, and the klockner oxygen blown maxhutte (KOBM) flarestack (also known as the KOBM scrubber) and associated oxidising processes' stacks are the major sources of pollutants (Beca, 2009; Simpson, 2009). CO_2 emission estimates have remained static because of the use of an emission factor for this pollutant derived from the volume of steel produced per annum, 650 000 tonnes.

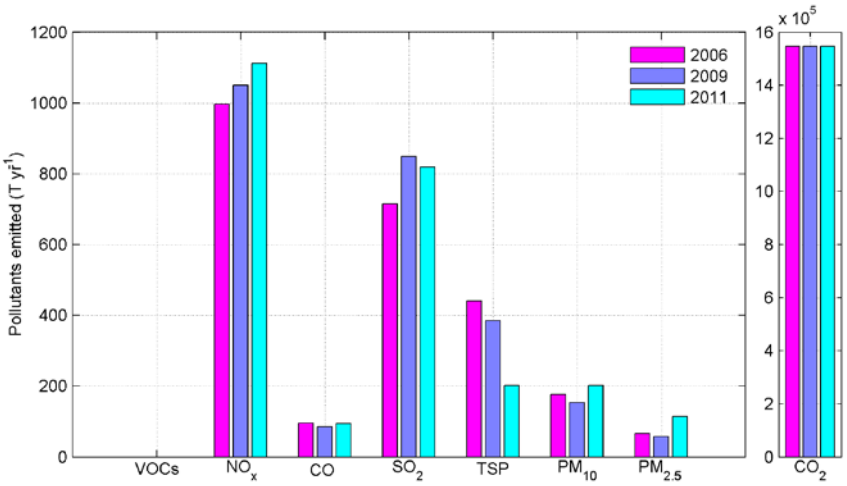


Figure 4.4. Emission estimation trends of New Zealand Steel for the three inventories.

4.3.1.3 Pacific Steel

Estimated emissions of gaseous pollutants from the Pacific Steel recycling foundry were greater in 2011 when compared to the past, except for CO_2 (Figure 4.5). Particulates of all size classes were estimated to be less in 2011 than 2009 and 2006 because of the stricter enforcement of the particulate consent limit of the new consent conditions and emission testing results (Dissmeyer, 2009). CO emissions have increased due to more recent emission testing results.

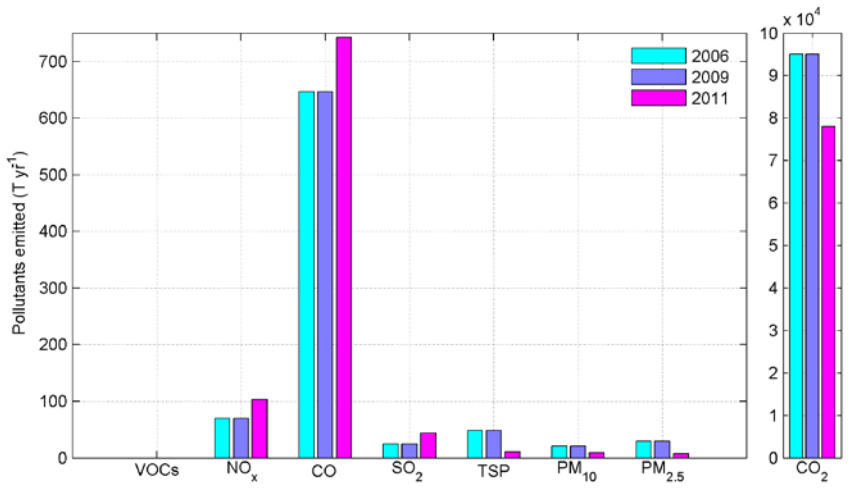


Figure 4.5. Emission estimation trends of Pacific Steel for the three inventories.

4.3.1.4 Otahuhu B Power Station

Otahuhu B's emissions were estimated to be lower in 2011 than in 2006 and 2009 (Figure 4.6). Emission testing results (used for 2011 estimates) show that NO_x and CO emissions at normal turbine operation are very low when compared to the levels of the consent limits (used for 2006 and 2009 estimates). A slight increase of power generation capacity has resulted in slightly greater estimated CO_2 emissions for 2009 and 2011.

