Technical Report No. 8

Air Emissions Inventory for the Greater Metropolitan Region in New South Wales

On-Road Mobile Emissions Module: Results

Department of Environment & Climate Change NSW

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Executive Summary

The Department of Environment and Climate Change NSW (DECC) has completed a three year air emissions inventory project for on-road mobile sources. The base year of the on-road mobile inventory represents activities that took place during the 2003 calendar year and is accompanied by emission projections up to the 2031 calendar year. The area included in the study covers greater Sydney, Newcastle and Wollongong regions, known collectively as the Greater Metropolitan Region (GMR).

The study region defined as the GMR measures 210 km (east-west) by 273 km (north-south). The region is defined in Table ES1 and shown in Figure ES1.

Table ES1: Definition of Greater Metropolitan, Sydney, Newcastle and Wollongong regions

Region	South-west corner MGA[1] co-ordinates		North-east corner MGA[1] co-ordinates	
	Easting (km)	Northing (km)	Easting (km)	Northing (km)
Greater Metropolitan	210	6159	420	6432
Sydney	261	6201	360	6300
Newcastle	360	6348	408	6372
Wollongong	279	6174	318	6201

1 MGA = Map Grid of Australia based on the Geocentric Datum of Australia 1994 (GDA94) (ICSM, 2002).

The on-road mobile air emissions inventory includes emissions from the following sources:

- exhaust emissions from petrol passenger cars
- exhaust emissions from diesel light duty vehicles
- exhaust emissions from petrol light duty commercial vehicles
- exhaust emissions from diesel heavy duty commercial vehicles
- exhaust emissions from other vehicles
- evaporative emissions from all petrol vehicles.

The substances inventoried include criteria pollutants specified in the National Environment Protection Measure (NEPM) for ambient air quality (NEPC, 2003), air toxics associated with the National Pollutant Inventory (NEPC, 2000) and the Air Toxics NEPM (NEPC, 2004).

Figure ES1: Definition of the Greater Metropolitan, Sydney, Newcastle and Wollongong regions

Table ES2 shows total estimated annual emissions (for selected substances) from all on-road mobile sources in the study region (i.e. GMR) and for Sydney, Newcastle and Wollongong. Total estimated annual emissions are also presented for the region defined as Non-Urban. This region is the area of the GMR minus the combined areas of the Sydney, Newcastle and Wollongong. These substances have been selected because they are:

- the most common air pollutants found in airsheds according to the National Pollutant Inventory (NEPC, 2000)
- referred to in the NEPMs for criteria pollutants (NEPC, 2003) and air toxics (NEPC, 2004)
- classified as priority air pollutants (NEPC, 2005).

Table ES2: Total estimated annual emissions (for selected substances) from on-road mobile sources in each region

Substance	Emissions (tonnes/year)				
	Sydney	Newcastle	Wollongong	Non-Urban	GMR
1,3 butadiene	199.04	14.06	8.66	34.54	256.31
Acetaldehyde	614.50	41.02	30.56	132.62	818.69
Benzene	1832.90	129.75	79.57	313.91	2356.13
Carbon monoxide	431269.85	31675.12	19172.63	76929.48	559047.07
Formaldehyde	709.43	48.10	33.22	138.90	929.65
Isomers of xylene	2678.95	189.98	116.23	458.84	3444.00
Lead & compounds	10.71	0.71	0.47	1.81	13.70
Oxides of nitrogen	65996.26	4947.23	3255.29	14409.90	88608.69
Particulate matter ≤ 10 µm	2552.05	177.42	119.00	500.75	3349.22
Particulate matter ≤ 2.5 µm	2426.26	169.02	113.45	479.48	3188.21
Polycyclic aromatic hydrocarbons	173.21	11.33	7.43	27.55	219.51
Sulfur dioxide	1253.77	98.11	59.45	248.63	1659.96
Toluene	1902.29	134.79	82.55	326.47	2446.10
Total suspended particulates (TSP)	2912.33	200.11	133.67	548.20	3794.30
Total VOCs	50171.04	3555.75	2194.83	8571.75	64493.38

Tables ES3, ES4, ES5, ES6 and ES7 show total estimated annual emissions (for selected substances) from each on-road mobile source type in the GMR, Sydney, Newcastle, Wollongong and Non-Urban regions respectively.

Table ES3: Total estimated annual emissions (for selected substances) by on-road mobile source type in the GMR

Substance	Emissions (tones/year)						
	Exhaust emissions – petrol passenger cars	Exhaust emissions – diesel light duty vehicles	Exhaust emissions – petrol light duty commercial vehicles	Exhaust emissions – diesel heavy duty commercial vehicles	Exhaust emissions - other vehicles	Evaporative emissions – all petrol vehicles	On-Road Mobile Total
1,3 butadiene	185.12	0.47	33.13	4.96	32.64	0.00	256.31
Acetaldehyde	261.61	23.20	46.81	440.95	46.12	0.00	818.69
Benzene	1543.59	22.54	276.22	42.62	272.14	199.02	2356.13
Carbon monoxide	413721.34	10193.65	71128.51	12424.36	51579.21	0.00	559047.07
Formaldehyde	431.85	44.86	77.28	299.53	76.14	0.00	929.65
Isomers of xylene	2302.07	13.48	411.95	42.12	405.86	268.53	3444.00
Lead & compounds	8.18	1.44	0.47	2.88	0.72	0.00	13.70
Oxides of nitrogen	49010.88	5286.69	5851.35	25288.73	3171.03	0.00	88608.69
Particulate matter ≤ 10 µm	1056.26	1105.88	61.03	1032.77	93.28	0.00	3349.22
Particulate matter ≤ 2.5 µm	971.76	1072.71	56.15	1001.78	85.82	0.00	3188.21
Polycyclic aromatic hydrocarbons (PAH)	148.78	11.63	15.28	25.92	17.90	0.00	219.51
Sulfur dioxide	821.48	317.52	63.81	425.25	31.91	0.00	1659.96
Toluene	1662.53	9.94	297.51	31.06	293.11	151.97	2446.10
Total suspended particulates (TSP)	1425.95	1116.94	82.39	1043.09	125.93	0.00	3794.30
Total VOCs	33061.68	1146.80	5916.30	3583.30	5828.85	14956.44	64493.38

Table ES4: Total estimated annual emissions (for selected substances) by on-road mobile source type in the Sydney region

Substance	Emissions (tones/year)						
	Exhaust emissions – petrol passenger cars	Exhaust emissions – diesel light duty vehicles	Exhaust emissions - petrol light duty commercial vehicles	Exhaust emissions – diesel heavy duty commercial vehicles	Exhaust emissions - other vehicles	Evaporative emissions – all petrol vehicles	On-Road Mobile Total
1,3 butadiene	145.95	0.39	25.91	3.59	23.20	0.00	199.04
Acetaldehyde	206.26	19.31	36.61	319.54	32.79	0.00	614.50
Benzene	1217.00	18.76	216.01	30.89	193.45	156.80	1832.90
Carbon monoxide	323953.12	7935.39	55293.61	8533.58	35554.14	0.00	431269.85
Formaldehyde	340.48	37.34	60.43	217.06	54.12	0.00	709.43
Isomers of xylene	1814.99	11.22	322.16	30.52	288.51	211.55	2678.95
Lead & compounds	6.72	1.13	0.39	1.96	0.52	0.00	10.71
Oxides of nitrogen	38175.02	4245.05	4533.89	16907.72	2134.59	0.00	65996.26
Particulate matter ≤ 10 µm	866.76	865.77	50.14	701.69	67.68	0.00	2552.05
Particulate matter ≤ 2.5 µm	797.42	839.80	46.13	680.64	62.27	0.00	2426.26
Polycyclic aromatic hydrocarbons (PAH)	120.27	9.47	12.05	18.59	12.83	0.00	173.21
Sulfur dioxide	644.96	249.06	49.67	287.86	22.22	0.00	1253.77
Toluene	1310.77	8.27	232.66	22.51	208.36	119.72	1902.29
Total suspended particulates (TSP)	1170.13	874.43	67.69	708.71	91.37	0.00	2912.33
Total VOCs	26066.45	954.65	4626.73	2596.68	4143.46	11783.08	50171.04

Table ES5: Total estimated annual emissions (for selected substances) by on-road mobile source type in the Newcastle region

Substance	Emissions (tones/year)						
	Exhaust emissions – petrol passenger cars	Exhaust emissions – diesel light duty vehicles	Exhaust emissions – petrol light duty commercial vehicles	Exhaust emissions – diesel heavy duty commercial vehicles	Exhaust emissions - other vehicles	Evaporative emissions – all petrol vehicles	On-Road Mobile Total
1,3 butadiene	10.78	0.02	1.26	0.23	1.77	0.00	14.06
Acetaldehyde	15.23	1.02	1.79	20.48	2.50	0.00	41.02
Benzene	89.87	0.99	10.54	1.98	14.77	11.61	129.75
Carbon monoxide	24897.06	567.86	2783.93	637.87	2788.39	0.00	31675.12
Formaldehyde	25.14	1.96	2.95	13.91	4.13	0.00	48.10
Isomers of xylene	134.03	0.59	15.71	1.96	22.03	15.66	189.98
Lead & compounds	0.42	0.08	0.02	0.15	0.04	0.00	0.71
Oxides of nitrogen	2951.60	265.00	217.26	1340.23	173.14	0.00	4947.23
Particulate matter ≤ 10 µm	54.71	61.98	2.10	53.93	4.69	0.00	177.42
Particulate matter ≤ 2.5 µm	50.33	60.13	1.93	52.32	4.32	0.00	169.02
Polycyclic aromatic hydrocarbons (PAH)	8.04	0.56	0.57	1.23	0.94	0.00	11.33
Sulfur dioxide	51.49	18.50	2.64	23.71	1.78	0.00	98.11
Toluene	96.80	0.43	11.35	1.44	15.91	8.86	134.79
Total suspended particulates (TSP)	73.85	62.60	2.83	54.47	6.34	0.00	200.11
Total VOCs	1924.95	50.18	225.66	166.43	316.42	872.12	3555.75

Table ES6: Total estimated annual emissions (for selected substances) by on-road mobile source type in the Wollongong region

Substance	Emissions (tones/year)						
	Exhaust emissions – petrol passenger cars	Exhaust emissions – diesel light duty vehicles	Exhaust emissions – petrol light duty commercial vehicles	Exhaust emissions – diesel heavy duty commercial vehicles	Exhaust emissions - other vehicles	Evaporative emissions – all petrol vehicles	On-Road Mobile Total
1,3 butadiene	6.35	0.01	0.94	0.20	1.16	0.00	8.66
Acetaldehyde	8.97	0.69	1.33	17.93	1.63	0.00	30.56
Benzene	52.92	0.67	7.86	1.73	9.64	6.74	79.57
Carbon monoxide	14415.00	346.52	2049.71	513.07	1848.33	0.00	19172.63
Formaldehyde	14.80	1.34	2.20	12.18	2.70	0.00	33.22
Isomers of xylene	78.92	0.40	11.73	1.71	14.37	9.09	116.23
Lead & compounds	0.27	0.05	0.01	0.12	0.03	0.00	0.47
Oxides of nitrogen	1742.61	169.66	163.51	1067.05	112.45	0.00	3255.29
Particulate matter ≤ 10 µm	34.44	37.63	1.70	41.73	3.50	0.00	119.00
Particulate matter ≤ 2.5 µm	31.68	36.50	1.56	40.48	3.22	0.00	113.45
Polycyclic aromatic hydrocarbons (PAH)	4.93	0.37	0.43	1.05	0.65	0.00	7.43
Sulfur dioxide	29.38	10.97	1.93	15.94	1.22	0.00	59.45
Toluene	56.99	0.30	8.47	1.26	10.38	5.15	82.55
Total suspended particulates (TSP)	46.49	38.00	2.29	42.15	4.73	0.00	133.67
Total VOCs	1133.42	34.33	168.45	145.68	206.43	506.53	2194.83

Table ES7: Total estimated annual emissions (for selected substances) by on-road mobile source type in the Non-Urban region

Substance	Emissions (tones/year)						
	Exhaust emissions – petrol passenger cars	Exhaust emissions – diesel light duty vehicles	Exhaust emissions – petrol light duty commercial vehicles	Exhaust emissions – diesel heavy duty commercial vehicles	Exhaust emissions – other vehicles	Evaporative emissions – all petrol vehicles	On-Road Mobile Total
1,3 butadiene	22.04	0.04	5.01	0.93	6.51	0.00	34.54
Acetaldehyde	31.15	2.18	7.09	83.00	9.20	0.00	132.62
Benzene	183.81	2.12	41.81	8.02	54.28	23.88	313.91
Carbon monoxide	50456.15	1343.88	11001.26	2739.84	11388.35	0.00	76929.48
Formaldehyde	51.42	4.21	11.70	56.38	15.18	0.00	138.90
Isomers of xylene	274.12	1.27	62.35	7.93	80.95	32.22	458.84
Lead & compounds	0.78	0.18	0.05	0.66	0.13	0.00	1.81
Oxides of nitrogen	6141.65	606.99	936.69	5973.73	750.85	0.00	14409.90
Particulate matter ≤ 10 µm	100.35	140.50	7.09	235.41	17.40	0.00	500.75
Particulate matter ≤ 2.5 µm	92.32	136.28	6.52	228.35	16.01	0.00	479.48
Polycyclic aromatic hydrocarbons (PAH)	15.54	1.23	2.24	5.05	3.49	0.00	27.55
Sulfur dioxide	95.64	38.99	9.57	97.74	6.69	0.00	248.63
Toluene	197.97	0.93	45.03	5.85	58.46	18.24	326.47
Total suspended particulates (TSP)	135.48	141.90	9.57	237.76	23.49	0.00	548.20
Total VOCs	3936.86	107.64	895.46	674.53	1162.55	1794.71	8571.75

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1 Introduction

The Department of Environment and Climate Change NSW (DECC) has completed a three year air emissions inventory project for on-road mobile sources. The base year of the on-road mobile inventory represents activities that took place during the 2003 calendar year and is accompanied by emission projections up to the 2031 calendar year. The area included in the study covers greater Sydney, Newcastle and Wollongong regions, known collectively as the Greater Metropolitan Region (GMR).

The purpose of this document is to provide a good understanding of the methodology used to develop the inventory and to provide a summary of the main outcome of the development of emission inventory estimates for selected substances. The information is structured as follows:

- A description of the on-road mobile air emissions inventory specifications (Section 2) including:
  - the study year of the inventory (Section 2.1)
  - a description of the study region (Section 2.2)
  - a description of the grid coordinate system (Section 2.3)
  - a description of emission sources considered (Section 2.4)
  - a description of the substances evaluated (Section 2.5)
  - a broad discussion of the methodology (Section 2.6).
- More specific details of the data and methodology used to estimate each individual source type of on-road mobile emission sources for the GMR, Sydney, Newcastle, Wollongong and Non-Urban regions, and the emission inventory estimates for selected substances for each of those source types (Section 3).
- An overall emissions summary for selected substances presented for all on-road mobile sources for the GMR, Sydney, Newcastle, Wollongong and Non-Urban regions (Section 4).
- A complete list of references (Section 5).
- A flowchart outlining the steps of data generation for the inventory database (Appendix A).
- Projected emission trends for the period of 2003 to 2031 (Appendix B).
- Total on-road mobile emissions of all substances emitted in the GMR (Appendix C).

This inventory for 2003 will supersede the existing official inventory – the Metropolitan Air Quality Study (MAQS) (Carnovale et al, 1996) of 1992. The new inventory was built on the MAQS inventory and its progress is outlined as follows:

1. The new inventory and the MAQS inventory cover the GMR.
2. When building the new inventory, the road category system used in the MAQS inventory was retained.
3. When building the new inventory, the approach of deriving composite emission factors was adopted from the MAQS inventory.
4. In developing the new inventory, the vehicle category system of the MAQS inventory was largely adopted, except for the category of diesel heavy duty commercial vehicles which was broken down into rigid trucks, articulated trucks and buses;
5. Base emission factors for petrol passenger cars manufactured before 1986 were adopted from the MAQS inventory

6. Base emission factors for petrol passenger cars manufactured after 1986 were completely redeveloped incorporating later available test data under Australian conditions as well as information from overseas.

7. Base emission factors for all types of diesel vehicles were redeveloped using the latest test data.

8. Base emission factors for light duty commercial petrol vehicles, heavy duty commercial petrol vehicles and motorcycles were largely kept the same as the MAQS inventory because of the lack of more recent data.

9. Vehicle kilometres travelled (VKT) data was completely redeveloped by commissioning the Traffic and Population Data Centre, Department of Planning to generate travel forecasts using the redeveloped Sydney Strategic Travel Model (STM) and latest the Household Travel Survey (HTS).

10. The number of inventoried substances increased from five criteria pollutants (VOC, NO_x, CO, PM and SO_2) in the MAQS inventory to over 220 including speciated PAHs and other air toxic substances.

11. Spatial resolution was improved from a 3 km by 3 km grid mesh used in the MAQS inventory to a 1 km by 1 km grid.

12. The MAQS inventory contains only emission estimates for an average weekday, weekend day and the whole year. The new inventory accommodates a set of hourly, weekly and monthly temporal profiles enabling the conversion of annual emissions to different time scales.

2 Inventory Specifications

2.1 The Study Year

The on-road mobile air emissions inventory results presented in this report are based on activities that took place in the 2003 calendar year.

2.2 The Study Region

The study region defined as the GMR measures 210 km (east-west) by 273 km (north-south). The study region is defined in Table 2.1 and shown in Figure 2.2.

Table 2.1: Definition of Greater Metropolitan, Sydney, Newcastle and Wollongong regions

Region	South-west corner MGA[1] co-ordinates		North-east corner MGA[1] co-ordinates	
	Easting (km)	Northing (km)	Easting (km)	Northing (km)
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[1] MGA = Map Grid of Australia based on the Geocentric Datum of Australia 1994 (GDA94) (ICSM, 2002).

2.3 Grid Coordinate System

The grid coordinate system used for the on-road mobile air emissions inventory uses 1 km by 1 km grid cells. The grid coordinates start from the bottom left corner having index number with Easting (km) in the horizontal and Northing (km) in the vertical direction. The grid coordinate system is illustrated in Figure 2.1.

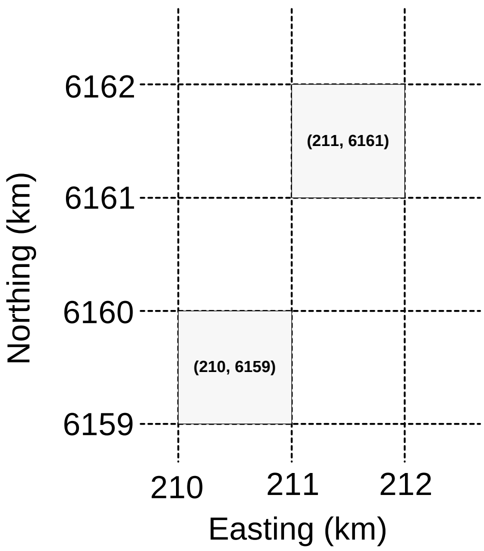

Figure 2.1: Grid coordinate system

2.4 Emission Sources Considered

The on-road mobile air emissions inventory includes emissions from the following sources:

- exhaust emissions from petrol passenger cars
- exhaust emissions from diesel light duty vehicles
- exhaust emissions from petrol light duty commercial vehicles
- exhaust emissions from diesel heavy duty commercial vehicles
- exhaust emissions from other vehicles
- evaporative emissions from all petrol vehicles.

2.5 Substances Evaluated

The inventory includes on-road mobile emission releases to air in the region depicted by Figure 2.2. The following substances have been considered:

- substances included in the National Pollutant Inventory (NPI) National Environment Protection Measure (NEPC, 2000)
- pollutants included in the Air Quality National Environment Protection Measure (NEPC, 2003)
- pollutants included in the Air Toxics National Environment Protection Measure (NEPC, 2004)
- speciation of oxides of nitrogen for photochemical modelling (i.e. NO and NO_2)[1]
- speciated organic compounds for photochemical modelling sourced from Carter, Tonnesen & Yarwood (2003)
- speciated particulate emissions (i.e. TSP (total suspended particulate), PM_{10} (particulate matter with an aerodynamic diameter ≤ 10 μm) and $PM_{2.5}$ (particulate matter with an aerodynamic diameter ≤ 2.5 μm))
- Environment Protection Authority of Victoria air toxic pollutants sourced from *Hazardous Air Pollutants – A Review of Studies Performed in Australia and New Zealand* (EPAV, 1999)
- Commonwealth Government Air Toxics Program Technical Advisory Group (13 March 2000) priority air pollutants (DEH, 2001)
- U.S. Environmental Protection Agency list of 189 Hazardous Air Pollutants (USEPA, 2005)
- air pollutants included in the Office of Environmental Human Health Assessment (OEHHA)/Air Resources Board (ARB) ‘hot spots’ list (CARB, 2005)
- DEC regulated pollutants with design ground level concentrations (DEC, 2005)
- USEPA 16 priority PAHs (Keith & Telliard, 1979)
- WHO97 dioxin and furans and PCBs (Van den Berg et al, 1998).

[1] The default NO_x speciation profile used in the inventory is 5% NO_2 and 95% NO (USEPA, 2005a)

Figure 2.2: Definition of the Greater Metropolitan, Sydney, Newcastle and Wollongong regions

2.6 Methodology Overview

This section contains a broad overview of the methodology used to develop the on-road mobile air emissions inventory.

2.6.1 On-Road Mobile Source Classification

Six emission source types are defined:

- exhaust emissions from petrol passenger cars
- exhaust emissions from diesel light duty vehicles
- exhaust emissions from petrol light duty commercial vehicles
- exhaust emissions from diesel heavy duty commercial vehicles
- exhaust emissions from other vehicles
- evaporative emissions from all petrol vehicles.