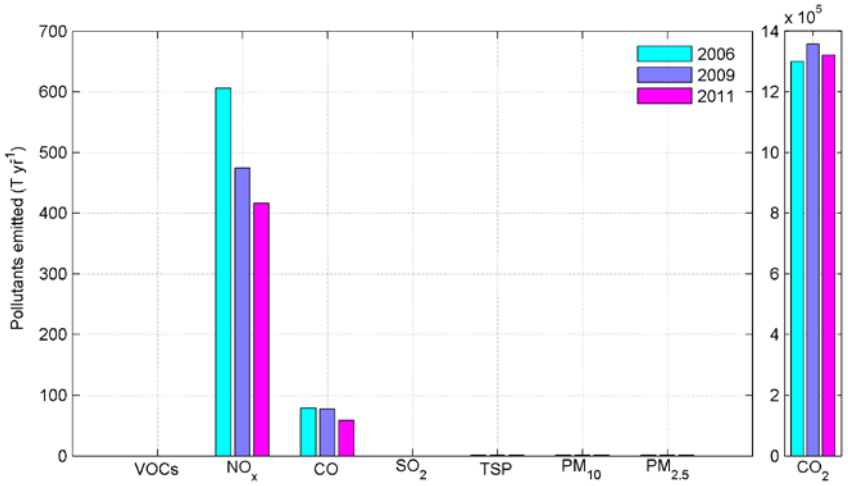


Figure 4.6. Emission estimation trends of Otahuhu B for the three inventories.

4.3.1.5 Southdown Power Station

Southdown's NO_x emissions were previously underestimated by emission factors based on fuel consumption. Stack testing conducted in 2010 demonstrates that the NO_x emissions (1,226 T yr^{-1}) were much higher than previously estimated (368 T yr^{-1} for 2006 and 2009) (Figure 4.7). As a result, Southdown became the top NO_x emitter in the Auckland region. The other

inventoried pollutants estimates show minor changes due to slightly different stack testing results.

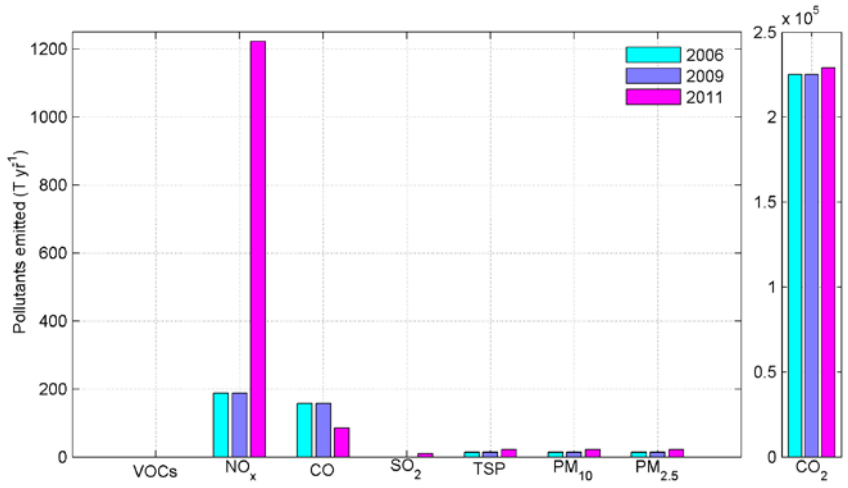


Figure 4.7. Emission estimation trends of Southdown for the three inventories.

4.3.1.6 Huhtamaki

Huhtamaki New Zealand Limited is the largest VOC emitter in Auckland. In 2011, the emissions of VOCs were estimated by using emission testing data and were lower than those in 2006 and 2009 (Figure 4.8) which were estimated based on total solvent usage. Other pollutants were emitted from a number of natural gas driers, boilers, and heaters.