Petrol passenger cars (gross vehicle mass (GVM) ≤ 2.7 tonnes) are the major VKT contributor in the GMR accounting for nearly 79% of total VKT generated in the region. The behaviour of passenger car travel, commuting travel in particular, has been well studied through a long-term Household Travel Survey (TPDC, 2005) and is modelled in a sophisticated way by the Transport and Population Data Centre (Milthorpe, 2002). The emission behaviour of passenger cars is also well understood thanks to a wealth of emission test data that have been made available in Australia and overseas. Passenger cars have long been targeted by the Commonwealth Government for emission control and by many jurisdictional governments for travel demand management and other pollution control strategies. Petrol passenger cars are thus treated as an individual source type.

There are fewer passenger cars running on diesel than those running on petrol. Many of these diesel cars are 4WD vehicles. Therefore, the categorisation of 4WD vehicles is quite ambiguous, crossing both passenger cars and light duty commercial vehicle groups in the Roads and Traffic Authority's (RTA) registration data. Therefore, diesel passenger cars and diesel light duty commercial vehicles (2.7tonnes<GVM≤ 3.5 tonnes) are combined into one source type. This type accounts for about 7.4% of total VKT in the GMR.

The above two categories cover most of the light duty vehicles except light duty commercial petrol vehicles (2.7tonnes<GVM≤ 3.5 tonnes). Therefore light duty commercial petrol vehicles are kept as one group which account only for about 5.4% of total VKT in the GMR.

The diesel heavy duty commercial vehicle (GVM>3.5 tonnes) is another important vehicle category which includes rigid and articulated trucks as well as buses. These heavy duty diesel vehicles, accounting for about 6.4% of total VKT in the GMR, contribute disproportionately to the fine particle and NO_x emissions of the urban fleet. The heavy duty diesel vehicle is another major vehicle group that is subjected to emission control policies and reporting procedures at both federal and state levels. As discussed in the planning stage of developing this inventory, they are treated as one source type.

Petrol heavy duty commercial vehicles are rare and their performance is largely unknown. On the private travel side, motorcycles (nearly all petrol powered) have also very small contributions to total VKT and their emission performance is also largely unknown under Australian conditions. While emissions from the two types of vehicles are calculated separately, they are placed in one category termed the 'Other Vehicles' in the final delivery to the Emissions Data Management System (EDMS). In total, the two types of vehicles account for only 2.20% of total regional VKT.

There are some vehicles in the fleet that are run by alternative fuels such as LPG, CNG and bio-diesel. However, the number of those vehicles is unknown, and for this project are considered to be negligible in comparison with other types of vehicles. Adequate emission data for these alternative fuel vehicles are also unavailable. Therefore these alternative fuel vehicles are excluded from this edition of inventory.

The composition and behaviour of VOC evaporative emissions is significantly different to that of exhaust emissions. Therefore, evaporative emissions from petrol vehicles are separated from exhaust emissions and are treated as a separate category.

2.6.2 Base Emission Factors

Base emission factors are emission factors for a certain type of vehicle manufactured in a specific calendar year. If the emission performance of vehicles manufactured in a number of consecutive calendar years is taken to be practically the same, for example, being equipped with the same emission control technology or under the same emission standards, one set of base emission factors are used to represent all these vintage years to reduce data redundancy in modelling.

A base emission factor (*EFb*) is in general composed of an emission factor for zero mileage (*EF0*), an emission deterioration rate (*EDR*), an emission tampering rate (*ETR*), an emission factor for tampered car (*EFt*) and an emission ceiling (*EFc*). At a cumulative distance travelled (*dist),* the base emission factor is expressed as:

$$EFb = Max\{ (EF0 + EDR * dist) * (1 - ETR) + EFt * ETR, EFc \}$$

The base emission factors of petrol passenger cars currently used for the inventory are derived from a large data pool involving over eight thousand emission testing records originated from a number of government and industry laboratories, covering late-70s to early-90s vehicle models (Xu, 2000, 2001a).

A much smaller database, which represents the latest and best available data under Australian conditions, was used to develop diesel vehicle emission factors (Xu, 2001b). Due to the small size of the dataset, base emission factors for heavy duty diesel vehicles were made to represent the emission behaviours of an average vehicle life, without taking explicit consideration of emission deterioration. This simplification is justified by the fact that emission deterioration for heavy duty vehicles is much less significant than that of passenger cars owing to the robustness of the heavy duty diesel engines. To compensate for the deficiency of the Australian diesel testing data, a desktop analysis of overseas diesel emission data and relevant regulations were undertaken because nearly all diesel vehicles used in Australia are imported, and the overseas information is highly relevant.

2.6.3 Fleet Structure

The fleet of vehicles of a particular type, for example, petrol passenger cars is a mixture of vehicles of different ages, ranging from new to those which can be over 35 years old. Vehicles of different ages have different emission performance - usually new vehicles on average emit much less than old ones on a per-VKT basis. This difference relates to two factors: (1) new vehicles are usually equipped with more advanced emission control technologies, and (2) emissions from an in-service vehicle would usually increase over time owing to the operating conditions gradually moving away from optimum and emission control devices physically deteriorating. To deal with the first fact, different emission factors are used for different vehicle model years. For the second, it is assumed that emissions from a vehicle increase gradually (linearly) over the cumulative mileage until a maximum possible level is reached.

Vehicles of different ages in a fleet also differ in their usage. As a result of fleet turnover (aged vehicles being removed from the fleet and new vehicles entering the fleet), older vehicles usually account for a smaller fraction of the fleet than do newer ones. Secondly, old vehicles tend to drive less on a per vehicle basis than do newer ones. Profiles capturing these two tendencies, which are derived from RTA registration data, are incorporated in the modelling. Emissions for a vehicle type can then be calculated by summing up emissions from each age group of the vehicle type.

Using the above approach, average emission levels for each vehicle type can be estimated for a given fleet under standard conditions (under which the emission factors are developed).

2.6.4 Driving Conditions

Emissions from vehicles are significantly influenced by driving conditions, for example, relatively smooth driving on a highway will result in less emissions than driving in the CBD which involves more frequent stops. In developing the inventory, emission factors were first estimated for a standard, or in other words, average driving conditions. These were then converted into emission factors for other driving conditions, for example, driving on highways, arterial roads, local roads and in congested driving conditions.

A 2-dimensional matrix of emission factors with vehicle types as one dimension and driving conditions as another can then be generated. Matching this emission factor matrix, a VKT composition matrix is also created: under each of the driving conditions; the fraction of total VKT accounted for by each of those vehicle types is specified. The average emission factor for a particular type of driving condition is therefore calculated as the sum of the products of emission factors and VKT fractions for different types of vehicles under this driving condition. This process is carried out for five road types including their congested conditions.

There are both advantages and disadvantages using this method. The advantages are its less demanding data requirements and its simplicity in modelling in comparison with some more advanced methods. The disadvantages are its lack of adaptability and out-datedness. As the driving condition factors of passenger cars were derived many years ago on the basis of ADR27 drive cycle, all the base emission factors later developed on ADR37 cycle or the latest EURO cycles, when used in emission modelling, must be converted back to equivalents for the ADR27 cycle. This extra step of conversion inevitably brings in errors. Those dated driving condition conversion factors are becoming less representative of today's urban driving conditions. An update to the driving condition factors is almost impossible as it requires second-by-second emission test data which are unavailable from any of existing data sources.

2.6.5 Influencing Factors

Apart from fleet structure and driving conditions, there are many other factors affecting motor vehicle emissions. The following emission-influencing factors have been taken into account:

- petrol volatility – high volatility directly raises evaporative emissions and slightly but discernibly increases exhaust emissions
- sulfur content in petrol – sulfur in petrol decreases the performance of three-way catalysts, and contributes directly to SO_2 emissions
- sulfur content in diesel – sulfur in diesel contributes to the sulfate component of particle emissions, and offsets oxidation catalysts efficiency
- diesel density – decreased diesel density tends to decrease CO, HC and PM_{10} emissions and increasing NO_x emissions for light duty vehicles but has the opposite effect for heavy duty vehicles on gaseous emissions and no significant effect on PM_{10} emissions (EPEFE, 1999)
- diesel cetane number – an increase in cetane number decreases CO and VOC emissions from heavy duty vehicles (EPEFE, 1999)
- petrol vehicle in-service maintenance – an inspection/maintenance program reduces emission deterioration
- diesel vehicle in-service maintenance – an inspection initiative improves in-service emission performance.

When the baseline emission factors are generated, they are adjusted for these emission influencing factors. Petrol volatility is incorporated in the generation of base evaporative emissions factors, while other fuel parameters are treated as modification factors to the composite emission factors. For in-service maintenance, dedicated procedures are developed to simulate the complex interactions between program parameters and emissions.

2.7 Emission Speciation

Emission speciation profiles for motor vehicle emissions are mainly derived from the Motor Vehicle Toxic Emission Database (MVTED) that had been purpose-developed for the inventory project, built on an extensive literature review and data collection.

Most of the major motor vehicle emission testing studies collected only criteria pollutant emissions. Miscellaneous emission experiments that did measure individual VOC substances are usually of a small scale and far from comprehensive in terms of substances coverage. The profiles collected in the US Environmental Protection Agency (USEPA) database – SPECIATE (USEPA 2003) do not contain speciated PAH substances. Besides, many studies focused only on a few specific vehicle types, vintages and/or driving conditions. In view of these deficiencies, it was decided to develop emission speciation profiles with the following steps:

1. An extensive search, review and compilation of data from literatures and original data sources;
2. The development of a relational database to accommodate the data compiled; and
3. The derivation of a number of representative speciation profiles from the database.

The aim is to compensate the incomplete coverage, and to average out probable errors, of individual datasets. The database also facilitates a future update by admitting new data once available.

2.7.1 Data Collection

An extensive literature review was undertaken. Dozens of journal papers and research reports on motor vehicle toxic emission testing were collected. Given the time limit and the existence of the USEPA's SPECIATE database, the effort was mainly focused on gathering PAHs data. Of these, a short list of 16 quality data sources was finally identified. Apart from the USEPA's SPECIATE database, the former NSWEPA) Petrohol study (Brown et al, 1998) and CSIRO/PARSON's air toxic study, the data were from individual research efforts in the US and Europe (Yang, 2004; Lev-On et a., 2002; Westerholm, 2001; Cook & Somer, 1999; Schauer, 1999; Norbeck, 1998; Staehelin, 1998; Collier, 1998; Wolfgang, 1993; Westerholm, 1996; Lies, 1988 as in Staehelin 1998).

2.7.2 Database Construction

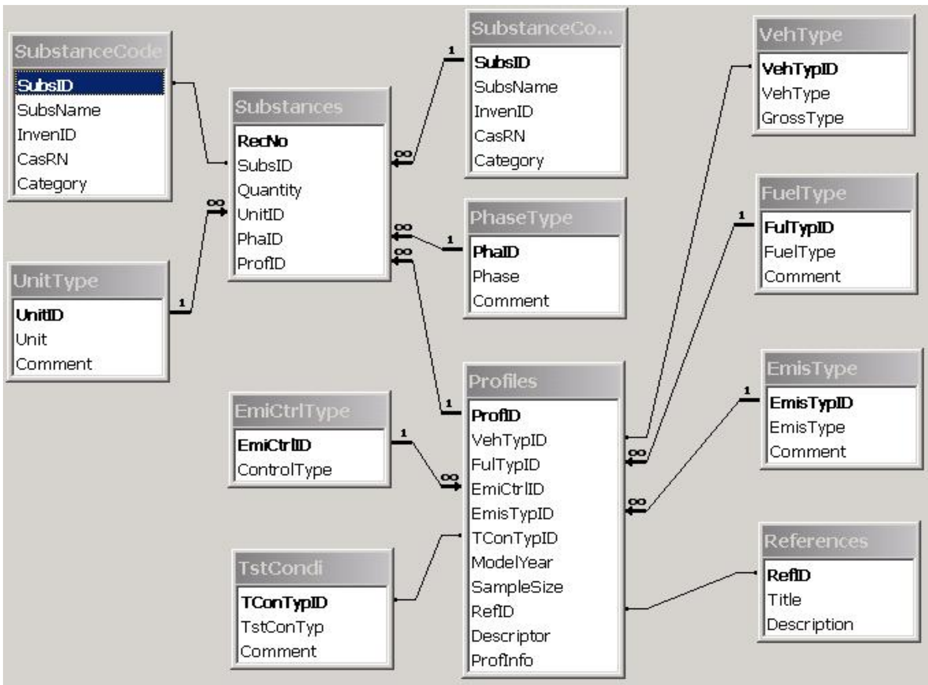

Figure 2.3: MVTEF database structure

The data compiled from the above sources were imported into a relational database termed the Motor Vehicle Toxic Emission Factors (MVTEF) database. The database so far contains 280 substances, 150 profiles, and totals over 6000 records for emission factors. Some major fields of the database are:

- vehicle type
- fuel type
- emission control status
- vehicle model year
- emission test conditions
- emission units
- emission phases (i.e. gaseous, semi-volatile or particle).

2.7.3 Speciation Profile Derivation

There are nine vehicle types involved in the inventory. When deriving speciation profiles, there has to be a balance between the number of profiles representing different vehicle types and the size of the dataset supporting each of the profiles. While a specific vehicle type would ideally need its own speciation profile, the quality of the profiles would be compromised by the reduced size of the raw data in each group given that the current database is not sufficiently large. The usable size of the database is further reduced by excluding data for vehicles manufactured before 1986 that were considered to be irrelevant to the 2003 base case. The following four speciation profiles were then established:

1. VOC/PM exhaust emissions from petrol passenger cars

2. VOC/PM exhaust emissions from diesel light vehicles

3. VOC/PM exhaust emissions from diesel heavy vehicles

4. VOC evaporative emissions from petrol vehicles.

Table 2.2 gives the match between the four speciation profiles and the six sources types.

Table 2.2: Match of source types and profiles

Source types	Speciation profiles
Exhaust – Petrol Car	(1)
Exhaust – Diesel Light Duty	(2)
Exhaust – Petrol Light Duty Commercial	(1)
Exhaust – Diesel Heavy Duty Commercial	(3)
Exhaust – Others	(1)
Evaporative – All Petrol	(4)

For exhaust emissions, speciation processes are carried out for both VOCs and particulate matter as follows.

1. for all the non-PAH hydrocarbons, speciation is made against total VOCs

2. for all the metals and solid substances such as arsenic, speciation is made against PM_{10}

3. for PAHs, the process is somewhat more complex, speciation being made against both VOC and PM (details will be given later).

For evaporative emissions, only VOC speciation is needed.

2.7.4 Dioxin Emissions

Measurements for dioxin emissions from on-road motor vehicles are rare. A road tunnel study by Oehme et al (1991) was selected for deriving dioxin speciation profiles owing to the possibility of differentiating, to a degree, the effects of different types of vehicles using traffic composition data collected under different circumstances in the study. Three types of vehicles were identified for speciation profile derivation, namely, petrol passenger cars, diesel light duty trucks and heavy duty diesel trucks.

2.8 Temporal Profile

The EDMS contains a main dataset of annual emissions and a suite of temporal profiles that are used to convert the annual emissions to emissions in different time scales. For on-road mobile sources, three temporal profiles are required by the EDMS: daily profile, weekly profile, and monthly profile.

2.8.1 Daily Profile

The daily profile for a typical weekday is directly derived from the TPDC hourly travel forecast data. An application routine was written to derive the daily profile (24 hours of an average weekday) for each of the six source types in each grid cell.

To satisfy the temporal data requirement of the inventory and maintain a relatively simple data structure, it was decided that the six source types all have their own daily profiles but all the criteria pollutants of one source type shares a common profile for a specific grid. This is justified in that hourly emission variation patterns are largely dependent on the hourly variation patterns of activity behaviour of the source of emissions. Different source types will be very likely to have different daily travel patterns, for example, most commuting travel features dual peaks in the morning and afternoon rush hours but commercial travel largely utilise business hours of the day. The non-activity based hourly variations in emissions which may differ from one substance to another result mainly from temperature effects, cold-start being the chief influencing factor, for example, CO is much more sensitive to cold-start than NO_x. However, the current activity data (i.e. VKT being used in the inventory), prevent the inclusion of a cold-start effect in emission modelling. Therefore, without considering the cold-start, differences in hourly pattern between substances from one source type will be minimal in comparison with the magnitude of hourly changes in source activities.

As evaporative emissions are significantly affected by the hourly change of ambient temperature, a separate daily temporal profile is derived for evaporative emissions. This profile is not derived for exhaust emissions because temperature has little influence on exhaust emissions under hot-stabilised conditions.

Weekend days should have different hourly profiles from those of weekdays owing to changes in travel behaviours. A set of conversion factors was derived from RTA road traffic counts data (RTA, 2002) to convert hourly profile data for weekdays to those of weekend days.

For speciated substances, all VOC-based substances use VOC daily profiles and all PM-based substances use PM daily profiles. For PAH substances that are speciated against both VOC and PM, daily profiles of PM emissions are adopted. NO and NO_2 use the NO_x daily profile.

2.8.2 Weekly Profile

A weekly profile has two values for each source activity: the proportion of total weekly emissions attributable to the five weekdays activity and the proportion attributable to the two weekend days. The weekly factors are adopted from the MAQS inventory: if VKT on a weekday is 1, VKTs on Saturday and Sunday traffic are then 0.93 and 0.82 respectively. Due to data limitation, the factors are applied to all source types at this stage.

2.8.3 Monthly Profile

Seasonal variations in emissions will result from both seasonal variations in travel activity, for example, lower urban travel demand in school holiday and Christmas/New Year periods, and the influence on emissions of seasonal changes in ambient temperatures. Table 2.3 gives monthly profile factors for traffic variations and temperature effects. Due to data limitation, they are applied to all source types at this stage. The traffic variation factors are derived from RTA traffic counts data. The temperature effect factors of exhaust emissions are derived from the winter emission conversion factors used in MAQS inventory: assuming emissions from the whole vehicle fleet on an average summer day are 1, emissions on an average winter day are 1.72, 1.08, 1.48, 1.13 for CO, NO_x, VOC, and PM_{10} respectively. For the three months of autumn and three months of spring, values from a linear interpolation between the summer and winter emission levels are assigned.

For evaporative emissions, the winter/summer ratio of emissions is calculated from DEC Motor Vehicle Emission Projection System (MVEPS) (Xu, 1998) results assuming summer time and winter time Reid vapour pressure (RVP) to be 62 kPa and 90 kPa respectively. Note that if summer RVP changes, the ratio will change accordingly, for example, if using 76kPa, the ratio to be about 0.5 instead of 1.08.

The final monthly profile values are the product of traffic factors and corresponding temperature factors.

Table 2.3: Monthly profiles for all source types

Month	Traffic factor	Temperature effect				
		CO	NO_x	VOC	PM	Evaporation
Jan	0.0789	1	1	1	1	1
Feb	0.0843	1	1	1	1	1
Mar	0.0848	1.18	1.02	1.12	1.03	1.02
Apr	0.0830	1.36	1.04	1.24	1.07	1.04
May	0.0848	1.54	1.06	1.36	1.10	1.06
Jun	0.0826	1.72	1.08	1.48	1.13	1.08
Jul	0.0836	1.72	1.08	1.48	1.13	1.08
Aug	0.0845	1.72	1.08	1.48	1.13	1.08
Sep	0.0849	1.54	1.06	1.36	1.1	1.06
Oct	0.0844	1.36	1.04	1.24	1.07	1.04
Nov	0.0872	1.18	1.02	1.12	1.03	1.02
Dec	0.0769	1	1	1	1	1

It should be noted that the above described monthly adjustment is still very crude. It does not address the spatial variations across the GMR region and is not sophisticated enough to cover a very important seasonal demand factor with local impact in particular – school holidays.

2.9 Future Trends Projection

Applying activity growth factors to a baseline inventory to generate emission inventories for future years is a commonly used method for industry and domestic sources. However, for on-road mobile sources, owing to their dynamic nature, this approach is not appropriate. The change of motor vehicle emissions along the timeline are not just determined by changes in travel activities but also by changes in emission performance as well as by changes in fleet structure. While total emissions are proportional to the VKT for a given fleet, the fleet itself is continuously evolving by taking in new model vehicles and scraping old ones. This way, new vehicle technologies gradually penetrate the fleet over a long period of time. At the same time, emission standards and fuel quality standards are also tightened. As a new emission standard regulates only vehicles manufactured since the introduction of the standard, only a very small proportion of the fleet will be affected in the first year. While the implementation of a new fuel standard will immediately affect all vehicles in the fleet that use the fuel, the actual effects are likely to be different for vehicles with different technologies, for example diesel emission factors for reduced sulfur content. Vehicles equipped with catalysts will be much more sensitive to certain level of change in sulfur content than those without catalysts.

For the purpose of producing emission estimates for a future year, a projected emission inventory for that year will need to be built on the basis of an emission scenario e.g. perceived future emission control levels. The methodology of base year inventory introduced in this report is totally applicable to a future year inventory. In Appendix B, time trends of emissions for the period of 2003 to 2031 are presented using the results of emission inventory projection for those years.

3 Data Sources and Results

In this section, total estimated emissions (for selected substances) are presented for each on-road mobile source type in the study region (i.e. GMR), Sydney, Newcastle and Wollongong regions. Total estimated emissions are also presented for the region defined as Non-Urban. This region is the area of the GMR minus the combined areas of the Sydney, Newcastle and Wollongong regions. In this section emissions are presented for the following substances only:

- 1,3-butadiene
- Acetaldehyde
- Benzene
- Carbon monoxide (CO)
- Formaldehyde
- Isomers of xylene
- Lead & compounds
- Oxides of nitrogen (NO_x)
- Particulate matter ≤ 10 µm (PM_{10})
- Particulate matter ≤ 2.5 µm ($PM_{2.5}$)
- Polycyclic aromatic hydrocarbons (PAHs)
- Sulfur dioxide (SO_2)
- Toluene
- Total suspended particulates (TSP)
- Total VOCs (VOCs)

These substances have been selected since they are:

- the most common air pollutants found in airsheds according to the National Pollutant Inventory (NEPC, 2000)
- referred to in National Environment Protection Measures (NEPMs) for criteria pollutants (NEPC, 2003) and air toxics (NEPC, 2004)
- they have been classified as priority air pollutants (NEPC, 2005).

Total on-road mobile emissions of all substances emitted in the GMR are presented in Appendix C.

3.1 Petrol Passenger Cars

3.1.1 Emission Factors

Emission factors for cars with model years up to 1987 have been well studied and developed in the MAQS emission inventory, and were adopted for all updates afterwards. Their importance to the current inventory is diminishing. For cars beyond 1987 model years, a dedicated study was carried out in 2000 to redevelop their emission factors using extensively collected emission test data (Xu, 2000). Efforts were made to suppress data 'noise' and linear regression was carried out to establish emission deterioration profiles. Finally, estimates for individual vehicle makes, for example, Toyota and Ford are integrated to generate fleet-representative base emission factors on the basis of the market share of these makes.

The base emission factors of petrol passenger cars have been developed using all the available emission test data generated under Australian conditions, including:

- the database of the former NSW EPA and VicEPA motor vehicle laboratories (1972–1990) (NSW EPA, 1990)
- the database of National In-Service Study (NISE) (FORS, 1998)
- the dataset of NSW EPA dyno calibration (NSWEPA, 1998)
- the dataset of Drive Cycle Comparison Study by FORD Australia (FORS, 2000).

Efforts had also been made to develop projected emission factors for the future years using trend information revealed by the existing emission test data in conjunction with knowledge about future emission control policies and technology (Xu, 2001a). Final refinements were made in 2004. Table 3.1 lists the base emission factors and emission deterioration rates for NO_x, VOC and CO.

Table 3.1: Fleet averaged base emission factors (based on CVS-C cycle)

Model year	NO_x		VOC		CO	
	New car emissions (g/km)	Deterioration rate (g/km/km)	New car emissions (g/km)	Deterioration rate (g/km/km)	New car emissions (g/km)	Deterioration rate (g/km/km)
1988	0.795	8.91×10^{-6}	0.345	6.81×10^{-6}	5.076	1.11×10^{-4}
1990	0.663	1.03×10^{-5}	0.352	3.94×10^{-6}	4.59	7.82×10^{-5}
1992	0.591	1.12×10^{-5}	0.339	3.23×10^{-6}	4.264	6.83×10^{-5}
1994	0.503	1.04×10^{-5}	0.324	2.59×10^{-6}	3.872	5.57×10^{-5}
1996	0.412	9.55×10^{-6}	0.306	1.85×10^{-6}	3.456	4.34×10^{-5}
1998	0.343	8.49×10^{-6}	0.288	1.68×10^{-6}	3.119	3.64×10^{-5}
1999	0.167	8.50×10^{-6}	0.27	1.50×10^{-6}	1.74	3.20×10^{-5}
2002	0.15	8.10×10^{-6}	0.25	1.40×10^{-6}	1.6	2.80×10^{-5}

There is no emission test data available for PM_{10} emissions from petrol passenger cars under Australian conditions. Particulate emissions from petrol vehicles are not regulated by current emission standards and are believed to be much lower than those from diesel vehicles on a per vehicle basis. However, it is noted that given the dominant proportion of petrol passenger cars in an urban motor vehicle fleet, contributions from petrol vehicles to the fleet-wide PM emissions may become significant, particularly when diesel particulate emissions are reduced by ever tightening emission standards. This could become a significant source of uncertainty. PM_{10} emission factors used in this inventory are adopted from the MAQS inventory (Table 3.2).

Table 3.2: PM_{10} emission factors (lifetime average) for petrol passenger cars

Year	g/km
1975	0.111
1986	0.070
1989	0.050
1992	0.030

3.1.2 Emission Modification Factors

Emission modification parameters for petrol passenger cars are set as follows:

1. driving conditions – detailed below
2. petrol fuel volatility – detailed below
3. in-service maintenance – assumed to be none for this inventory
4. fuel sulfur content – assumed to be 150ppm for this inventory
5. ethanol blending – assumed to be none for this inventory
6. season – calculated for both average summer and average winter for this inventory.

3.1.2.1 Driving Condition Modification

Driving conditions include five road types defined in the MAQS inventory – highway, arterial road, commercial highway, commercial arterial road and local/residential road, as well as two traffic flow conditions – free-flow and congested – for each type of road. Driving condition modification factors are (1) adopted from the MAQS inventory for petrol vehicles, and (2) derived from the Diesel National Environmental Protection Measure (DNEPM) Preparatory Project 2.2 for diesel vehicles (MVEC, 2000). Table 3.3 lists the driving condition modification factors.

Table 3.3: Driving condition modification factors for petrol passenger cars

Substance	Free-flow					Congested				
	Arterial	Highway/ Freeway	Commercial Arterial	Commercial Highway	Local/ Residential Roads	Arterial	Highway/ Freeway	Commercial Arterial	Commercial Highway	Local/ Residential Roads
PM	1.000	0.550	1.000	0.550	1.000	1.800	1.332	2.000	1.379	1.474
NO_x	0.850	1.300	0.850	1.300	1.000	0.950	1.074	0.950	1.084	1.105
VOC	0.650	0.700	0.650	0.700	1.000	0.800	1.131	0.800	1.150	1.188
CO	0.650	0.650	0.650	0.650	1.000	0.700	1.050	0.700	1.057	1.071

3.1.2.2 Petrol Volatility Modification

While evaporative emissions are most sensitive to changes in petrol volatility (Reid Vapour Pressure or RVP), the exhaust emissions of VOC and CO are also affected by RVP, though to a much lesser extent. NO_x emissions are almost independent of RVP. The current approach to quantify this effect is very simplistic and may not be precise. The method is actually a quadratic equation for VOC and straight-line equations for CO and NO_x linking emissions to RVP values (Figure 3.1) on the basis of a Canadian study (Environment Canada, 1995). As this study provides only three valid data points for hydrocarbons (HC) and two for NO_x and CO. Large errors may occur in this process, in particular, for the CO emissions at the lower end of the RVP curve, which was extrapolated past the valid data range.

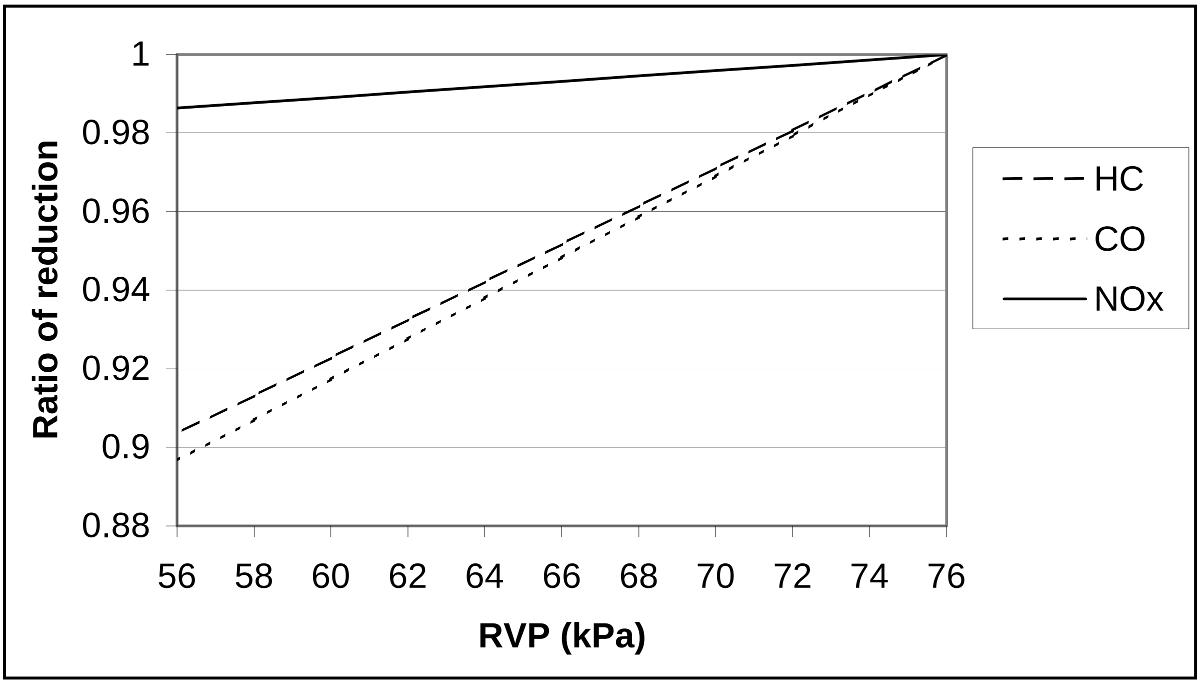

Figure 3.1: RVP effects on exhaust emissions (derived from Environment Canada, 1995)

3.1.3 Emission Speciation

- Emission speciation profiles for petrol passenger cars are derived from a number of sources, including: Emission tests on two 3-way catalyst equipped petrol vehicles by Westerholm and Christensen (1996);

- Emission tests and analysis of PAH from vehicle exhaust, Collier et al (1998);

- US EPA SPECIATE database (2003); and

- NSW EPA Petrohol Study datasets (Brown et al, 1998).

The PAH data extracted from sources 1 and 2 are in the unit of mass emissions – µg/km. The profile data are then derived as the ratios of the mass emissions of individual PAH substances to the mass emissions of VOC, and also of PM_{10}, separately. That is to say, two profiles for PAHs are derived, one against VOC and the other against PM_{10}. When the speciation profiles are integrated with criteria pollutants emission estimates, PAH emissions are calculated using both profiles and the results based on VOC and PM_{10} are then averaged to generate the final PAH emission estimates. This dual-speciation approach is chosen as an interim measure to reduce the level of uncertainty in relation to PAH estimation. Many PAH substances are presented in both gaseous and particle forms depending on exhaust conditions, and whether to speciate PAHs against VOC or PM_{10} in an inventory is still a subject of debate (e.g. Cook & Somers, 2000). Another approach is to partition PAH substances into semi-volatile and particle phases at the exit of exhaust pipe, but this approach requires the support of very detailed data which are currently not available.

For other organic substances, there is only one profile against total VOC emissions, which is derived from sources 3 and 4. Table 3.4 gives a sample of speciation data for selected substances.

Table 3.4: Sample of speciation profile for petrol passenger cars

Substance ID	Substance name	% PM	% VOC
201	1,3-butadiene	NA	0.55991
356	Benzene	NA	4.668823
49	Formaldehyde	NA	1.306181
482	Toluene	NA	8.197187
1257	Fluorene	0.335196	0.005882
1299	phenanthrene	0.161732	0.002838
1329	1-methylphenanthrene	0.008045	0.000141
1358	Fluoranthene	0.033799	0.000593
1356	Pyrene	0.02419	0.000425
1386	benzo[ghi]fluoranthene	0.00432	7.58×10^{-05}
1390	benzo(a)anthracene	0.004581	8.04×10^{-05}
1388	chrysene	0.007989	0.00014
1405	benzo(b)fluoranthene	0.00482	8.46×10^{-05}
1408	benzo(k)fluoranthene	0.00482	8.46×10^{-05}
1406	benzo(e)pyrene	0.001341	2.35×10^{-05}
1404	benzo(a)pyrene	0.001666	2.92×10^{-05}
1420	benzo(g,h,I)perylene	0.004134	7.25×10^{-05}
1407	perylene	0.000149	2.61×10^{-06}
1418	Indeno(1,2,3-CD)pyrene	0.001397	2.45×10^{-05}
83	Acetylene	NA	2.312549
288	Cyclopentene	NA	0.011198
596	M-xylene	NA	5.028566
597	O-xylene	NA	1.934375
144	Propylene	NA	3.062209
210	Trans-2-butene	NA	0.552979
12	Calcium	0.2475	NA
16	Chromium	0.006333	NA
19	Copper	0.01375	NA
3	Lead	0.77475	NA
27	Manganese	0.009	NA
28	Mercury	0.002	NA
30	Nickel	0.00525	NA
41	Zinc	1.1845	NA
36	Dioxins & Furans	3.58×10^{-07}	NA

3.1.4 Temporal Profiles

Every individual source activity (i.e. every source type in each grid cell) has its own daily profiles. As a result, a great number of daily profiles are generated. Figure 3.2 gives the average hourly travel profile for petrol passenger cars, which is a profile averaged over the entire GMR.

Weekly and monthly profiles have already been discussed in Section 2.8.

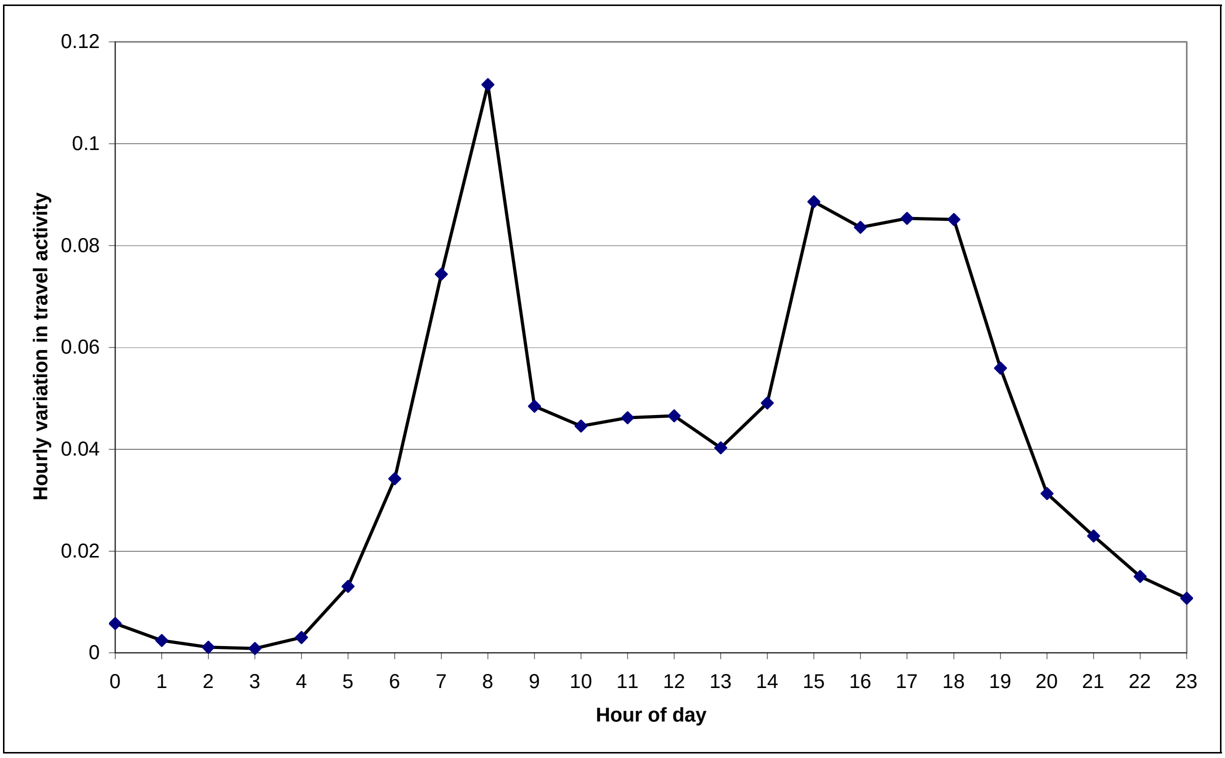

Figure 3.2: Average hourly variation in travel activity for petrol passenger cars

3.1.5 Emission Estimates

Table 3.5 presents total estimated annual emissions (for selected substances) from petrol passenger cars for the GMR, Sydney, Newcastle, Wollongong and Non-Urban regions. Total estimated annual emissions of all substances from petrol passenger cars are presented in Appendix C.

Table 3.5: Total estimated annual emissions from petrol passenger cars in each region

Substance	Emissions (tonnes/year)				
	Sydney	Newcastle	Wollongong	Non-Urban	GMR
1,3 butadiene	146	11	6	22	185
Acetaldehyde	206	15	9	31	262
Benzene	1217	90	53	184	1544
Carbon monoxide	323953	24897	14415	50456	413721
Formaldehyde	340	25	15	51	432
Isomers of xylene	1815	134	79	274	2302
Lead & compounds	6.715	0.424	0.267	0.777	8.183
Oxides of nitrogen	38175	2952	1743	6142	49011
Particulate matter ≤ 10 µm	867	55	34	100	1056
Particulate matter ≤ 2.5 µm	797.4	50.33	31.68	92.32	971.7
Polycyclic aromatic hydrocarbons	120.26	8.037	4.934	15.543	148.78
Sulfur dioxide	645	51	29	96	821
Toluene	1311	97	57	198	1663
Total suspended particulates (TSP)	1170	74	46	135	1426
Total VOCs	26066	1925	1133	3937	33062

Tables 3.6, 3.7, 3.8 and 3.9 present total estimated daily emissions (for selected substances) from passenger cars for the GMR, Sydney, Newcastle, Wollongong and Non-Urban regions. These daily emission estimates are representative of a typical January weekday, January weekend day, a July weekday and July weekend day.

Table 3.6: Total estimated daily emissions from petrol passenger cars in each region for a typical January weekday

Substance	Emissions (tonnes/day)				
	Sydney	Newcastle	Wollongong	Non-Urban	GMR
1,3 butadiene	0.311	0.023	0.014	0.047	0.394
Acetaldehyde	0.439	0.032	0.019	0.066	0.557
Benzene	2.589	0.191	0.113	0.391	3.284
Carbon monoxide	628.40	48.29	27.96	97.87	802.53
Formaldehyde	0.724	0.053	0.031	0.109	0.919
Isomers of xylene	3.861	0.285	0.168	0.583	4.898
Lead & compounds	0.017	0.001	0.001	0.002	0.020
Oxides of nitrogen	96.84	7.49	4.42	15.58	124.32
Particulate matter ≤ 10 µm	2.146	0.135	0.085	0.248	2.615
Particulate matter ≤ 2.5 µm	1.975	0.125	0.078	0.229	2.406
Polycyclic aromatic hydrocarbons	0.298	0.020	0.012	0.038	0.368
Sulfur dioxide	1.597	0.127	0.073	0.237	2.034
Toluene	2.789	0.206	0.121	0.421	3.537
Total suspended particulates (TSP)	2.897	0.183	0.115	0.335	3.531
Total VOCs	55.46	4.10	2.41	8.38	70.34

Table 3.7: Total estimated daily emissions from petrol passenger cars in each region for a typical January weekend day

Substance	Emissions (tonnes/day)				
	Sydney	Newcastle	Wollongong	Non-Urban	GMR
1,3 butadiene	0.272	0.020	0.012	0.041	0.345
Acetaldehyde	0.384	0.028	0.017	0.058	0.487
Benzene	2.266	0.167	0.099	0.342	2.873
Carbon monoxide	549.85	42.26	24.47	85.64	702.21
Formaldehyde	0.634	0.047	0.028	0.096	0.804
Isomers of xylene	3.379	0.250	0.147	0.510	4.285
Lead & compounds	0.015	0.001	0.001	0.002	0.018
Oxides of nitrogen	84.73	6.55	3.87	13.63	108.78
Particulate matter ≤ 10 µm	1.878	0.119	0.075	0.217	2.288
Particulate matter ≤ 2.5 µm	1.728	0.109	0.069	0.200	2.105
Polycyclic aromatic hydrocarbons	0.261	0.017	0.011	0.034	0.322
Sulfur dioxide	1.397	0.112	0.064	0.207	1.780
Toluene	2.440	0.180	0.106	0.369	3.095
Total suspended particulates (tsp)	2.535	0.160	0.101	0.294	3.089
Total VOCs	48.52	3.58	2.11	7.33	61.55

Table 3.8: Total estimated daily emissions from petrol passenger cars in each region for a typical July weekday

Substance	Emissions (tonnes/day)				
	Sydney	Newcastle	Wollongong	Non-Urban	GMR
1,3 butadiene	0.487	0.036	0.021	0.074	0.618
Acetaldehyde	0.689	0.051	0.030	0.104	0.874
Benzene	4.064	0.300	0.177	0.614	5.154
Carbon monoxide	1146	88.09	51.00	178.52	1463
Formaldehyde	1.137	0.084	0.049	0.172	1.442
Isomers of xylene	6.060	0.448	0.264	0.915	7.687
Lead & compounds	0.020	0.001	0.001	0.002	0.024
Oxides of nitrogen	110.90	8.57	5.06	17.84	142.38
Particulate matter ≤ 10 µm	2.572	0.162	0.102	0.298	3.134
Particulate matter ≤ 2.5 µm	2.366	0.149	0.094	0.274	2.883
Polycyclic aromatic hydrocarbons	0.357	0.024	0.015	0.046	0.441
Sulfur dioxide	1.914	0.153	0.087	0.284	2.437
Toluene	4.377	0.323	0.190	0.661	5.551
Total suspended particulates (tsp)	3.472	0.219	0.138	0.402	4.231
Total VOCs	87.04	6.43	3.78	13.15	110.39

Table 3.9: Total estimated daily emissions from petrol passenger cars in each region for a typical July weekend day

Substance	Emissions (tonnes/day)				
	Sydney	Newcastle	Wollongong	Non-Urban	GMR
1,3 butadiene	0.426	0.031	0.019	0.064	0.541
Acetaldehyde	0.603	0.045	0.026	0.091	0.764
Benzene	3.556	0.263	0.155	0.537	4.510
Carbon monoxide	1002.90	77.08	44.63	156.20	1280
Formaldehyde	0.995	0.073	0.043	0.150	1.262
Isomers of xylene	5.303	0.392	0.231	0.801	6.726
Lead & compounds	0.017	0.001	0.001	0.002	0.021
Oxides of nitrogen	97.04	7.50	4.43	15.61	124.59
Particulate matter ≤ 10 µm	2.250	0.142	0.089	0.261	2.742
Particulate matter ≤ 2.5 µm	2.070	0.131	0.082	0.240	2.523
Polycyclic aromatic hydrocarbons	0.312	0.021	0.013	0.040	0.386
Sulfur dioxide	1.674	0.134	0.076	0.248	2.133
Toluene	3.830	0.283	0.167	0.578	4.857
Total suspended particulates (tsp)	3.038	0.192	0.121	0.352	3.702
Total VOCs	76.16	5.62	3.31	11.50	96.59

3.2 Diesel Heavy Duty Commercial Vehicles

Diesel heavy duty commercial vehicles account only for a small proportion of the on-road fleet in comparison with passenger cars. However, they make disproportionately high contributions to the total particulate and NO_x emissions from on-road mobile sources.