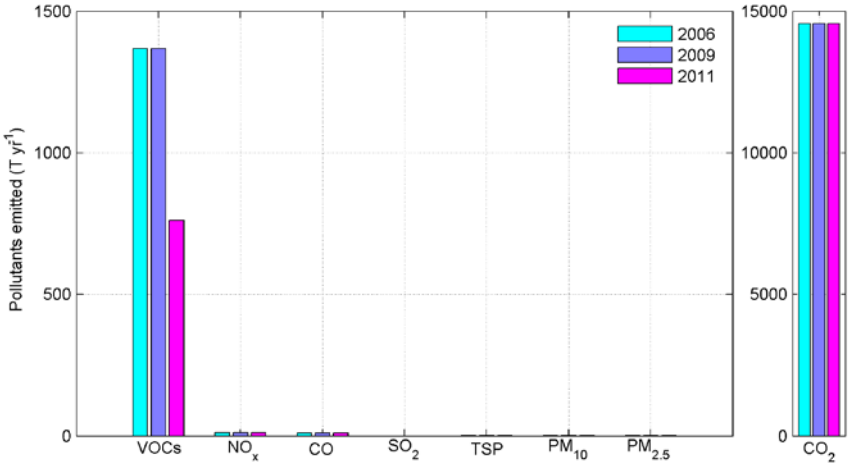


Figure 4.8. Emission estimation trends of Huhtamaki for the three inventories.

4.4 Industrial categories emission contributions

4.4.1 Particulates

Industrial facilities which process metal were estimated to be the greatest contributor to industrial particulate emissions in Auckland. Metal industries emitted the majority of TSP, PM_{10}, and $PM_{2.5}$ mass. Food and animal processing, non-metal, waste, and power generation facilities were the other important sources of industrial particulate emissions in Auckland (Figure 4.9).