3.2.1 Base Emission Factors

The base emission factors of diesel rigid trucks have been completely redeveloped using the data of Diesel NEPM Preparatory Project 2 (MVEC 2000) and project 7 (MVEC, 2001), the USEPA AP42 (USEPA, 1995a), PART5 (USEPA, 1995b) and European Union's CORINA data (EEA, 2002), as well as knowledge about relevant emission regulations in the US, EU and Japan. As heavy duty diesel vehicles in Australia are exclusively imported, overseas data on these vehicles would have a much greater relevance than in the case of passenger cars. The market shares of different origin countries and technology penetration trends are also taken into account when drawing on Diesel NEPM Preparatory Project 1.

The size of the diesel emission test dataset was not sufficiently large to establish satisfactory emission deterioration profiles for different types of diesel vehicles. On the other hand, the limited data suggests that the magnitude of emission deterioration for heavy-duty diesel vehicles is much less significant than that of passenger cars. It is therefore decided at this stage that no deterioration rates are explicitly included in diesel base emission factors. That is to say, the base emission factors of diesel vehicles are actually average emission factors over the vehicles useful lifetime. A brief discussion of the development of the emission factors is given here but a detailed discussion is available in *MVEPS Improvement Program Technical Report 3 – Development of Diesel Vehicle Emission Factors* (Xu, 2001b).

There were two parallel streams of work involved in the development:

Stream 1: desktop research to re-assemble overseas diesel vehicle emission factors in the Australian context, taking the notion of all diesel vehicles having overseas origins.

Stream 2: analysis of Diesel NEPM emission test data to construct emission factors.

Outcomes from the two streams were compared and consolidated to produce base emission factors for diesel vehicles.

Stream 1 sourced data from US and European emission models and inventories as well as an overview of diesel vehicle emission standards of exporting countries (namely US, Europe and Japan). A time-delay scheme was devised to transform emission factors developed for the domestically used vehicles by the exporting countries into ones suitable for Australian conditions. The impacts of diesel sulfur content on the composition of diesel particulate matter and on the efficiency of diesel oxidation catalysts were also incorporated in the compilation. Emission factors compiled for vehicles imported from different origin countries were finally assembled based on Australian market share.

Stream 2 emission test data were sourced from Diesel NPEM preparatory projects 2 and 7. The two projects cover a range of vehicles from light vehicles to articulated trucks. These vehicles were tested on a set of innovative real-world urban driving cycles.

A comparison between the outcomes of Stream 1 and Stream 2 suggests that:

- emission factors based on compilation of overseas data (stream 1) and those based on Australian emission testing (stream 2) agree reasonably well for PM, NO_x and CO emissions from heavy duty vehicles

- for heavy duty vehicles, compiled HC emission levels are significantly higher than measured ones (the reason for this discrepancy is yet to be investigated)

- for light vehicles, compiled PM and NO_x emission levels are significantly lower than measured ones. This discrepancy highlights the importance of local emission tests and supports our perception that light duty vehicles in the Australian market (mostly Japanese brands), imported or locally manufactured, fall significantly behind those manufactured in the US and Europe in terms of emission control.

Tables 3.10 to 3.12 presents base emission factors diesel rigid trucks, diesel articulated trucks and diesel buses respectively. They are all for the baseline fuel sulfur content of 1500ppm. Base emission factors for other diesel sulfur contents is discussed in Section 3.2.2.

Table 3.10: Base emission factors for diesel rigid trucks (under 1500 ppm diesel sulfur content)

PM_{10} (g/km)		NO_x (g/km)		VOC (g/km)		CO (g/km)	
1975	0.702	1975	11.437	1975	1.733	1975	6.131
1980	0.669	1980	9.687	1980	1.567	1980	5.995
1983	0.649	1985	8.009	1985	1.400	1985	5.858
1986	0.629	1988	7.169	1990	1.275	1989	5.109
1989	0.609	1991	6.618	1995	1.150	1993	3.769
1992	0.589	1996	5.701	1996	1.125	1996	2.765
1995	0.515	1999	5.150	1997	1.100	1999	1.760
1996	0.454	2000	4.967	1998	1.075		
1998	0.332	2001	4.783	1999	1.050		
1999	0.271			2000	1.050		
				2001	1.050		

Table 3.11: Base emission factors for diesel articulated trucks (under 1500 ppm diesel sulfur content)

PM_{10} (g/km)		NO_x (g/km)		VOC (g/km)		CO (g/km)	
1975	1.130	1975	17.930	1975	2.085	1975	11.105
1987	1.068	1980	17.291	1978	1.837	1980	9.653
1989	0.944	1985	16.651	1981	1.588	1983	8.781
1991	0.819	1990	16.012	1985	1.256	1985	8.200
1993	0.695	1994	15.500	1990	1.128	1988	6.910
1995	0.570	1996	13.700	1996	0.779	1991	5.620
1997	0.445	1998	11.900	1997	0.779	1994	4.330
1999	0.262	1999	11.000	1998	0.654	1997	3.603
2001	0.242			1999	0.599	1998	2.944
						1999	2.630

Table 3.12: Base emission factors for diesel buses (under 1500 ppm diesel sulfur content)

PM_{10} (g/km)		NO_x (g/km)		VOC (g/km)		CO (g/km)	
1975	1.081	1975	16.064	1975	1.541	1975	10.753
1980	0.962	1980	15.403	1980	1.431	1980	8.599
1983	0.887	1985	14.812	1985	1.322	1983	7.496
1986	0.817	1990	13.958	1990	1.213	1986	6.728
1989	0.738	1995	11.926	1995	1.103	1989	5.828
1992	0.636	1998	10.706	2000	0.994	1992	4.799
1995	0.601	2001	9.345	2001	0.972	1995	3.771
1998	0.532					1998	2.743
1999	0.336					1999	2.400

3.2.2 Emission Modification Factors

Emission modification parameters for heavy duty diesel vehicles are set as follows:

- driving conditions – detailed below,
- several levels of diesel sulfur content – detailed below,
- diesel fuel density – assumed to be 850 kg/m^3,
- cetane number – assumed to be 50, and
- diesel in-service maintenance program – assumed to be none.

3.2.2.1 Driving Condition Modification

Driving condition modification factors for heavy duty diesel vehicles are given here. The standard driving condition to which the conversion factors are applied is the so-called CUEDC (Composite Urban Emissions Drive Cycle) drive cycle developed in Diesel NEPM Preparatory Project 2.1 in 1999 (Brown, Bryett, & Mowle 1999). Tables 3.13 to 3.15 present driving condition modification factors for diesel rigid trucks, articulated trucks and diesel buses respectively.

Table 3.13: Driving condition modification factors for diesel rigid trucks

Substance	Free-flow					Congested				
	Arterial	Highway/ Freeway	Commercial Arterial	Commercial Highway	Local/ Residential Roads	Arterial	Highway/ Freeway	Commercial Arterial	Commercial Highway	Local/ Residential Roads
PM	0.960	1.017	0.960	1.017	0.918	1.273	1.109	1.000	1.124	1.155
NO_x	1.031	0.960	1.031	0.960	0.985	1.309	1.145	1.292	1.166	1.207
VOC	1.111	0.702	1.111	0.702	1.176	2.889	1.379	1.950	1.433	1.541
CO	1.181	0.825	1.181	0.825	1.077	1.958	1.133	0.956	1.152	1.189

Table 3.14: Driving condition modification factors for diesel articulated trucks

Substance	Free-flow					Congested				
	Arterial	Highway/ Freeway	Commercial Arterial	Commercial Highway	Local/ Residential Roads	Arterial	Highway/ Freeway	Commercial Arterial	Commercial Highway	Local/ Residential Roads
PM	0.945	0.932	0.945	0.932	0.932	1.619	1.243	1.273	1.277	1.346
NO_x	0.906	1.071	0.906	1.071	0.928	1.193	1.193	1.309	1.221	1.276
VOC	1.081	0.692	1.081	0.692	1.081	3.131	1.449	2.889	1.513	1.641
CO	0.875	0.969	0.875	0.969	1.091	1.580	1.354	1.958	1.404	1.505

Table 3.15: Driving condition modification factors for diesel buses

Substance	Free-flow					Congested				
	Arterial	Highway/ Freeway	Commercial Arterial	Commercial Highway	Local/ Residential Roads	Arterial	Highway/ Freeway	Commercial Arterial	Commercial Highway	Local/ Residential Roads
PM	1.311	0.909	1.311	0.909	0.845	1.344	1.081	1.619	1.092	1.115
NO_x	1.164	0.876	1.164	0.876	0.953	1.413	1.075	1.193	1.085	1.107
VOC	1.100	0.798	1.100	0.798	1.007	1.767	1.386	3.131	1.441	1.551
CO	1.311	0.805	1.311	0.805	0.912	1.591	1.121	1.580	1.139	1.173

3.2.2.2 Sulfur Content Modification

To quantify the effect of fuel sulfur content, two mechanisms are taken into account: sulfate contribution to the composition of diesel particulate matter and sulfur impact on the efficiency of diesel oxidation catalysts. As PM emission factors were developed for baseline sulfur content (1300–1500 ppm), the baseline emission factors should be adjusted for lower sulfur levels when relevant EURO standards are in place. Ratios of PM emissions factors under 500 ppm and 50 ppm sulfur content to those under 1500 ppm were derived from a desktop compilation of data. Those ratios are multiplied to the consolidated baseline PM emission factors for EURO2 emission standards (500 ppm) and EURO4 standards (50 ppm) wherever needed. Table 3.16 presents the diesel sulfur content conversion factors for 500 ppm and 50 ppm sulfur levels.

Table 3.16: Sulfur content conversion factors for 500 and 50 ppm

Diesel sulfur content	500 ppm			50 ppm		
Model year	Rigid trucks	Articulated trucks	Bus	Rigid trucks	Articulated trucks	Bus
1970	0.92	0.92	0.91	0.88	0.88	0.87
1972	0.92	0.92	0.91	0.88	0.89	0.87
1974	0.92	0.92	0.91	0.88	0.89	0.87
1976	0.92	0.93	0.91	0.88	0.89	0.87
1978	0.91	0.93	0.91	0.88	0.90	0.87
1980	0.90	0.93	0.91	0.85	0.90	0.87
1982	0.90	0.93	0.91	0.85	0.90	0.87
1984	0.89	0.93	0.90	0.84	0.90	0.85
1986	0.89	0.93	0.89	0.84	0.90	0.85
1988	0.88	0.93	0.88	0.83	0.90	0.83
1990	0.88	0.93	0.86	0.83	0.90	0.80
1992	0.87	0.92	0.85	0.82	0.89	0.78
1994	0.87	0.92	0.85	0.82	0.88	0.79
1996	0.86	0.83	0.85	0.80	0.75	0.78
1998	0.86	0.83	0.83	0.80	0.75	0.76
2000	0.84	0.81	0.85	0.77	0.72	0.78
2002	0.84	0.79	0.82	0.77	0.70	0.73
2004	0.82	0.77	0.76	0.74	0.67	0.65
2006	0.83	0.77	0.76	0.75	0.67	0.65

3.2.3 Emission Speciation

Speciation profiles for diesel heavy duty commercial vehicles were derived from a number of studies including:

- CSIRO/Parsons diesel vehicles emission test (Bernaudat et al, 2002)
- Speciation of organic compounds from the exhaust of trucks and buses (Lev-on et al, 2002)
- a Swedish study of emission testing of a EURO2 heavy duty trucks (Westerholm et al, 2001)
- measurement of emissions from medium duty trucks (Schauer et al, 1999)
- upgrades to USEPA's SPECIATE database(Hsu et al, 2004)
- a study to quantify sources of fine organic aerosol from vehicles (Wolfgang et al, 1993)
- revised methodology and emissions factors for estimating mobile source PAH emissions in the National Toxic inventory (Cook & Somers, 2000).

Diesel vehicles are the main on-road source of PAH emissions. PAH substances are emitted in different phases, some in semi-volatile, some in particle, and some in both phases depending on the exhaust and ambient conditions. This poses a great difficulty in the derivation of PAH speciation profiles. Good quality phase differentiation data are very rare. In practice, PAH substances are usually speciated against particulate matter emissions in an emission inventory, as the heavy PAH substances, which are the most toxic take the form of particles. However, a study sponsored by the USEPA (Cook & Somers, 2000) tended to suggest that speciation against VOC would be a better way. With the phase issue still largely uncertain, it was decided that speciation profiles for PAH substances are derived against both total VOC and particulate matter. The ultimate emission estimates of PAH substances are the average of the estimates calculated from the profile based on

VOC and the estimates calculated from the profile based on particulates. Table 3.17 presents a sample of speciation data for selected substances, in which profiles for both PM and VOC are given.

Table 3.17: Sample of speciation profile for heavy duty diesel vehicles

Substance ID	Substance name	% PM	% VOC
201	1,3-butadiene	NA	0.13844
356	Benzene	NA	1.189408
49	Formaldehyde	NA	8.359172
482	Toluene	NA	1.400654
1257	Fluorene	0.014561	0.024514
1299	Phenanthrene	0.016913	0.039291
1329	1-methylphenanthrene	0.003387	0.006169
1358	Fluoranthene	0.009529	0.018847
1356	Pyrene	0.018508	0.030684
1386	benzo[ghi]fluoranthene	0.000917	0.001975
1390	benzo(a)anthracene	0.00201	0.001708
1388	Chrysene	0.002834	0.001684
1405	benzo(b)fluoranthene	0.00125	0.001162
1408	benzo(k)fluoranthene	0.001032	0.000954
1406	benzo(e)pyrene	0.00047	0.000435
1404	benzo(a)pyrene	0.002987	0.002807
1420	benzo(g,h,I)perylene	0.003099	0.002926
1407	Perylene	NA	5.95×10^{-05}
1418	Indeno(1,2,3-CD)pyrene	0.001911	0.001817
83	Acetylene	NA	2.4889
288	Cyclopentene	NA	0.1136
596	M-xylene	NA	0.866728
597	O-xylene	NA	0.308755
144	Propylene	NA	0.422
210	Trans-2-butene	NA	0.2813
12	Calcium	0.1765	NA
16	Chromium	0.0044	NA
19	Copper	0.006833	NA
3	Lead	0.279	NA
27	Manganese	0.012	NA
28	Mercury	0.002	NA
30	Nickel	0.002167	NA
41	Zinc	1.070333	NA
36	Dioxins & Furans	7.24×10^{-07}	NA

3.2.4 Temporal Profiles

Figure 3.3 gives the average daily hourly travel profile for diesel heavy duty commercial vehicles, which is a profile averaged over the entire GMR. Weekly and monthly profiles have already been discussed in Section 2.8.

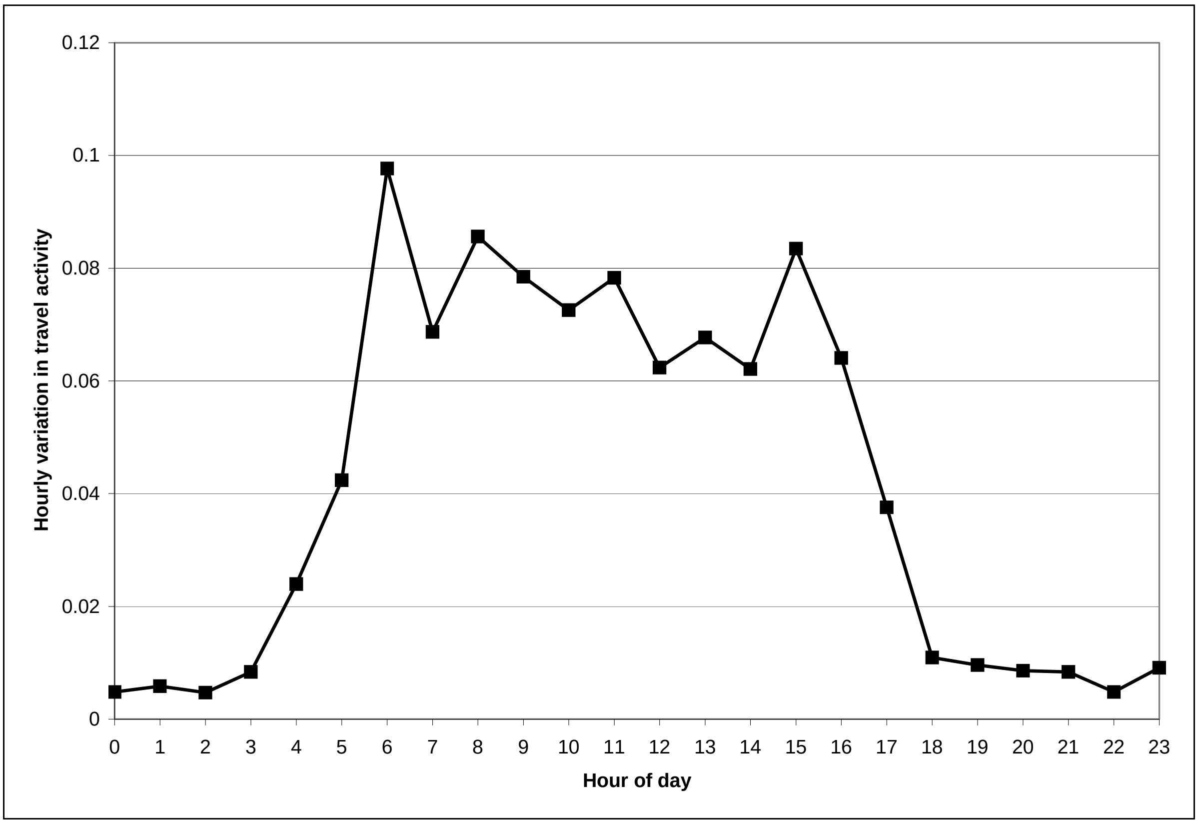

Figure 3.3: Average hourly variation in travel activity for diesel heavy duty commercial vehicles

3.2.5 Emission Estimates

Table 3.18 presents total estimated annual emissions (for selected substances) from heavy duty commercial diesel vehicles for the GMR, Sydney, Newcastle, Wollongong and Non-Urban regions. Total estimated annual emissions of all substances from heavy duty commercial diesel vehicles are presented in Appendix C.

Table 3.18: Total estimated annual emissions from diesel heavy duty commercial vehicles in each region

Substance	Emissions (tonnes/year)				
	Sydney	Newcastle	Wollongong	Non-Urban	GMR
1,3 butadiene	3.59	0.23	0.20	0.93	4.96
Acetaldehyde	319.54	20.48	17.93	83.00	440.95
Benzene	30.89	1.98	1.73	8.02	42.62
Carbon monoxide	8534	638	513	2740	12424
Formaldehyde	217.06	13.91	12.18	56.38	299.53
Isomers of xylene	30.52	1.96	1.71	7.93	42.12
Lead & compounds	1.958	0.150	0.116	0.657	2.881
Oxides of nitrogen	16908	1340	1067	5974	25289
Particulate matter ≤ 10 µm	702	54	42	235	1033
Particulate matter ≤ 2.5 µm	681	52	40	228	1002
Polycyclic aromatic hydrocarbons	18.59	1.23	1.05	5.05	25.92
Sulfur dioxide	287.86	23.71	15.94	97.74	425.25
Toluene	22.51	1.44	1.26	5.85	31.06
Total suspended particulates (TSP)	709	54	42	238	1043
Total VOCs	2597	166	146	675	3583

Tables 3.19, 3.20, 3.21 and 3.22 present total estimated daily emissions (for selected substances) from heavy duty diesel commercial vehicles for the GMR, Sydney, Newcastle, Wollongong and Non-Urban regions. These daily emission estimates are representative of a typical January weekday, January weekend day, a July weekday and July weekend day.

Table 3.19: Total estimated daily emissions from diesel heavy duty commercial vehicles in each region for a typical January weekday

Substance	Emissions (tonnes/day)				
	Sydney	Newcastle	Wollongong	Non-Urban	GMR
1,3 butadiene	0.008	0.000	0.000	0.002	0.011
Acetaldehyde	0.680	0.044	0.038	0.177	0.938
Benzene	0.066	0.004	0.004	0.017	0.091
Carbon monoxide	16.553	1.237	0.995	5.315	24.101
Formaldehyde	0.462	0.030	0.026	0.120	0.637
Isomers of xylene	0.065	0.004	0.004	0.017	0.090
Lead & compounds	0.005	0.000	0.000	0.002	0.007
Oxides of nitrogen	42.89	3.40	2.71	15.15	64.15
Particulate matter ≤ 10 µm	1.737	0.134	0.103	0.583	2.557
Particulate matter ≤ 2.5 µm	1.685	0.130	0.100	0.565	2.481
Polycyclic aromatic hydrocarbons	0.046	0.003	0.003	0.012	0.064
Sulfur dioxide	0.713	0.059	0.039	0.242	1.053
Toluene	0.048	0.003	0.003	0.012	0.066
Total suspended particulates (TSP)	1.755	0.135	0.104	0.589	2.583
Total VOCs	5.524	0.354	0.310	1.435	7.623

Table 3.20: Total estimated daily emissions from diesel heavy duty commercial vehicles in each region for a typical January weekend day

Substance	Emissions (tonnes/day)				
	Sydney	Newcastle	Wollongong	Non-Urban	GMR
1,3 butadiene	0.007	0.000	0.000	0.002	0.009
Acetaldehyde	0.595	0.038	0.033	0.155	0.821
Benzene	0.057	0.004	0.003	0.015	0.079
Carbon monoxide	14.484	1.083	0.871	4.650	21.088
Formaldehyde	0.404	0.026	0.023	0.105	0.558
Isomers of xylene	0.057	0.004	0.003	0.015	0.078
Lead & compounds	0.004	0.000	0.000	0.001	0.006
Oxides of nitrogen	37.53	2.97	2.37	13.26	56.13
Particulate matter ≤ 10 µm	1.520	0.117	0.090	0.510	2.238
Particulate matter ≤ 2.5 µm	1.475	0.113	0.088	0.495	2.170
Polycyclic aromatic hydrocarbons	0.040	0.003	0.002	0.011	0.056
Sulfur dioxide	0.624	0.051	0.035	0.212	0.921
Toluene	0.042	0.003	0.002	0.011	0.058
Total suspended particulates (TSP)	1.535	0.118	0.091	0.515	2.260
Total VOCs	4.834	0.310	0.271	1.256	6.671

Table 3.21: Total estimated daily emissions from diesel heavy duty commercial vehicles in each region for a typical July weekday

Substance	Emissions (tonnes/day)				
	Sydney	Newcastle	Wollongong	Non-Urban	GMR
1,3 butadiene	0.012	0.001	0.001	0.003	0.017
Acetaldehyde	1.067	0.068	0.060	0.277	1.472
Benzene	0.103	0.007	0.006	0.027	0.142
Carbon monoxide	30.192	2.257	1.815	9.694	43.958
Formaldehyde	0.725	0.046	0.041	0.188	1.000
Isomers of xylene	0.102	0.007	0.006	0.026	0.141
Lead & compounds	0.006	0.000	0.000	0.002	0.009
Oxides of nitrogen	49.12	3.89	3.10	17.35	73.47
Particulate matter ≤ 10 µm	2.082	0.160	0.124	0.698	3.064
Particulate matter ≤ 2.5 µm	2.020	0.155	0.120	0.678	2.972
Polycyclic aromatic hydrocarbons	0.055	0.004	0.003	0.015	0.077
Sulfur dioxide	0.854	0.070	0.047	0.290	1.262
Toluene	0.075	0.005	0.004	0.020	0.104
Total suspended particulates (TSP)	2.103	0.162	0.125	0.705	3.095
Total VOCs	8.670	0.556	0.486	2.252	11.965

Table 3.22: Total estimated daily emissions from diesel heavy duty commercial vehicles in each region for a typical July weekend day

Substance	Emissions (tonnes/day)				
	Sydney	Newcastle	Wollongong	Non-Urban	GMR
1,3 butadiene	0.011	0.001	0.001	0.003	0.014
Acetaldehyde	0.934	0.060	0.052	0.243	1.288
Benzene	0.090	0.006	0.005	0.023	0.125
Carbon monoxide	26.418	1.975	1.588	8.482	38.464
Formaldehyde	0.634	0.041	0.036	0.165	0.875
Isomers of xylene	0.089	0.006	0.005	0.023	0.123
Lead & compounds	0.005	0.000	0.000	0.002	0.007
Oxides of nitrogen	42.98	3.41	2.71	15.19	64.28
Particulate matter ≤ 10 µm	1.822	0.140	0.108	0.611	2.681
Particulate matter ≤ 2.5 µm	1.767	0.136	0.105	0.593	2.601
Polycyclic aromatic hydrocarbons	0.048	0.003	0.003	0.013	0.067
Sulfur dioxide	0.747	0.062	0.041	0.254	1.104
Toluene	0.066	0.004	0.004	0.017	0.091
Total suspended particulates (TSP)	1.840	0.141	0.109	0.617	2.708
Total VOCs	7.587	0.486	0.426	1.971	10.469

3.3 Diesel Light Duty Vehicles

The source type of diesel light duty vehicles include diesel passenger cars and diesel light duty commercial vehicles. Diesel cars are not a big component in the GMR fleet. It includes some light 4WD vehicles with GVM less than 2.7 tonnes. Light duty commercial diesel vehicles may have a similar weight to their petrol counterparts in fleet composition, but they have significantly distinctive emission characteristics.

3.3.1 Base Emission Factors

The base emission factors were completely redeveloped using the data of Diesel NEPM Preparatory Projects 2 and 7, in association with a review of the US, European Union and Japan's relevant data and regulatory information. Because of the small sample size of the data, no deterioration rates were derived even though they may deteriorate significantly. Therefore, it is more appropriate to consider these base emission factors as lifetime averages. Tables 3.23 and 3.24 present the base emission factors for diesel cars and diesel light duty commercial vehicles respectively, for the baseline diesel sulfur content of 1500 ppm. Emission factors for other sulfur levels are discussed in Section 3.2.2.

Table 3.23: Base emission factors for diesel cars (g/km) – lifetime averages (under 1500 ppm diesel sulfur content)

PM_{10} (g/km)		NO_x (g/km)		VOC (g/km)		CO (g/km)	
1975	0.531	1975	1.706	1975	0.617	1975	4.100
1980	0.489	1985	1.618	1980	0.533	1980	4.000
1983	0.464	1990	1.514	1985	0.450	1985	3.900
1986	0.439	1993	1.428	1986	0.360	1988	3.300
1989	0.413	1996	1.342	1990	0.302	1991	2.700
1992	0.388	1999	1.256	1993	0.258	1994	2.100
1995	0.349	2000	1.227	1995	0.228	1997	1.500
1998	0.309	2001	1.199	1997	0.199	1998	1.300
1999	0.296			2000	0.170	2000	1.193
2000	0.283						

Table 3.24: Base emission factors for diesel light commercial vehicles (g/km) – lifetime averages (under 1500 ppm diesel sulfur content)

PM_{10} (g/km)		NO_x (g/km)		VOC (g/km)		CO (g/km)	
1975	0.677	1975	1.587	1975	0.352	1975	4.275
1980	0.642	1985	1.509	1980	0.303	1986	4.000
1983	0.620	1988	1.535	1983	0.274	1990	3.631
1986	0.563	1991	1.562	1985	0.255	1995	3.169
1989	0.488	1994	1.588	1986	0.245	1999	2.800
1992	0.413	1997	1.615	1990	0.192		
1998	0.413	2000	1.641	1995	0.185		
1999	0.400	2001	1.650	2000	0.178		
2000	0.386						

3.3.2 Emission Modification Factors

Emission modification parameters for light diesel vehicles are set as follows:

- driving conditions – detailed below
- several levels of diesel sulfur content – detailed below
- diesel fuel density – assumed to be 850 kg/m^3
- cetane number – assumed to be 50
- diesel in-service maintenance program – assumed to be none.

3.3.2.1 Driving Condition Modification

Driving conditions include five road types defined in the MAQS inventory – highway, arterial road, commercial highway, commercial arterial road and local/residential road, as well as two traffic flow conditions – free-flow and congested – for each type of road. Driving condition modification factors are (1) adopted from the MAQS inventory for petrol vehicles, and (2) derived from the Diesel NEPM Preparatory Project 2.2 for diesel vehicles. Tables 3.25 and 3.26 present the driving condition modification factors for diesel cars and diesel light duty commercial vehicles respectively.

Table 3.25: Driving condition modification factors for diesel cars

Substance	Free-flow					Congested				
	Arterial	Highway/ Freeway	Commercial Arterial	Commercial Highway	Local/ Residential Roads	Arterial	Highway/ Freeway	Commercial Arterial	Commercial Highway	Local/ Residential Roads
PM	1.038	0.952	1.038	0.952	1.052	1.138	1.062	1.138	1.070	1.088
NO_x	0.985	0.917	0.985	0.917	1.051	1.651	1.282	1.651	1.323	1.403
VOC	1.000	0.717	1.000	0.717	1.248	2.613	1.432	2.613	1.494	1.617
CO	1.063	0.930	1.063	0.930	1.086	1.109	1.029	1.109	1.033	1.041

Table 3.26: Driving condition modification factors for diesel light duty commercial vehicles

Substance	Free-flow					Congested				
	Arterial	Highway/ Freeway	Commercial Arterial	Commercial Highway	Local/ Residential Roads	Arterial	Highway/ Freeway	Commercial Arterial	Commercial Highway	Local/ Residential Roads
PM	1.000	1.000	1.000	1.000	1.000	1.273	1.150	1.273	1.172	1.214
NO_x	0.980	0.940	0.980	0.940	1.009	1.309	1.176	1.309	1.201	1.251
VOC	1.240	0.668	1.240	0.668	1.120	2.889	1.400	2.889	1.457	1.571
CO	1.107	1.004	1.107	1.004	0.921	1.958	1.304	1.958	1.348	1.435

3.3.2.2 Sulfur Content Modification

To quantify the effect of fuel sulfur content, two mechanisms are taken into account: sulfate contribution to the composition of diesel particulate matter and sulfur impact on the efficiency of diesel oxidation catalysts. As PM emission factors were developed for baseline sulfur content (1300–1500 ppm), the baseline emission factors should be adjusted for lower sulfur levels when relevant EURO standards are in place. Ratios of PM emissions factors under 500 ppm and 50 ppm sulfur content to those under 1500 ppm were derived from a desktop compilation of data. Those ratios are multiplied to the consolidated baseline PM emission factors for EURO2 emission standards (500ppm) and EURO4 standards (50 ppm) wherever needed. Table 3.27 presents the diesel sulfur content conversion factors for 500 ppm and 50 ppm sulfur levels.

Table 3.27: Sulfur content conversion factors for 500 and 50 ppm

Diesel sulfur content	500 ppm		50 ppm	
Model year	Diesel car	Diesel light duty commercial vehicle	Diesel car	Diesel light duty commercial vehicle
1970	0.91	0.93	0.93	0.95
1972	0.90	0.93	0.93	0.95
1974	0.90	0.93	0.93	0.95
1976	0.90	0.93	0.93	0.95
1978	0.90	0.92	0.93	0.95
1980	0.90	0.92	0.93	0.94
1982	0.89	0.92	0.93	0.94
1984	0.89	0.91	0.93	0.94
1986	0.89	0.91	0.92	0.94
1988	0.89	0.91	0.92	0.94
1990	0.88	0.90	0.92	0.93
1992	0.88	0.90	0.92	0.93
1994	0.85	0.85	0.89	0.90
1996	0.83	0.85	0.88	0.90
1998	0.83	0.85	0.88	0.90
2000	0.73	0.70	0.82	0.79
2002	0.73	0.72	0.82	0.81
2004	0.61	0.72	0.73	0.81
2006	0.62	0.72	0.74	0.81

3.3.3 Emission Speciation

Original data dedicated for light diesel vehicles are very limited. The following data sources were used to derive PAH speciation profile for these vehicles:

- CSIRO/Parsons diesel emission testing study (CSIRO/Parsons, 2002)
- Test of PAH emissions from a EURO3 diesel engine on EURO3 drive cycle (Collier et al, 1998)
- A tunnel study in Switzerland for emissions of organic compounds (Staehelin et al, 1998).

To make up for the paucity of data for diesel light duty vehicles, speciation profile data developed for heavy diesel vehicles were also used. This approach is acceptable as an interim measure considering the commonality of compressed combustion and that the data are only used in a relative way. Table 3.28 presents a sample of speciation data for selected substances for diesel light duty vehicles.

Table 3.28: Sample of speciation profile for diesel light duty vehicles

Substance ID	Substance name	% PM	% VOC
201	1,3-butadiene	NA	0.041221
356	Benzene	NA	1.965176
49	Formaldehyde	NA	3.911451
482	Toluene	NA	0.870433
1257	Fluorene	0.011375	0.020256
1299	phenanthrene	0.016913	0.041601
1329	1-methylphenanthrene	0.003387	0.006169
1358	Fluoranthene	0.006324	0.01126
1356	Pyrene	0.008197	0.014596
1386	benzo[ghi]fluoranthene	0.000917	0.001975
1390	benzo(a)anthracene	0.005344	0.009515
1388	chrysene	0.003215	0.005724
1405	benzo(b)fluoranthene	0.00323	0.005751
1408	benzo(k)fluoranthene	0.003314	0.005902
1406	benzo(e)pyrene	0.001581	0.002816
1404	benzo(a)pyrene	0.003468	0.006175
1420	benzo(g,h,I)perylene	0.004868	0.008669
1407	perylene	NA	5.95×10^{-05}
1418	Indeno(1,2,3-CD)pyrene	0.004713	0.008392
83	Acetylene	NA	2.4889
288	Cyclopentene	NA	0.1136
596	M-xylene	NA	0.669743
597	O-xylene	NA	0.238583
144	Propylene	NA	0.422
210	Trans-2-butene	NA	0.2813
12	Calcium	0.074	NA
16	Chromium	0.001667	NA
19	Copper	0.003	NA
3	Lead	0.13025	NA
27	Manganese	0.0645	NA
28	Mercury	0.000667	NA
30	Nickel	0.001	NA
41	Zinc	1.06025	NA
36	Dioxins & Furans	5.41×10^{-07}	NA

3.3.4 Temporal Profiles

Figure 3.4 gives the average hourly travel profile for diesel light duty vehicles, which is a profile averaged over the entire GMR. Weekly and monthly profiles have already been discussed in Section 2.8.

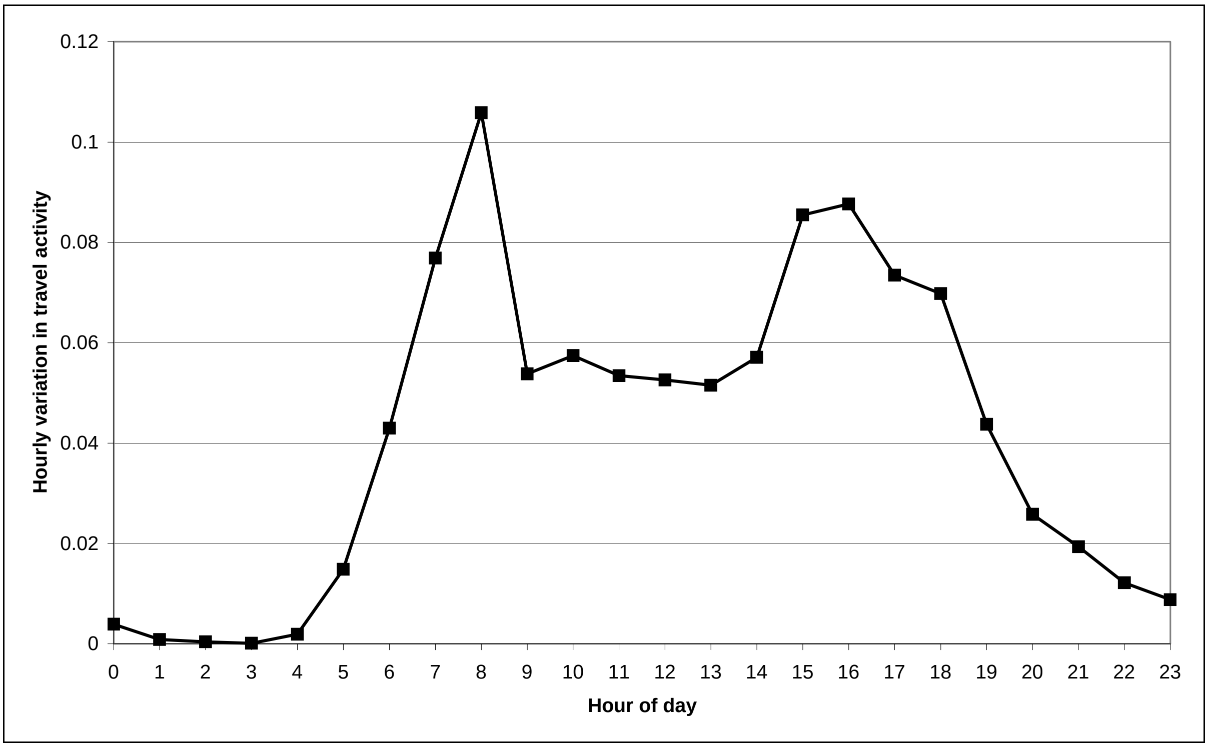

Figure 3.4: Average hourly variation in travel activity for diesel light duty vehicles

3.3.5 Emission Estimates

Table 3.29 presents total estimated annual emissions (for selected substances) from diesel light duty vehicles for the GMR, Sydney, Newcastle, Wollongong and Non-Urban regions. Total estimated annual emissions of all substances from diesel light duty vehicles are presented in Appendix C.

Table 3.29: Total estimated annual emissions from diesel light duty vehicles in each region

Substance	Emissions (tonnes/year)				
	Sydney	Newcastle	Wollongong	Non-Urban	GMR
1,3 butadiene	0.394	0.021	0.014	0.044	0.473
Acetaldehyde	19.311	1.015	0.694	2.177	23.198
Benzene	18.761	0.986	0.675	2.115	22.537
Carbon monoxide	7935	568	347	1344	10194
Formaldehyde	37.341	1.963	1.343	4.210	44.857
Isomers of xylene	11.222	0.590	0.404	1.265	13.480
Lead & compounds	1.128	0.081	0.049	0.183	1.440
Oxides of nitrogen	4245	265	170	607	5287
Particulate matter ≤ 10 µm	866	62	38	140	1106
Particulate matter ≤ 2.5 µm	839.801	60.125	36.499	136.283	1072.708
Polycyclic aromatic hydrocarbons	9.473	0.560	0.365	1.231	11.630
Sulfur dioxide	249.06	18.50	10.97	38.99	317.52
Toluene	8.274	0.435	0.298	0.933	9.940
Total suspended particulates (TSP)	874	63	38	142	1117
Total VOCs	955	50	34	108	1147

Tables 3.30, 3.31, 3.32 and 3.33 present total estimated daily emissions (for selected substances) from diesel light duty vehicles for the GMR, Sydney, Newcastle, Wollongong and Non-Urban regions. These daily emission estimates are representative of a typical January weekday, January weekend day, a July weekday and July weekend day.

Table 3.30: Total estimated daily emissions from diesel light duty vehicles in each region for a typical January weekday

Substance	Emissions (tonnes/day)				
	Sydney	Newcastle	Wollongong	Non-Urban	GMR
1,3 butadiene	0.001	0.000	0.000	0.000	0.001
Acetaldehyde	0.041	0.002	0.001	0.005	0.049
Benzene	0.040	0.002	0.001	0.005	0.048
Carbon monoxide	15.39	1.10	0.67	2.61	19.77
Formaldehyde	0.079	0.004	0.003	0.009	0.095
Isomers of xylene	0.024	0.001	0.001	0.003	0.029
Lead & compounds	0.003	0.000	0.000	0.000	0.004
Oxides of nitrogen	10.77	0.67	0.43	1.54	13.41
Particulate matter ≤ 10 µm	2.144	0.153	0.093	0.348	2.738
Particulate matter ≤ 2.5 µm	2.079	0.149	0.090	0.337	2.656
Polycyclic aromatic hydrocarbons	0.023	0.001	0.001	0.003	0.029
Sulfur dioxide	0.617	0.046	0.027	0.097	0.786
Toluene	0.018	0.001	0.001	0.002	0.021
Total suspended particulates (TSP)	2.165	0.155	0.094	0.351	2.766
Total VOCs	2.031	0.107	0.073	0.229	2.440

Table 3.31: Total estimated daily emissions from diesel light duty vehicles in each region for a typical January weekend day

Substance	Emissions (tonnes/day)				
	Sydney	Newcastle	Wollongong	Non-Urban	GMR
1,3 butadiene	0.001	0.000	0.000	0.000	0.001
Acetaldehyde	0.036	0.002	0.001	0.004	0.043
Benzene	0.035	0.002	0.001	0.004	0.042
Carbon monoxide	13.47	0.96	0.59	2.28	17.30
Formaldehyde	0.070	0.004	0.002	0.008	0.084
Isomers of xylene	0.021	0.001	0.001	0.002	0.025
Lead & compounds	0.002	0.000	0.000	0.000	0.003
Oxides of nitrogen	9.42	0.59	0.38	1.35	11.73
Particulate matter ≤ 10 µm	1.876	0.134	0.082	0.304	2.396
Particulate matter ≤ 2.5 µm	1.820	0.130	0.079	0.295	2.324
Polycyclic aromatic hydrocarbons	0.021	0.001	0.001	0.003	0.025
Sulfur dioxide	0.540	0.040	0.024	0.084	0.688
Toluene	0.015	0.001	0.001	0.002	0.019
Total suspended particulates (TSP)	1.895	0.136	0.082	0.307	2.420
Total VOCs	1.777	0.093	0.064	0.200	2.135

Table 3.32: Total estimated daily emissions from diesel light duty vehicles in each region for a typical July weekday

Substance	Emissions (tonnes/day)				
	Sydney	Newcastle	Wollongong	Non-Urban	GMR
1,3 butadiene					
Acetaldehyde	0.001	0.000	0.000	0.000	0.002
Benzene	0.064	0.003	0.002	0.007	0.077
Carbon monoxide	0.063	0.003	0.002	0.007	0.075
Formaldehyde	28.08	2.01	1.23	4.75	36.07
Isomers of xylene	0.125	0.007	0.004	0.014	0.150
Lead & compounds	0.037	0.002	0.001	0.004	0.045
Oxides of nitrogen	0.003	0.000	0.000	0.001	0.004
Particulate matter ≤ 10 µm	12.33	0.77	0.49	1.76	15.36
Particulate matter ≤ 2.5 µm	2.569	0.184	0.112	0.417	3.281
Polycyclic aromatic hydrocarbons	2.492	0.178	0.108	0.404	3.183
Sulfur dioxide	0.028	0.002	0.001	0.004	0.035
Toluene	0.739	0.055	0.033	0.116	0.942
Total suspended particulates (TSP)	0.028	0.001	0.001	0.003	0.033
Total VOCs	2.595	0.186	0.113	0.421	3.314

Table 3.33: Total estimated daily emissions from diesel light duty vehicles in each region for a typical July weekend day

Substance	Emissions (tonnes/day)				
	Sydney	Newcastle	Wollongong	Non-Urban	GMR
1,3 butadiene	0.001	0.000	0.000	0.000	0.001
Acetaldehyde	0.056	0.003	0.002	0.006	0.068
Benzene	0.055	0.003	0.002	0.006	0.066
Carbon monoxide	24.57	1.76	1.07	4.16	31.56
Formaldehyde	0.109	0.006	0.004	0.012	0.131
Isomers of xylene	0.033	0.002	0.001	0.004	0.039
Lead & compounds	0.003	0.000	0.000	0.000	0.004
Oxides of nitrogen	10.79	0.67	0.43	1.54	13.44
Particulate matter ≤ 10 µm	2.248	0.161	0.098	0.365	2.871
Particulate matter ≤ 2.5 µm	2.180	0.156	0.095	0.354	2.785
Polycyclic aromatic hydrocarbons	0.025	0.001	0.001	0.003	0.030
Sulfur dioxide	0.647	0.048	0.028	0.101	0.824
Toluene	0.024	0.001	0.001	0.003	0.029
Total suspended particulates (TSP)	2.270	0.163	0.099	0.368	2.900
Total VOCs	2.789	0.147	0.100	0.314	3.351

3.4 Petrol Light Duty Commercial Vehicles

This type of vehicle includes panel vans, utilities and heavy 4WD vehicles driven by petrol. They are significantly less in number than petrol passenger cars but represent (together with their diesel counterpart) the most rapidly growing component of the urban fleet. There are an increasing number of light duty commercial vehicles, 4WD in particular, being used for commuting and other private purposes on urban streets. Many of those vehicles fall in a loophole of the current and past Australian emission standards and are not regulated for emissions (will be regulated from EURO2). Their emissions could be therefore much higher than passenger cars in terms of fleet averages. Ironically, for the same reason, there is little emission test data available for these vehicles.