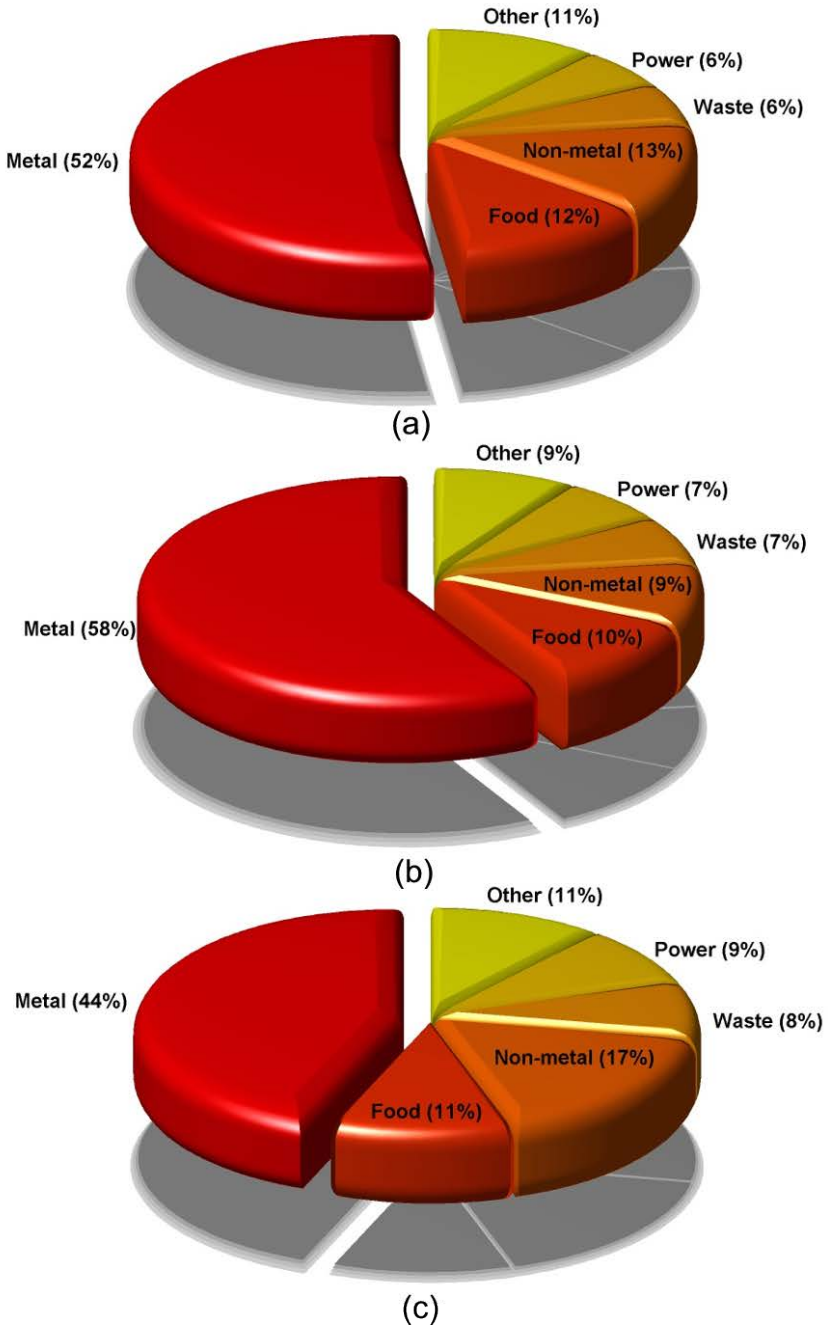


Figure 4.9.Estimated annual industrial particulate emissions (TSP (a), PM_{10} (b), and $PM_{2.5}$ (c)) in respect to industrial activities in 2011.

4.4.2 Oxides of nitrogen

Industrial estimates of NO_x emissions were dominated by thermal power plants and metal processing industries in Auckland (Figure 4.10). Food and animal processing facilities were estimated to be the third largest contributor of NO_x in Auckland.

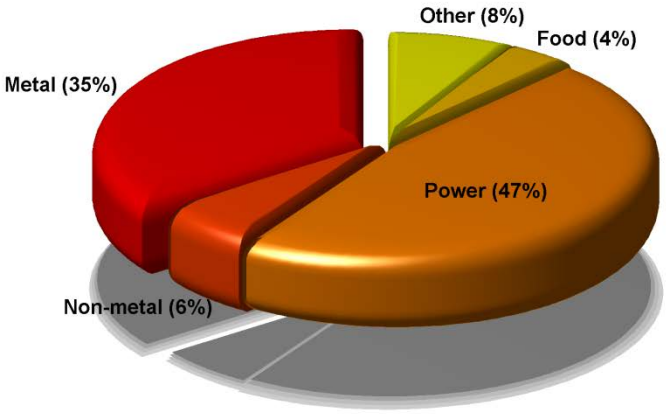


Figure 4.10.Estimated annual industrial NO_x emissions in respect to industrial activities in 2011.

4.4.3 Sulphur dioxide

Estimated industrial SO_2 emissions in Auckland were mostly from metal processing industries (Figure 4.11). Most SO_2 emitted in Auckland was sourced from the Glenbrook Steel Mill because of the rate of consumption of sub-bituminous coal at this facility.

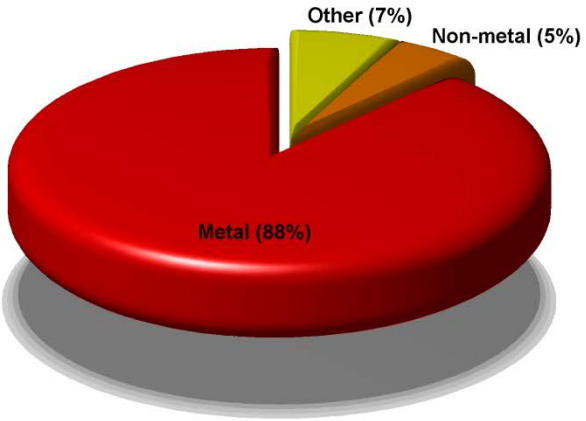


Figure 4.11.Estimated annual industrial SO_2 emissions in respect to industrial activities in 2011.