3.4.1 Base Emission Factors

For petrol light duty commercial vehicles, the implementation of ADR37/00 (in 1989) and the ADR37/01 (in 1999) are supposed to be the only events that could possibly bring about some changes in emissions. Without adequate information, it is assumed that the new vehicle emission rates are about 70-80% of the ADR limits (this is a conservative estimate with high level of uncertainty). The deterioration rates are assumed to be the same as those for non-catalyst cars.

For vehicles in later model years when they are covered by EURO standards, the emissions of these vehicles are tied to the relevant emission limits. Specifically, it is assumed that new vehicle emission levels are at 90% of the EURO2 limit in 2004, and 50% of the EURO3 limit in 2006. It is also assumed that deterioration rates are unchanged for vehicles under EURO2 relative to pre-EURO models, and are half that of EURO2 for vehicles under EURO3.

As drive cycles for emission testing under different emission standards are different, the above derivation is subjected to adjustments incorporating the cycle differences. Cycle conversion factors between EURO standards are derived from a cycle comparative study by FORD Laboratory Australia. Tables 3.34 and 3.35 present the base emission factors for petrol light commercial vehicles.

Table 3.34: Gaseous emission factors for petrol light commercial vehicles

Substance	NO_x		VOC		CO	
Model year	New car emissions (g/km)	Deterioration rate (g/km/km)	New car emissions (g/km)	Deterioration rate (g/km/km)	New car emissions (g/km)	Deterioration rate (g/km/km)
1988	1.474714	6.64×10^{-06}	1.372857	8.08886×10^{-06}	13.82114	0.00013
1999	1.386532	6.94×10^{-06}	1.225776	7.95289×10^{-06}	12.59515	0.00013
2004	0.373846	6.94×10^{-06}	0.294545	7.95289×10^{-06}	4.707692	0.00013
2006	0.10625	3.47×10^{-06}	0.114183	3.97645×10^{-06}	1.924615	6.48×10^{-05}

Table 3.35: PM_{10} Emission factors for petrol light commercial vehicles

Model year	g/km
1989	0.05
1992	0.03
2004	0.022
2006	0.022

3.4.2 Emission Modification Factors

Emission modification parameters for petrol light duty commercial vehicles are set as follows:

- driving conditions – detailed below
- petrol fuel volatility – the same as petrol passenger cars (Section 3.1.2.2)
- in-service maintenance – assumed to be none for this inventory
- fuel sulfur content – assumed to be 150 ppm for this inventory
- ethanol blending – assumed to be none for this inventory
- season – calculated for both average summer and average winter for this inventory.

Table 3.36 presents the driving condition modification factors for petrol light duty commercial vehicles.

Table 3.36: Driving condition modification factors for petrol light duty commercial vehicles

Substance	Free-flow					Congested				
	Arterial	Highway/ Freeway	Commercial Arterial	Commercial Highway	Local/ Residential Roads	Arterial	Highway/ Freeway	Commercial Arterial	Commercial Highway	Local/ Residential Roads
PM_{10}	1.000	0.550	1.000	0.550	1.000	1.800	1.332	2.000	1.379	1.474
NO_x	0.860	1.260	0.860	1.260	1.000	1.040	1.121	1.040	1.138	1.173
VOC	0.860	0.760	0.860	0.760	1.000	1.120	1.163	1.120	1.186	1.232
CO	0.840	0.720	0.840	0.720	1.000	1.010	1.118	1.010	1.135	1.168

3.4.3 Emission Speciation

Speciation profiles for petrol light duty commercial vehicles are the same as that for petrol passenger cars.

3.4.4 Temporal Profiles

Figure 3.5 gives the average hourly travel profile for petrol light duty commercial vehicles, which is a profile averaged over the entire GMR. Weekly and monthly profiles have already been discussed in Section 2.8.

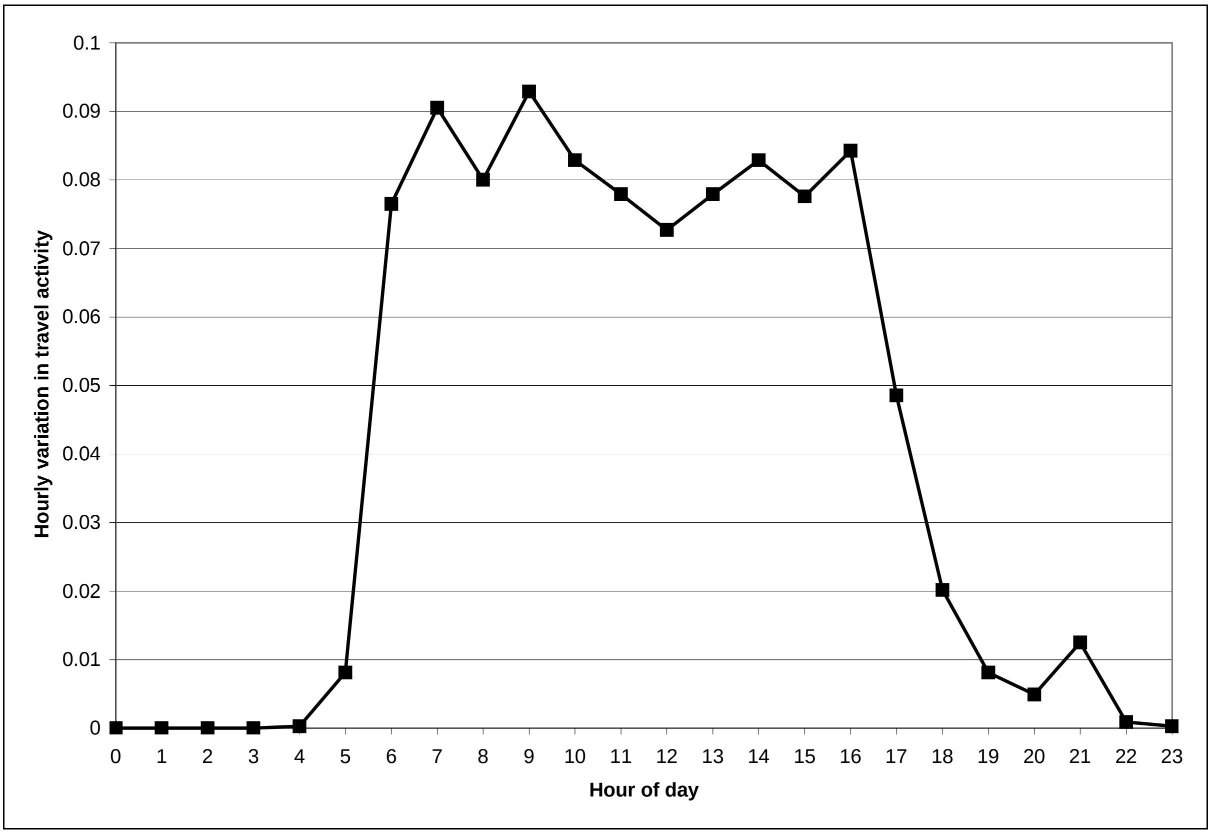

Figure 3.5: Average hourly variation in travel activity for petrol light duty commercial vehicles

3.4.5 Emission Estimates

Table 3.37 presents total estimated annual emissions (for selected substances) from petrol light duty commercial vehicles for the GMR, Sydney, Newcastle, Wollongong and Non-Urban regions. Total estimated annual emissions of all substances from petrol light duty commercial vehicles are presented in Appendix C.

Table 3.37: Total estimated annual emissions from petrol light duty commercial vehicles in each region

Substance	Emissions (tonnes/year)				
	Sydney	Newcastle	Wollongong	Non-Urban	GMR
1,3 butadiene	25.91	1.26	0.94	5.01	33.13
Acetaldehyde	36.61	1.79	1.33	7.09	46.81
Benzene	216.01	10.54	7.86	41.81	276.22
Carbon monoxide	55294	2784	2050	11001	71129
Formaldehyde	60.43	2.95	2.20	11.70	77.28
Isomers of xylene	322.16	15.71	11.73	62.35	411.95
Lead & compounds	0.388	0.016	0.013	0.055	0.473
Oxides of nitrogen	4534	217	164	937	5851
Particulate matter ≤ 10 µm	50.14	2.10	1.70	7.09	61.03
Particulate matter ≤ 2.5 µm	46.13	1.93	1.56	6.52	56.15
Polycyclic aromatic hydrocarbons	12.05	0.57	0.43	2.24	15.28
Sulfur dioxide	49.67	2.64	1.93	9.57	63.81
Toluene	232.66	11.35	8.47	45.03	297.51
Total suspended particulates (TSP)	67.69	2.83	2.29	9.57	82.39
Total VOCs	4627	226	168	895	5916

Tables 3.38, 3.39, 3.40 and 3.41 present total estimated daily emissions (for selected substances) from light duty petrol commercial vehicles for the GMR, Sydney, Newcastle, Wollongong and Non-Urban regions. These daily emission estimates are representative of a typical January weekday, January weekend day, a July weekday and July weekend day.

Table 3.38: Total estimated daily emissions from petrol light duty commercial vehicles in each region for a typical January weekday

Substance	Emissions (tonnes/day)				
	Sydney	Newcastle	Wollongong	Non-Urban	GMR
1,3 butadiene	0.055	0.003	0.002	0.011	0.070
Acetaldehyde	0.078	0.004	0.003	0.015	0.100
Benzene	0.460	0.022	0.017	0.089	0.588
Carbon monoxide	107.26	5.40	3.98	21.34	137.97
Formaldehyde	0.129	0.006	0.005	0.025	0.164
Isomers of xylene	0.685	0.033	0.025	0.133	0.876
Lead & compounds	0.001	0.000	0.000	0.000	0.001
Oxides of nitrogen	11.50	0.55	0.41	2.38	14.84
Particulate matter ≤ 10 µm	0.124	0.005	0.004	0.018	0.151
Particulate matter ≤ 2.5 µm	0.114	0.005	0.004	0.016	0.139
Polycyclic aromatic hydrocarbons	0.030	0.001	0.001	0.006	0.038
Sulfur dioxide	0.123	0.007	0.005	0.024	0.158
Toluene	0.495	0.024	0.018	0.096	0.633
Total suspended particulates (TSP)	0.168	0.007	0.006	0.024	0.204
Total VOCs	9.843	0.480	0.358	1.905	12.587

Table 3.39: Total estimated daily emissions from petrol light duty commercial vehicles in each region for a typical January weekend day

Substance	Emissions (tonnes/day)				
	Sydney	Newcastle	Wollongong	Non-Urban	GMR
1,3 butadiene	0.048	0.002	0.002	0.009	0.062
Acetaldehyde	0.068	0.003	0.002	0.013	0.087
Benzene	0.402	0.020	0.015	0.078	0.514
Carbon monoxide	93.85	4.73	3.48	18.67	120.73
Formaldehyde	0.113	0.005	0.004	0.022	0.144
Isomers of xylene	0.600	0.029	0.022	0.116	0.767
Lead & compounds	0.001	0.000	0.000	0.000	0.001
Oxides of nitrogen	10.06	0.48	0.36	2.08	12.99
Particulate matter ≤ 10 µm	0.109	0.005	0.004	0.015	0.132
Particulate matter ≤ 2.5 µm	0.100	0.004	0.003	0.014	0.122
Polycyclic aromatic hydrocarbons	0.026	0.001	0.001	0.005	0.033
Sulfur dioxide	0.108	0.006	0.004	0.021	0.138
Toluene	0.433	0.021	0.016	0.084	0.554
Total suspended particulates (TSP)	0.147	0.006	0.005	0.021	0.179
Total VOCs	8.613	0.420	0.314	1.667	11.014

Table 3.40: Total estimated daily emissions from petrol light duty commercial vehicles for a typical July weekday

Substance	Emissions (tonnes/day)				
	Sydney	Newcastle	Wollongong	Non-Urban	GMR
1,3 butadiene	0.086	0.004	0.003	0.017	0.111
Acetaldehyde	0.122	0.006	0.004	0.024	0.156
Benzene	0.721	0.035	0.026	0.140	0.922
Carbon monoxide	195.63	9.85	7.25	38.92	251.66
Formaldehyde	0.202	0.010	0.007	0.039	0.258
Isomers of xylene	1.076	0.052	0.039	0.208	1.375
Lead & compounds	0.001	0.000	0.000	0.000	0.001
Oxides of nitrogen	13.17	0.63	0.48	2.72	17.00
Particulate matter ≤ 10 µm	0.149	0.006	0.005	0.021	0.181
Particulate matter ≤ 2.5 µm	0.137	0.006	0.005	0.019	0.167
Polycyclic aromatic hydrocarbons	0.036	0.002	0.001	0.007	0.045
Sulfur dioxide	0.147	0.008	0.006	0.028	0.189
Toluene	0.777	0.038	0.028	0.150	0.993
Total suspended particulates (TSP)	0.201	0.008	0.007	0.028	0.244
Total VOCs	15.449	0.753	0.562	2.990	19.755

Table 3.41: Total estimated daily emissions from petrol light duty commercial vehicles in each region for a typical July weekend day

Substance	Emissions (tonnes/day)				
	Sydney	Newcastle	Wollongong	Non-Urban	GMR
1,3 butadiene	0.076	0.004	0.003	0.015	0.097
Acetaldehyde	0.107	0.005	0.004	0.021	0.137
Benzene	0.631	0.031	0.023	0.122	0.807
Carbon monoxide	171.18	8.62	6.35	34.06	220.20
Formaldehyde	0.177	0.009	0.006	0.034	0.226
Isomers of xylene	0.941	0.046	0.034	0.182	1.204
Lead & compounds	0.001	0.000	0.000	0.000	0.001
Oxides of nitrogen	11.53	0.55	0.42	2.38	14.87
Particulate matter ≤ 10 µm	0.130	0.005	0.004	0.018	0.158
Particulate matter ≤ 2.5 µm	0.120	0.005	0.004	0.017	0.146
Polycyclic aromatic hydrocarbons	0.031	0.001	0.001	0.006	0.040
Sulfur dioxide	0.129	0.007	0.005	0.025	0.166
Toluene	0.680	0.033	0.025	0.132	0.869
Total suspended particulates (TSP)	0.176	0.007	0.006	0.025	0.214
Total VOCs	13.518	0.659	0.492	2.616	17.285

3.5 Other Vehicles

Other vehicles in this inventory include petrol heavy duty commercial vehicles and motorcycles. This is actually not a good category placing lightest and heaviest petrol vehicles in one group. However, in view of both types of vehicles being extremely lacking in adequate emissions data and accounting only for a very small proportion of the entire on-road fleet travel, it was decided to put them in one group for this inventory.

3.5.1 Emission Factors

For petrol heavy duty commercial vehicles, all gaseous emission factors are adopted from USEPA's AP42 data (USEPA, 1995a) as no Australian data are available. Before 2004, AP42 emission factors for 1989 models are used, and from 2004 onwards AP42 emission factors for 1998 models are used. Particulate matter emission factors are sourced from the USEPA PART5 model (USEPA, 1995b).

For motorcycles, gaseous emission factors are sourced from the European Emission Inventory Guide Book (European Environment Agency, 2002) assuming a 2-stroke engine under EC97/24/EC and an average speed of 35km/h. As the particulate matter emissions of motorcycles was set at a very high level in the MAQS inventory and, in the absence of adequate data, it is assumed that in 2004 particulate emissions were reduced to the level of petrol passenger cars, that is, 0.021 g/km. Tables 3.42 and 3.43 present base emission factors for heavy duty commercial petrol vehicles and motorcycles respectively.

Table 3.42: Gaseous emission factors for petrol heavy duty commercial vehicles

Substance	NO_x		VOC		CO	
Model year	New car emissions (g/km)	Deterioration rate (g/km/km)	New car emissions (g/km)	Deterioration rate (g/km/km)	New car emissions (g/km)	Deterioration rate (g/km/km)
1987	3.45	1.55×10^{-06}	5.8	6.6×10^{-06}	46.0	0.000172
1993	3.45	1.55×10^{-06}	4.35	3.5×10^{-06}	31.4	3.32×10^{-05}
2004	1.40	1.55×10^{-06}	0.86	3.48×10^{-06}	18.8	2.47×10^{-06}

Table 3.43: Gaseous emission factors for motorcycles

Substance	NO_x		VOC		CO	
Model year	New car emissions (g/km)	Deterioration rate (g/km/km)	New car emissions (g/km)	Deterioration rate (g/km/km)	New car emissions (g/km)	Deterioration rate (g/km/km)
1975	0.39	NA	7.48	NA	26.6	NA
1999	0.0215	NA	6.07	NA	10.4075	NA

Table 3.44 gives PM_{10} emissions factors for petrol heavy duty commercial vehicles. For motorcycles, PM_{10} emission factors are set at 0.06 g/km for all model years.

Table 3.44: Particulate emission factors for petrol heavy duty commercial vehicles

Model year	g/km
1986	0.230
1996	0.158
2004	0.070

3.5.2 Emission Modification Factors

Emission modification parameters for other vehicles are set as follows:

- driving conditions – detailed below
- petrol fuel volatility – the same as petrol passenger cars (Section 3.1.2.2)
- in-service maintenance – assumed to be none for this inventory
- fuel sulfur content – assumed to be 150 ppm for this inventory
- ethanol blending – assumed to be none for this inventory
- season – calculated for both average summer and average winter for this inventory.

Table 3.45 presents driving condition modification factors for heavy duty commercial petrol vehicles and motorcycles.

Table 3.45: Driving condition modification factors for other vehicles

Substance	Free-flow					Congested				
	Arterial	Highway/ Freeway	Commercial Arterial	Commercial Highway	Local/ Residential Roads	Arterial	Highway/ Freeway	Commercial Arterial	Commercial Highway	Local/ Residential Roads
PM	1.000	0.550	1.000	0.550	1.000	1.800	1.332	2.000	1.379	1.474
NO_x	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
VOC	0.870	0.770	0.870	0.770	1.000	1.120	1.156	1.120	1.179	1.223
CO	0.830	0.710	0.830	0.710	1.000	1.010	1.125	1.010	1.143	1.178

3.5.3 Emission Speciation

Speciation profiles for other vehicles are the same as that for petrol passenger cars.

3.5.4 Temporal Profiles

Figure 3.6 gives the average hourly travel profile for other vehicles, which is a profile averaged over the entire GMR. Weekly and monthly profiles have already been discussed in Section 2.8.

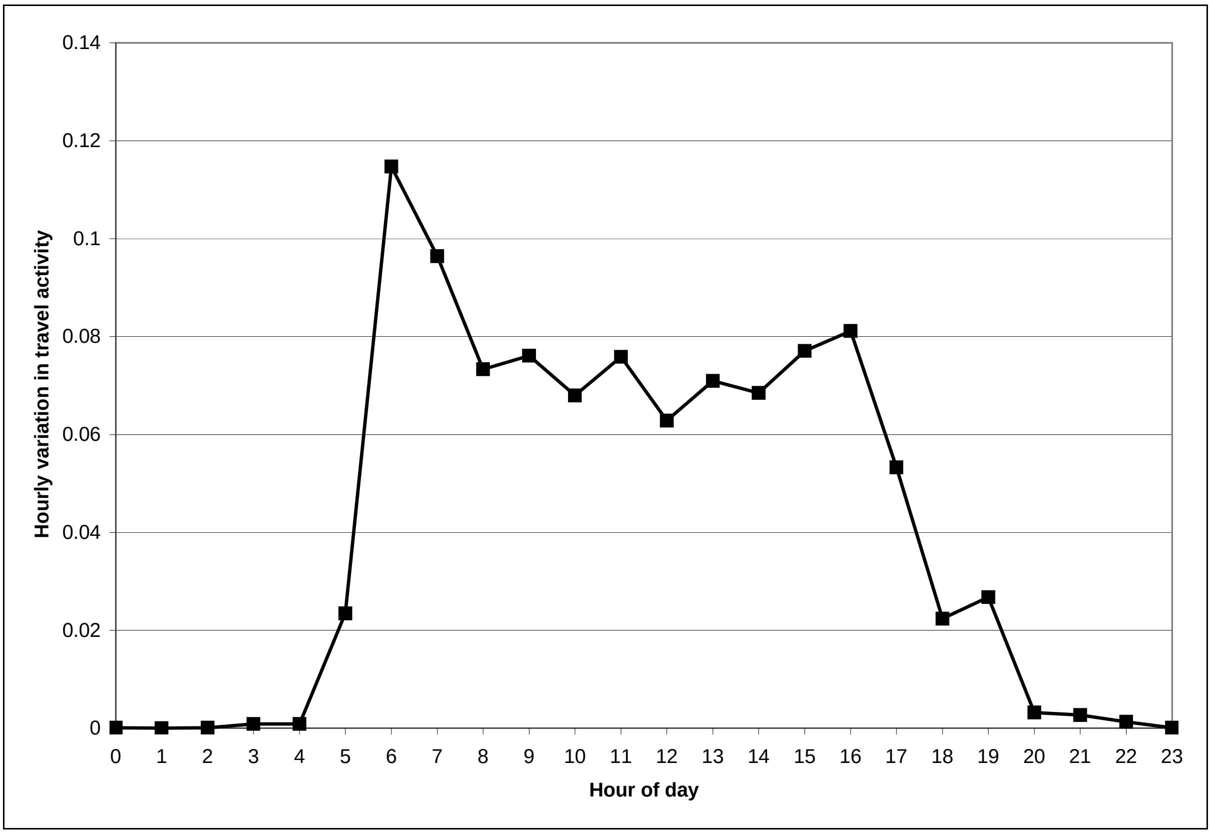

Figure 3.6: Average hourly variation in travel activity for other vehicles

3.5.5 Emission Estimates

Table 3.46 presents total estimated annual emissions (for selected substances) from other vehicles for the GMR, Sydney, Newcastle, Wollongong and Non-Urban regions. Total estimated annual emissions of all substances from other vehicles are presented in Appendix C.

Table 3.46: Total estimated annual emissions from other vehicles in each region

Substance	Emissions (tonnes/year)				
	Sydney	Newcastle	Wollongong	Non-Urban	GMR
1,3 butadiene	23.20	1.77	1.16	6.51	32.64
Acetaldehyde	32.79	2.50	1.63	9.20	46.12
Benzene	193.45	14.77	9.64	54.28	272.14
Carbon monoxide	35554	2788	1848	11388	51579
Formaldehyde	54.12	4.13	2.70	15.18	76.14
Isomers of xylene	288.51	22.03	14.37	80.95	405.86
Lead & compounds	0.524	0.036	0.027	0.135	0.723
Oxides of nitrogen	2135	173	112	751	3171
Particulate matter ≤ 10 µm	67.68	4.69	3.50	17.40	93.28
Particulate matter ≤ 2.5 µm	62.27	4.32	3.22	16.01	85.82
Polycyclic aromatic hydrocarbons	12.83	0.94	0.65	3.49	17.90
Sulfur dioxide	22.22	1.78	1.22	6.69	31.91
Toluene	208.36	15.91	10.38	58.46	293.11
Total suspended particulates (TSP)	91.37	6.34	4.73	23.49	125.93
Total VOCs	4143	316	206	1163	5829

Tables 3.47, 3.48, 3.49 and 3.50 present total estimated daily emissions (for selected substances) from other vehicles for the GMR, Sydney, Newcastle, Wollongong and Non-Urban regions. These daily emission estimates are representative of a typical January weekday, January weekend day, a July weekday and July weekend day.

Table 3.47: Total estimated daily emissions from other vehicles in each region for a typical January weekday

Substance	Emissions (tonnes/day)				
	Sydney	Newcastle	Wollongong	Non-Urban	GMR
1,3 butadiene	0.049	0.004	0.002	0.014	0.069
Acetaldehyde	0.070	0.005	0.003	0.020	0.098
Benzene	0.412	0.031	0.021	0.115	0.579
Carbon monoxide	68.967	5.409	3.585	22.091	100.05
Formaldehyde	0.115	0.009	0.006	0.032	0.162
Isomers of xylene	0.614	0.047	0.031	0.172	0.863
Lead & compounds	0.001	0.000	0.000	0.000	0.002
Oxides of nitrogen	5.415	0.439	0.285	1.905	8.044
Particulate matter ≤ 10 µm	0.168	0.012	0.009	0.043	0.231
Particulate matter ≤ 2.5 µm	0.154	0.011	0.008	0.040	0.212
Polycyclic aromatic hydrocarbons	0.032	0.002	0.002	0.009	0.044
Sulfur dioxide	0.055	0.004	0.003	0.017	0.079
Toluene	0.443	0.034	0.022	0.124	0.624
Total suspended particulates (TSP)	0.226	0.016	0.012	0.058	0.312
Total VOCs	8.815	0.673	0.439	2.473	12.401

Table 3.48: Total estimated daily emissions from other vehicles in each region for a typical January weekend day

Substance	Emissions (tonnes/day)				
	Sydney	Newcastle	Wollongong	Non-Urban	GMR
1,3 butadiene	0.043	0.003	0.002	0.012	0.061
Acetaldehyde	0.061	0.005	0.003	0.017	0.086
Benzene	0.360	0.028	0.018	0.101	0.507
Carbon monoxide	60.346	4.733	3.137	19.330	87.546
Formaldehyde	0.101	0.008	0.005	0.028	0.142
Isomers of xylene	0.537	0.041	0.027	0.151	0.756
Lead & compounds	0.001	0.000	0.000	0.000	0.002
Oxides of nitrogen	4.738	0.384	0.250	1.667	7.038
Particulate matter ≤ 10 µm	0.147	0.010	0.008	0.038	0.202
Particulate matter ≤ 2.5 µm	0.135	0.009	0.007	0.035	0.186
Polycyclic aromatic hydrocarbons	0.028	0.002	0.001	0.008	0.039
Sulfur dioxide	0.048	0.004	0.003	0.014	0.069
Toluene	0.388	0.030	0.019	0.109	0.546
Total suspended particulates (TSP)	0.198	0.014	0.010	0.051	0.273
Total VOCs	7.713	0.589	0.384	2.164	10.851

Table 3.49: Total estimated daily emissions from other vehicles in each region for a typical July weekday

Substance	Emissions (tonnes/day)				
	Sydney	Newcastle	Wollongong	Non-Urban	GMR
1,3 butadiene	0.077	0.006	0.004	0.022	0.109
Acetaldehyde	0.109	0.008	0.005	0.031	0.154
Benzene	0.646	0.049	0.032	0.181	0.909
Carbon monoxide	125.793	9.866	6.540	40.293	182.49
Formaldehyde	0.181	0.014	0.009	0.051	0.254
Isomers of xylene	0.963	0.074	0.048	0.270	1.355
Lead & compounds	0.002	0.000	0.000	0.000	0.002
Oxides of nitrogen	6.201	0.503	0.327	2.181	9.212
Particulate matter ≤ 10 µm	0.201	0.014	0.010	0.052	0.277
Particulate matter ≤ 2.5 µm	0.185	0.013	0.010	0.047	0.255
Polycyclic aromatic hydrocarbons	0.038	0.003	0.002	0.010	0.053
Sulfur dioxide	0.066	0.005	0.004	0.020	0.095
Toluene	0.696	0.053	0.035	0.195	0.979
Total suspended particulates (TSP)	0.271	0.019	0.014	0.070	0.374
Total VOCs	13.835	1.057	0.689	3.882	19.463

Table 3.50: Total estimated daily emissions from other vehicles in each region for a typical July weekend day

Substance	Emissions (tonnes/day)				
	Sydney	Newcastle	Wollongong	Non-Urban	GMR
1,3 butadiene	0.068	0.005	0.003	0.019	0.095
Acetaldehyde	0.096	0.007	0.005	0.027	0.135
Benzene	0.565	0.043	0.028	0.159	0.795
Carbon monoxide	110.069	8.632	5.722	35.256	159.68
Formaldehyde	0.158	0.012	0.008	0.044	0.222
Isomers of xylene	0.843	0.064	0.042	0.236	1.186
Lead & compounds	0.001	0.000	0.000	0.000	0.002
Oxides of nitrogen	5.426	0.440	0.286	1.909	8.061
Particulate matter ≤ 10 µm	0.176	0.012	0.009	0.045	0.242
Particulate matter ≤ 2.5 µm	0.162	0.011	0.008	0.042	0.223
Polycyclic aromatic hydrocarbons	0.033	0.002	0.002	0.009	0.046
Sulfur dioxide	0.058	0.005	0.003	0.017	0.083
Toluene	0.609	0.046	0.030	0.171	0.856
Total suspended particulates (TSP)	0.237	0.016	0.012	0.061	0.327
Total VOCs	12.106	0.924	0.603	3.397	17.030

3.6 Evaporative Sources

The source of evaporative emissions can be categorised into three types in terms of vehicle operating situations, that is, diurnal loss, hot soak loss, and running loss, together with a supplementary source – resting loss. Diurnal loss is the loss of fuel vapour from parked vehicles when increases in ambient temperature cause liquid fuel in the fuel tank to vaporise. The vapour expands and is forced out of the tank cap or other vents. Hot soak loss is the fuel vapour loss occurring immediately after the engine is switched off. The fuel in the carburettor float bowl is heated by the hot engine causing it to vaporise. Running loss is the fuel vapour loss occurring during vehicle operation. Resting loss is the loss of vapour due to vapour permeation from the fuel and evaporative system and migration to other systems like open-bottom canisters. A decrease in Reid Vapour Pressure (RVP) will reduce vapour losses from all the above sources.

Except running losses, evaporative emissions occur when vehicles are stationary. Therefore they are not directly VKT-related. Ideally, the quantification of diurnal and hot soak losses requires vehicular trip data, that is, number of trip starts, number of trip ends, as well as trip duration information. However, this approach requires extra and unconventional travel and emission data that are not currently available. For this version of emission inventory, the basic assumptions of the MAQS inventory (Carnovale et al, 1996) are still used, which use VKT as a surrogate.

3.6.1 Emission Factors

The Reddy equation, which relates vapour generation to RVP values and ambient temperatures, is employed to convert emission rates from the baseline of 76 kPa to emissions under other RVP levels. Hot soak losses are derived from diurnal losses according to the relationships estimated in the MAQS inventory. For average summer/winter days, hot soak losses (in *g/trip*) were assumed to be ½ of diurnal losses (in *g/day*) for pre-1976 and 1976–19'85 vehicles, and $^1/_3$ for post 1985 vehicles.

The running loss data used in the projection originate from the USEPA's AP42 Mobile Source Emission Factor Compilation (USEPA, 1995a). As the US data are provided for four RVP values (48.3 *kPa*, 62.1 *kPa*, 71.7 *kPa* and 80.1 *kPa*), quadratic regression equations were made through these values so that data for other RVP values can be estimated by interpolation. The US time periods, pre-1971, 1978–1980 and 1981+, in which the running loss data were assigned, are assumed to be equivalent to the Australian control periods, pre-1975, 1976–1985 and post 1985, respectively.

The resting loss estimates that are estimated by assuming the ratios of resting losses to running losses in the MAQS inventory are still applicable. The ratios are 0.33, 0.32, and 0.77 for high oxidant days, average summer days and average winter days.

RVP value in winter is about 90 *kPa* in NSW and is irrelevant to any RVP reduction initiatives. Because of the lack of proper data, it is assumed that the ratios derived from the MAQS inventory between high oxidant day's evaporative emissions and wintertime ones are still applicable. Therefore, the evaporative emissions for average winter days are obtained by converting the high oxidant day's emissions (with RVP=76 *kPa*).

Evaporative emissions calculated separately for the four sources are then summed up to yield total evaporative emissions for each of the control levels. No deterioration rates for evaporative emissions were assumed owing to lack of data.

As with exhaust emissions, the calculated evaporative emission factors apply only to residential roads. The following relationships (as used in MAQS) are used to convert the base emission factors for residential roads into those for the other types of road:

1. emission factors for arterial and commercial arterial roads are the same as residential/minor roads

2. highways and commercial highways – only 10% of the running loss is included in the emission factors to take account of the inverse relationship of running loss and average speed

3. congested categories – 50% of the running loss component is added to the base emission factors. This accounts for the extra losses at low average speed in these conditions.

3.6.2 Emission Speciation

Evaporative emissions do not contain PAH substances. Their speciation profiles are quite different from those of exhaust emissions. The profile data of evaporative emissions are mainly sourced from USEPA's SPECIATE database (2002) and datasets developed in the former NSW EPA's Petrohol Study (Brown et al, 1998). Table 3.51 presents a sample of speciation data for evaporative emissions for selected substances.

Table 3.51: Sample of speciation profile for evaporative emissions

Substance ID	Substance name	% VOC
356	Benzene	1.330689
594	Ethylbenzene	0.689592
593	Styrene	0.035694
482	Toluene	3.494517
83	Acetylene	0.226204
288	Cyclopentene	0.285554
1654	Dimethylbutene	0.016797
1619	Dimethylcyclopentane	0.218365
1786	Dimethylhexanes	0.027996
1748	Dimethylpentane	0.044793
85	Ethane	0.298619
617	Ethylcyclohexane	0.011198
84	Ethylene	0.604703
740	Indan	0.033595
212	Isobutane	1.916013
1794	Isomers of heptane	0.011198
287	Isoprene	0.347144
51	Methyl alcohol	0.694289
1529	Methylbutadiene	0.044793
493	Methylcyclohexane	0.223964
368	Methylcyclopentane	0.609525
360	1-methylcyclopentene	0.279955
1747	Methylhexenes	0.201568
1449	Methylindans	0.022396
1746	Methylpentenes	9.697648
748	M-ethyltoluene	0.45726
596	M-xylene	1.016058
597	O-xylene	0.779335
749	P-ethyltoluene	0.408735
145	Propane	1.441098
144	Propylene	0.24956
374	Trans-3-hexene	0.167973
210	Trans-2-butene	1.833967
375	Trans-2-hexene	0.335946
298	Trans-2-pentene	1.279473
1736	Trimethylcyclopentane	0.027996
1694	Trimethylpentane	0.403135

3.6.3 Temporal Profiles

The hourly variation of evaporative emissions have very complicated behaviours, which are affected not only by changes in traffic activity but also by changes in ambient temperature. As discussed previously, evaporative emissions are from four sources: diurnal losses, hot soak losses, running losses and resting losses. Emissions from different evaporative sources have very different dependences on ambient temperatures and different relationships with travel activities. In reality, diurnal losses and hot soak losses are not directly related to VKT. However, as VKT is usually the only traffic activity data available, a method was developed (Carnovale et al, 1996, pp A58–A60) for the MAQS inventory to derive VKT-based emission factors on the basis of assumptions about vehicle parking activities. These assumptions and data are assumed to be still valid for this inventory so that VKT data can be used to derive evaporative emission estimates. In the MAQS inventory, only average daily VKT data were used. A one-fit-to-all hourly traffic profile and one-fit-to-all hourly evaporative profile were used to convert daily exhaust emissions to hourly exhaust emissions, and daily evaporative emissions to hourly evaporative emissions, respectively. The MAQS hourly evaporative emission profile combines the effects of both hourly traffic and hourly ambient temperature.

In a departure from the MAQS inventory which used total daily VKT, hourly VKT data are used for this inventory. The hourly profile of the MAQS inventory combines the effect of traffic variation and temperature variation. However, as this inventory uses hourly VKT, the hourly profile should only be based on temperature variation. Therefore an effort was made to isolate the temperature effect from the combined temperature-traffic hourly profile of the MAQS inventory. The derivation of the combined evaporative profile was complicated by integrating the behaviours of the four different evaporative sources. It was assumed that overall, the combined profile can be regarded as the average of the traffic profile and the temperature effect profile (Carnavale et al, 1996, pp 4–76). This enabled the distillation of an overall temperature-effect profile for evaporative emissions (Figure 3.7). As the curve of the profile is quite spiky, a 7-step (3 forward and 3 backward) moving average was used to smooth the curve. This curve indicates that for a vehicle, on average, the highest evaporative emissions occur around noon and lowest evaporative emissions occur at dawn (5:00 am) for an average summer day.

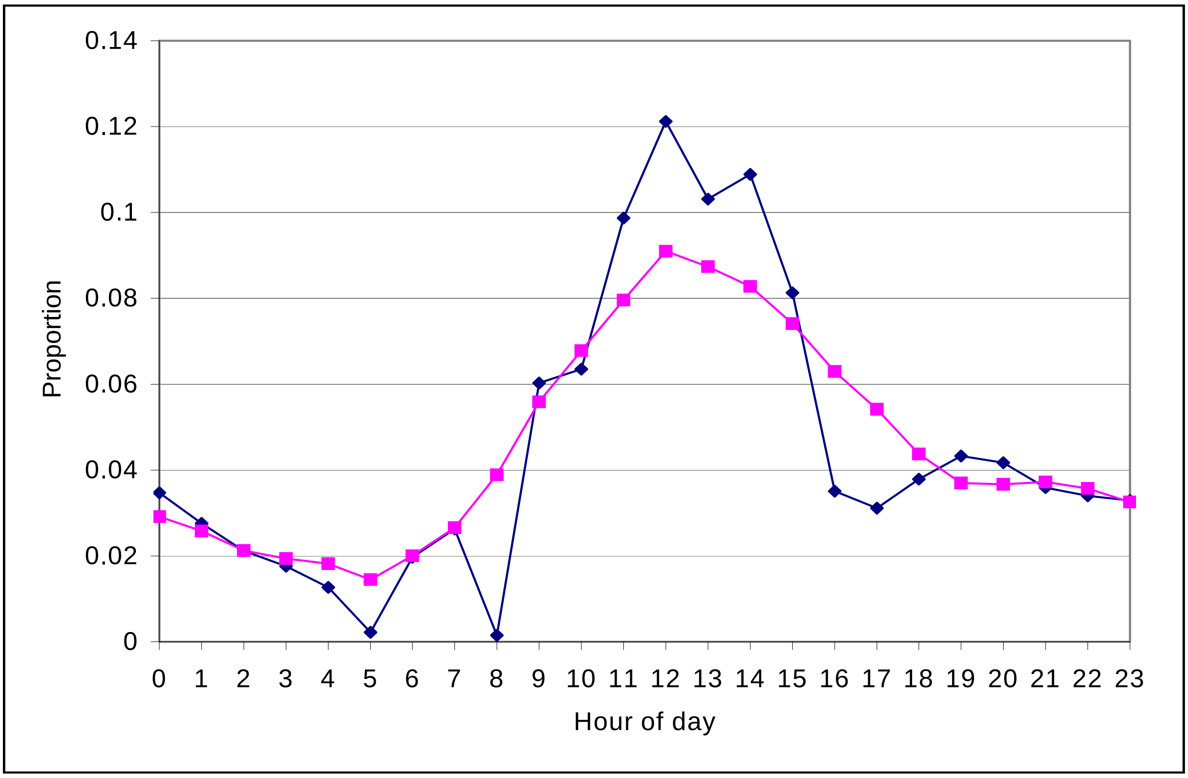

Figure 3.7: Hourly profile for overall temperature effects on evaporative emissions for an average summer day (red line being moving average)

3.6.4 Emission Estimates

Table 3.52 presents total estimated annual emissions (for selected substances) from evaporative sources of petrol vehicles for the GMR, Sydney, Newcastle, Wollongong and Non-Urban regions. Total estimated annual emissions of all substances from on-road mobile sources are presented in Appendix C.

Table 3.52: Total estimated annual evaporative emissions from mobile sources in each region

Substance	Emissions (tonnes/year)				
	Sydney	Newcastle	Wollongong	Non-Urban	GMR
1,3 butadiene	0.00	0.00	0.00	0.00	0.00
Acetaldehyde	0.00	0.00	0.00	0.00	0.00
Benzene	156.80	11.61	6.74	23.88	199.02
Carbon monoxide	0.00	0.00	0.00	0.00	0.00
Formaldehyde	0.00	0.00	0.00	0.00	0.00
Isomers of xylene	211.55	15.66	9.09	32.22	268.53
Lead & compounds	0.00	0.00	0.00	0.00	0.00
Oxides of nitrogen	0.00	0.00	0.00	0.00	0.00
Particulate matter ≤ 10 µm	0.00	0.00	0.00	0.00	0.00
Particulate matter ≤ 2.5 µm	0.00	0.00	0.00	0.00	0.00
Polycyclic aromatic hydrocarbons	0.00	0.00	0.00	0.00	0.00
Sulfur dioxide	0.00	0.00	0.00	0.00	0.00
Toluene	119.72	8.86	5.15	18.24	151.97
Total suspended particulates (TSP)	0.00	0.00	0.00	0.00	0.00
Total VOCs	11783	872	507	1795	14956

Tables 3.53, 3.54, 3.55 and 3.56 present total estimated daily emissions (for selected substances) from evaporative sources of petrol vehicles for the GMR, Sydney, Newcastle, Wollongong and Non-Urban regions. These daily emission estimates are representative of a typical January weekday, January weekend day, a July weekday and July weekend day.