4.4.4 Carbon monoxide

Estimated industrial emissions of CO were distributed throughout a number of industries in Auckland (Figure 4.12). The metal and waste processing industries were however, the greatest contributors of industrial CO emissions. Bitumen, power, and food industries were the other important industrial categories which emitted CO in Auckland.

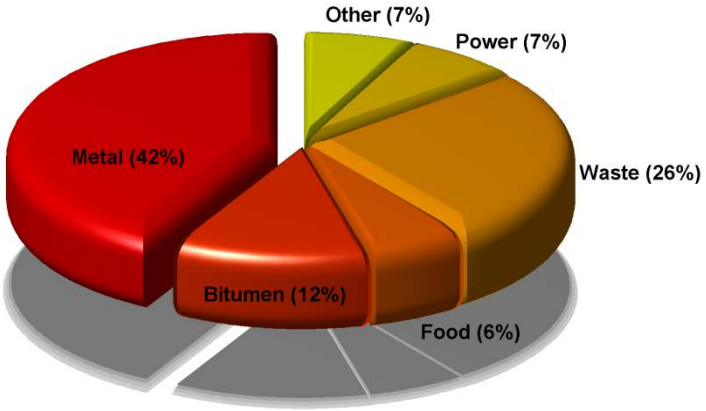


Figure 4.12. Estimated annual industrial CO emissions in respect to industrial activities in 2011.

4.4.5 Carbon dioxide

Estimated industrial CO_2 emissions in Auckland were mostly sourced from the metal and power generation facilities (Figure 4.13). CO_2 emissions in Auckland were generally a function of fossil fuel consumption, generally coal and natural gas.

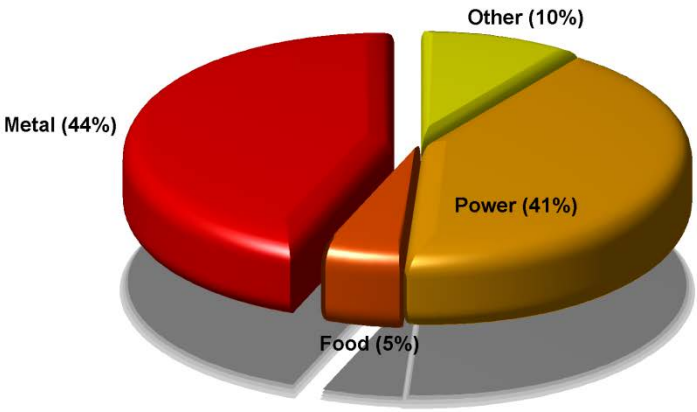


Figure 4.13. Estimated annual industrial CO_2 emissions in respect to industrial activities in 2011.

4.4.6 Volatile organic compounds

Estimated industrial VOC emissions were unsurprisingly dominated by the chemical industries (Figure 4.14). Wood processing industries were also an important source for VOCs in Auckland due to the use of solvents in laminated wood (laminates) manufacture.

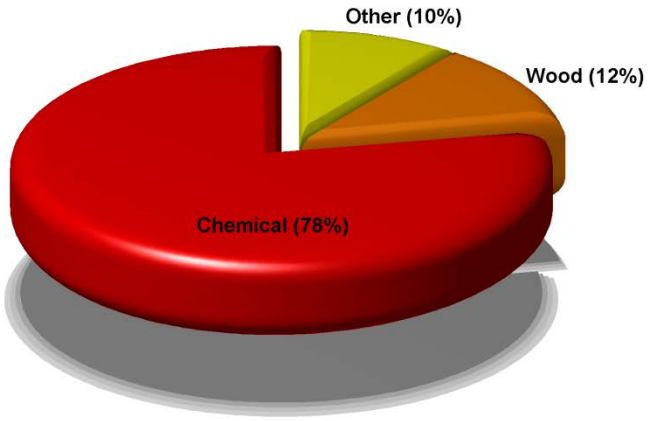


Figure 4.14. Estimated annual industrial VOC emissions in respect to industrial activities in 2011.

4.5 Recommendations

Reasonable information is available to estimate the mass emission (*m*) for many sources, especially the larger sources. Emission testing is becoming increasingly routine for industrial facilities in Auckland and this helps with the inventory's accuracy.

Annual operational hours (*t*) are however poorly documented. As *t* is the other major term of the principle equation, the importance of *t* cannot be overlooked. For most facilities and activities *t* is likely to variable, but an educated estimate or a calculation of a previous years' *t* would be beneficial to increase the accuracy of the inventory. Efforts should be made to improve estimates of *t* for industrial facilities in Auckland.

For combustion sources without emission testing data, emission factors (US EPA AP-42) are heavily relied upon to estimate emissions from such sources. The US EPA AP-42 emission factors require combustion devices' power output (*P*) as input. To enable future, effective emission estimates, *P* should be documented for all industrial combustion sources.

The updating procedure for the database (i.e., the Excel spreadsheet) is time consuming and laborious. The original database was designed to be user friendly by removing the equations from the front end and offering the user to simply populate the database with pollutant concentrations and masses. The database then calculates the outputs. The reality, however, is more complex and convoluted than simply entering values.

The diversity of testing, emission reporting, emitting devices, and facilities creates complexity, problems, and sources of error. The vast number of units used is a particular problem. This creates a situation where manual calculations outside the database's front end are unavoidable. It would be more effective to create a database which contains one value for the emitted pollutants for each source. A series of intuitive calculators could be developed to be used with the database so the input and the output are split. So, the tool used for generating the inventory should be improved, including investigating a better or more specialized tool than an Excel spreadsheet, which would speed up the updating of the inventory.

In summary, it is recommended to:

- Better estimate annual operational hours for industrial facilities,
- Document power outputs for all industrial combustion sources, and
- Improve the tool used for generating the inventory.

5. Conclusions

Emissions from consented industrial sources for 2011 were estimated as 3,505 T yr^{-1} for NOx; 2042 T yr^{-1} for CO; 3,767,319 T yr^{-1} for CO_2; 982 T yr^{-1} for SO_2; 386 T yr^{-1} for PM_{10}; 300 T yr^{-1} for $PM_{2.5}$; 434 T yr^{-1} for TSP and 2,363 T yr^{-1} for VOC.

For all pollutants, with the exception of NOx, estimated emissions have decreased since 2006. The decreasing trend is due to the closure or decommissioning of some industrial facilities and more stringent consent limits and emission controls for both existing and new industrial facilities.

The emissions of VOCs were much lower in 2011 when compared to the previous inventories. This was due to the closure of a large emitter (3M New Zealand limited) and a lower emission estimate for another large emitter (Huhtamaki New Zealand Limited) based on the recent stack testing results. The estimated NOx emissions were in 2011 higher than in 2009 and 2006. This was due to a higher emission estimate for the Southdown Power Station in 2011 from the recent stack testing results

All pollutants demonstrate that the majority of emitted mass was emitted by five or less individual facilities. New Zealand Steel's Glenbrook Steel Mill was especially dominating for all pollutants except for VOCs. The metal, non-metal, power, food, and waste industries were estimated to be the greatest emitters of particulates in Auckland. Power generation facilities and metal industries were estimated to emit the majority of NO_x. Estimated SO_2 emissions were mostly from the use of coal at the Glenbrook Steel Mill. CO emissions were estimated to also be sourced by the metal industries, however waste, power, and bitumen industries were also important industry categories. CO_2 emission estimates were mostly shared between the metal and power industries because the mass of CO_2 emissions were mostly dependent on fossil fuel consumption. VOC emissions were estimated to be dominated by the chemical industries with some input from wood processing industries due to solvent use in the manufacturing of laminates.

6. Acknowledgements

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Peer reviewers, Nick Reid and Jacqueline Joliffe of Auckland Council, provided valuable feedback on the draft of this technical report.

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