Table 3.53: Total estimated daily evaporative emissions from mobile sources in each region for a typical January weekday

Substance	Emissions (tonnes/day)				
	Sydney	Newcastle	Wollongong	Non-Urban	GMR
1,3 butadiene	0.000	0.000	0.000	0.000	0.000
Acetaldehyde	0.000	0.000	0.000	0.000	0.000
Benzene	0.398	0.029	0.017	0.061	0.505
Carbon monoxide	0.000	0.000	0.000	0.000	0.000
Formaldehyde	0.000	0.000	0.000	0.000	0.000
Isomers of xylene	0.537	0.040	0.023	0.082	0.681
Lead & compounds	0.000	0.000	0.000	0.000	0.000
Oxides of nitrogen	0.000	0.000	0.000	0.000	0.000
Particulate matter ≤ 10 µm	0.000	0.000	0.000	0.000	0.000
Particulate matter ≤ 2.5 µm	0.000	0.000	0.000	0.000	0.000
Polycyclic aromatic hydrocarbons	0.000	0.000	0.000	0.000	0.000
Sulfur dioxide	0.000	0.000	0.000	0.000	0.000
Toluene	0.304	0.022	0.013	0.046	0.385
Total suspended particulates (TSP)	0.000	0.000	0.000	0.000	0.000
Total VOCs	29.889	2.212	1.285	4.553	37.939

Table 3.54: Total estimated daily evaporative emissions from mobile sources in each region for a typical January weekend day

Substance	Emissions (tonnes/day)				
	Sydney	Newcastle	Wollongong	Non-Urban	GMR
1,3 butadiene	0.000	0.000	0.000	0.000	0.000
Acetaldehyde	0.000	0.000	0.000	0.000	0.000
Benzene	0.348	0.026	0.015	0.053	0.442
Carbon monoxide	0.000	0.000	0.000	0.000	0.000
Formaldehyde	0.000	0.000	0.000	0.000	0.000
Isomers of xylene	0.470	0.035	0.020	0.072	0.596
Lead & compounds	0.000	0.000	0.000	0.000	0.000
Oxides of nitrogen	0.000	0.000	0.000	0.000	0.000
Particulate matter ≤ 10 µm	0.000	0.000	0.000	0.000	0.000
Particulate matter ≤ 2.5 µm	0.000	0.000	0.000	0.000	0.000
Polycyclic aromatic hydrocarbons	0.000	0.000	0.000	0.000	0.000
Sulfur dioxide	0.000	0.000	0.000	0.000	0.000
Toluene	0.266	0.020	0.011	0.040	0.337
Total suspended particulates (TSP)	0.000	0.000	0.000	0.000	0.000
Total VOCs	26.153	1.936	1.124	3.983	33.197

Table 3.55: Total estimated daily evaporative emissions from mobile sources in each region for a typical July weekday

Substance	Emissions (tonnes/day)				
	Sydney	Newcastle	Wollongong	Non-Urban	GMR
1,3 butadiene	0.000	0.000	0.000	0.000	0.000
Acetaldehyde	0.000	0.000	0.000	0.000	0.000
Benzene	0.456	0.034	0.020	0.069	0.578
Carbon monoxide	0.000	0.000	0.000	0.000	0.000
Formaldehyde	0.000	0.000	0.000	0.000	0.000
Isomers of xylene	0.615	0.045	0.026	0.094	0.780
Lead & compounds	0.000	0.000	0.000	0.000	0.000
Oxides of nitrogen	0.000	0.000	0.000	0.000	0.000
Particulate matter ≤ 10 µm	0.000	0.000	0.000	0.000	0.000
Particulate matter ≤ 2.5 µm	0.000	0.000	0.000	0.000	0.000
Polycyclic aromatic hydrocarbons	0.000	0.000	0.000	0.000	0.000
Sulfur dioxide	0.000	0.000	0.000	0.000	0.000
Toluene	0.348	0.026	0.015	0.053	0.441
Total suspended particulates (TSP)	0.000	0.000	0.000	0.000	0.000
Total VOCs	34.232	2.534	1.472	5.214	43.451

Table 3.56: Total estimated daily evaporative emissions from mobile sources in each region for a typical July weekend day

Substance	Emissions (tonnes/day)				
	Sydney	Newcastle	Wollongong	Non-Urban	GMR
1,3 butadiene	0.000	0.000	0.000	0.000	0.000
Acetaldehyde	0.000	0.000	0.000	0.000	0.000
Benzene	0.399	0.030	0.017	0.061	0.506
Carbon monoxide	0.000	0.000	0.000	0.000	0.000
Formaldehyde	0.000	0.000	0.000	0.000	0.000
Isomers of xylene	0.538	0.040	0.023	0.082	0.683
Lead & compounds	0.000	0.000	0.000	0.000	0.000
Oxides of nitrogen	0.000	0.000	0.000	0.000	0.000
Particulate matter ≤ 10 µm	0.000	0.000	0.000	0.000	0.000
Particulate matter ≤ 2.5 µm	0.000	0.000	0.000	0.000	0.000
Polycyclic aromatic hydrocarbons	0.000	0.000	0.000	0.000	0.000
Sulfur dioxide	0.000	0.000	0.000	0.000	0.000
Toluene	0.304	0.023	0.013	0.046	0.386
Total suspended particulates (TSP)	0.000	0.000	0.000	0.000	0.000
Total VOCs	29.953	2.217	1.288	4.562	38.019

4 Emissions Summary

The on-road mobile air emissions inventory has been developed for the 2003 calendar year, which incorporates an area covering greater Sydney, Wollongong and Newcastle, known as the Greater Metropolitan Region (GMR).

The on-road mobile air emissions inventory includes emissions from the following sources:

- exhaust emissions from petrol passenger cars
- exhaust emissions from diesel light duty vehicles
- exhaust emissions from petrol light duty commercial vehicles
- exhaust emissions from diesel heavy duty commercial vehicles
- exhaust emissions from other vehicles
- evaporative emissions from all petrol vehicles.

The substances inventoried include criteria pollutants specified in the NEPM for ambient air quality (NEPC, 2003), air toxics associated with the National Pollutant Inventory (NEPC, 2000) and the air toxics NEPM (NEPC, 2004) and any other pollutants associated with state specific programs such as. Load Based Licensing (Protection of the Environment Operations (General) Regulation 1998 and Protection of the Environment Operations (Clean Air) Regulation 2002.

Table 4.1 shows total estimated annual emissions (for selected substances) from all on-road mobile sources in the GMR, Sydney, Newcastle, Wollongong and Non-Urban regions.

Figure 4.1 shows the proportion of total estimated annual emissions (for selected substances) from all on-road mobile sources in the GMR, Sydney, Newcastle, Wollongong and Non-Urban regions.

Tables 4.2, 4.3, 4.4 and 4.5 show total estimated daily emissions (for selected substances) from all on-road mobile sources the in GMR, Sydney, Newcastle, Wollongong and Non-Urban regions. These daily emission estimates are representative of a typical January weekday, January weekend day, a July weekday and July weekend day.

Figures 4.2, 4.3, 4.4 and 4.5 show the proportion of total estimated daily emissions (for selected substances) from all on-road mobile sources in the GMR, Sydney, Newcastle, Wollongong and Non-Urban regions. These daily emission estimates are representative of a typical January weekday, January weekend day, a July weekday and July weekend day.

Tables 4.6, 4.7, 4.8, 4.9 and 4.10 show total estimated annual emissions (for selected substances) from each on-road mobile source type in the GMR, Sydney, Newcastle, Wollongong and Non-Urban regions respectively.

Figures 4.6, 4.7, 4.8, 4.9 and 4.10 show the proportion of total estimated annual emissions (for selected substances) from each on-road mobile source type in the GMR, Sydney, Newcastle, Wollongong and Non-Urban regions respectively.

Table 4.1: Total estimated annual emissions from on-road mobile sources in each region

Substance	Emissions (tonnes/year)				
	Sydney	Newcastle	Wollongong	Non-Urban	GMR
1,3 butadiene	199.04	14.06	8.66	34.54	256.31
Acetaldehyde	614.50	41.02	30.56	132.62	818.69
Benzene	1832.90	129.75	79.57	313.91	2356.13
Carbon monoxide	431269.85	31675.12	19172.63	76929.48	559047.07
Formaldehyde	709.43	48.10	33.22	138.90	929.65
Isomers of xylene	2678.95	189.98	116.23	458.84	3444.00
Lead & compounds	10.71	0.71	0.47	1.81	13.70
Oxides of nitrogen	65996.26	4947.23	3255.29	14409.90	88608.69
Particulate matter ≤ 10 µm	2552.05	177.42	119.00	500.75	3349.22
Particulate matter ≤ 2.5 µm	2426.26	169.02	113.45	479.48	3188.21
Polycyclic aromatic hydrocarbons	173.21	11.33	7.43	27.55	219.51
Sulfur dioxide	1253.77	98.11	59.45	248.63	1659.96
Toluene	1902.29	134.79	82.55	326.47	2446.10
Total suspended particulates (TSP)	2912.33	200.11	133.67	548.20	3794.30
Total VOCs	50171.04	3555.75	2194.83	8571.75	64493.38

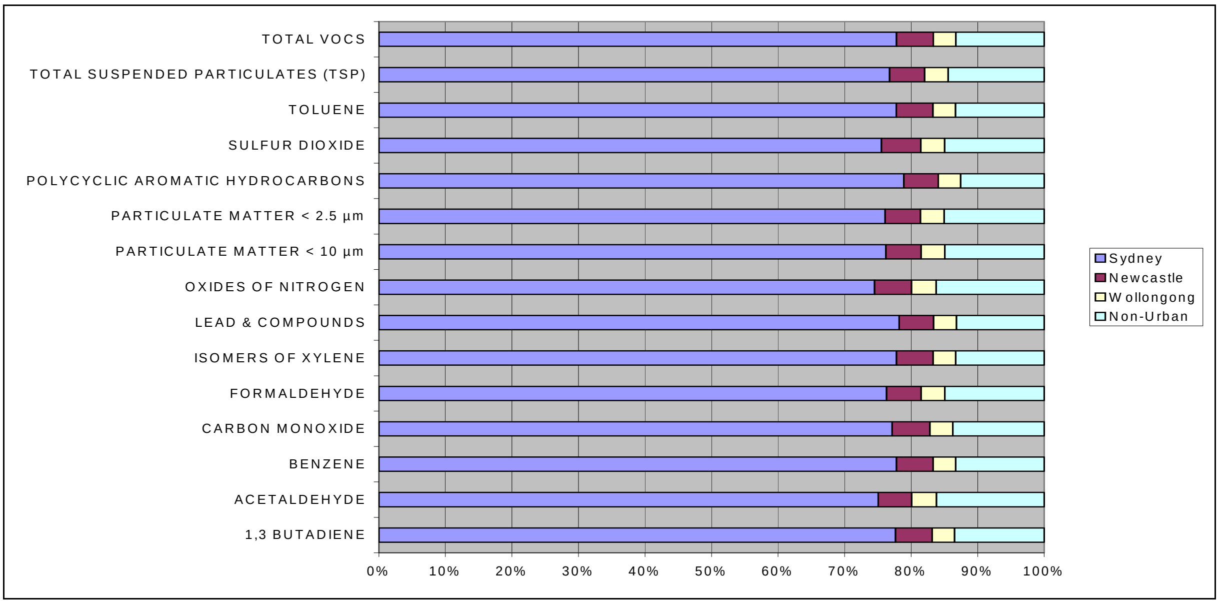

Figure 4.1: Proportion of total estimated annual emissions from on-road mobile sources in each region

Table 4.2: Total estimated daily emissions from on-road mobile sources in each region for a typical January weekday

Substance	Emissions (tonnes/day)				
	Sydney	Newcastle	Wollongong	Non-Urban	GMR
1,3 butadiene	0.42	0.03	0.02	0.07	0.55
Acetaldehyde	1.31	0.09	0.07	0.28	1.74
Benzene	3.96	0.28	0.17	0.68	5.09
Carbon monoxide	836.57	61.44	37.19	149.23	1084.43
Formaldehyde	1.51	0.10	0.07	0.30	1.98
Isomers of xylene	5.79	0.41	0.25	0.99	7.44
Lead & compounds	0.03	0.00	0.00	0.00	0.03
Oxides of nitrogen	167.41	12.55	8.26	36.55	224.77
Particulate matter ≤ 10 µm	6.32	0.44	0.29	1.24	8.29
Particulate matter ≤ 2.5 µm	6.01	0.42	0.28	1.19	7.89
Polycyclic aromatic hydrocarbons	0.43	0.03	0.02	0.07	0.54
Sulfur dioxide	3.10	0.24	0.15	0.62	4.11
Toluene	4.10	0.29	0.18	0.70	5.27
Total suspended particulates (TSP)	7.21	0.50	0.33	1.36	9.40
Total VOCs	111.56	7.92	4.88	18.97	143.33

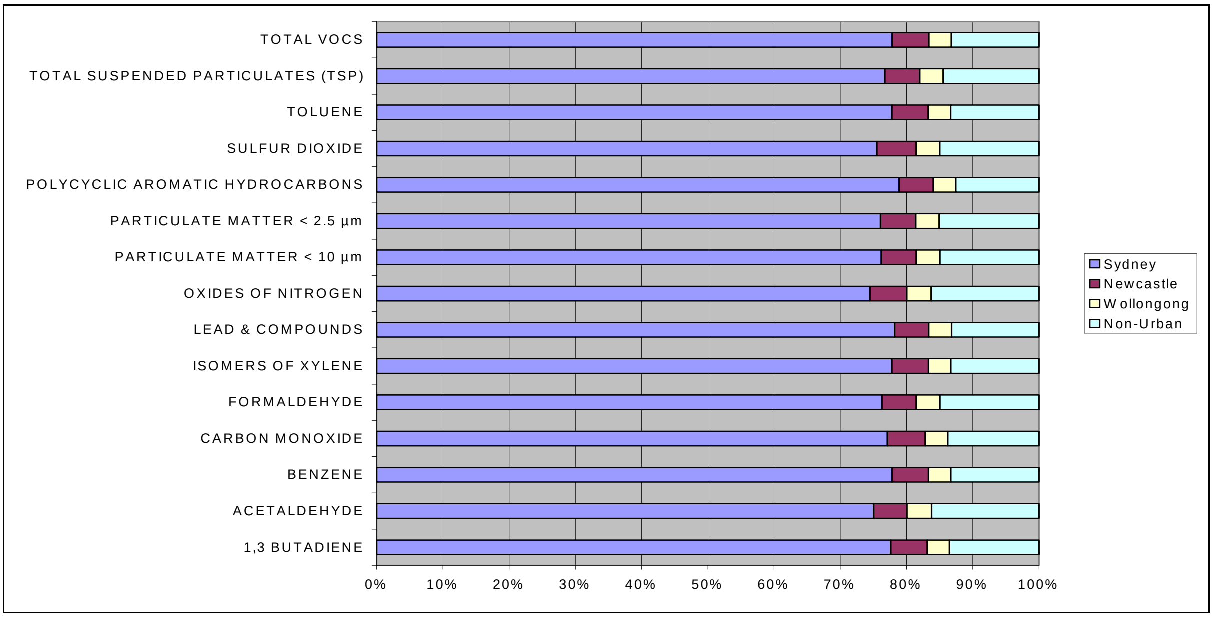

Figure 4.2: Proportion of total estimated daily emissions from on-road mobile sources in each region for typical January weekday

Table 4.3: Total estimated daily emissions from on-road mobile sources in each region for a typical January weekend day

Substance	Emissions (tonnes/day)				
	Sydney	Newcastle	Wollongong	Non-Urban	GMR
1,3 butadiene	0.37	0.03	0.02	0.06	0.48
Acetaldehyde	1.14	0.08	0.06	0.25	1.52
Benzene	3.47	0.25	0.15	0.59	4.46
Carbon monoxide	732.00	53.76	32.54	130.57	948.88
Formaldehyde	1.32	0.09	0.06	0.26	1.73
Isomers of xylene	5.06	0.36	0.22	0.87	6.51
Lead & compounds	0.02	0.00	0.00	0.00	0.03
Oxides of nitrogen	146.48	10.98	7.23	31.98	196.67
Particulate matter ≤ 10 µm	5.53	0.38	0.26	1.08	7.26
Particulate matter ≤ 2.5 µm	5.26	0.37	0.25	1.04	6.91
Polycyclic aromatic hydrocarbons	0.38	0.02	0.02	0.06	0.48
Sulfur dioxide	2.72	0.21	0.13	0.54	3.60
Toluene	3.58	0.25	0.16	0.61	4.61
Total suspended particulates (TSP)	6.31	0.43	0.29	1.19	8.22
Total VOCs	97.61	6.93	4.27	16.60	125.41

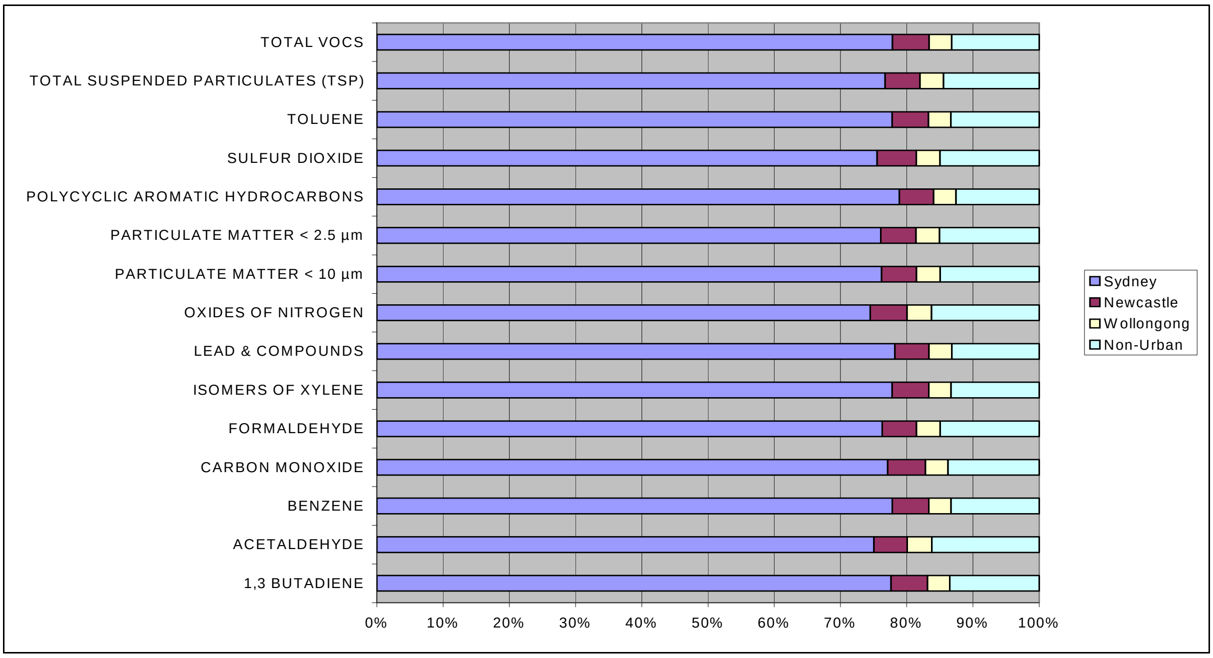

Figure 4.3: Proportion of total estimated daily emissions from on-road mobile sources in each region for a typical January weekend day

Table 4.4: Total estimated daily emissions from on-road mobile sources in each region for a typical July weekday

Substance	Emissions (tonnes/day)				
	Sydney	Newcastle	Wollongong	Non-Urban	GMR
1,3 butadiene	0.66	0.05	0.03	0.12	0.86
Acetaldehyde	2.05	0.14	0.10	0.44	2.73
Benzene	6.05	0.43	0.26	1.04	7.78
Carbon monoxide	1525.87	112.07	67.83	272.18	1977.95
Formaldehyde	2.37	0.16	0.11	0.46	3.10
Isomers of xylene	8.85	0.63	0.38	1.52	11.38
Lead & compounds	0.03	0.00	0.00	0.01	0.04
Oxides of nitrogen	191.73	14.37	9.46	41.86	257.42
Particulate matter ≤ 10 µm	7.57	0.53	0.35	1.49	9.94
Particulate matter ≤ 2.5 µm	7.20	0.50	0.34	1.42	9.46
Polycyclic aromatic hydrocarbons	0.51	0.03	0.02	0.08	0.65
Sulfur dioxide	3.72	0.29	0.18	0.74	4.93
Toluene	6.30	0.45	0.27	1.08	8.10
Total suspended particulates (TSP)	8.64	0.59	0.40	1.63	11.26
Total VOCs	162.41	11.49	7.11	27.84	208.85

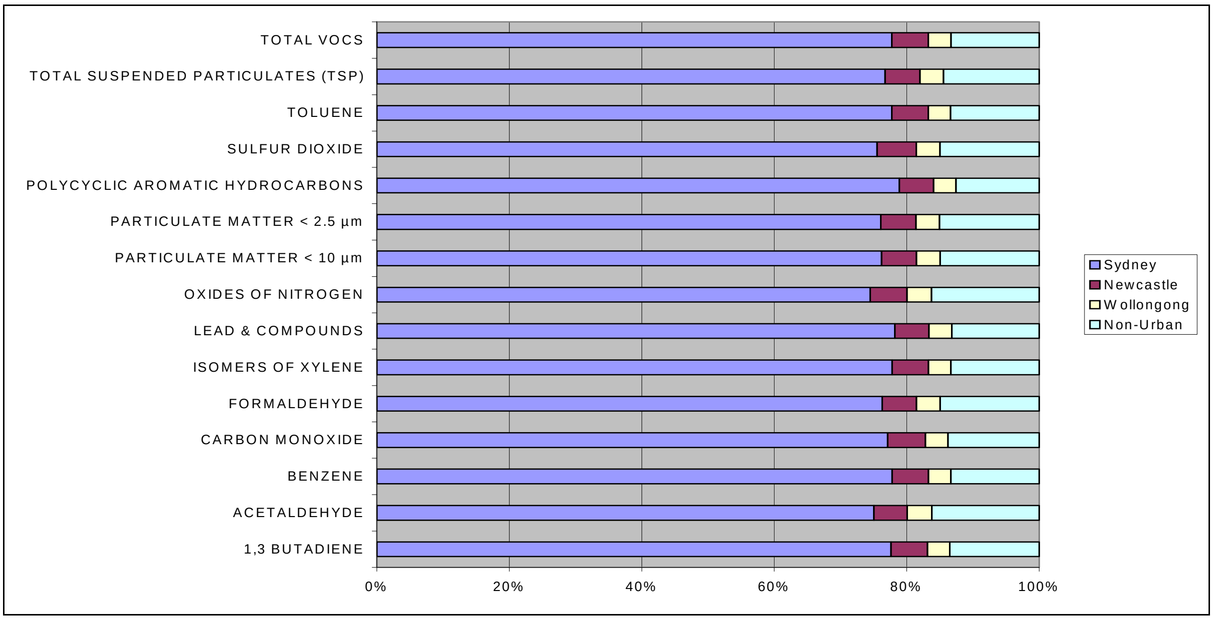

Figure 4.4: Proportion of total estimated daily emissions from on-road mobile sources in each region for a typical July weekday

Table 4.5: Total estimated daily emissions from on-road mobile sources in each region for a typical July weekend day

Substance	Emissions (tonnes/day)				
	Sydney	Newcastle	Wollongong	Non-Urban	GMR
1,3 butadiene	0.58	0.04	0.03	0.10	0.75
Acetaldehyde	1.80	0.12	0.09	0.39	2.39
Benzene	5.30	0.37	0.23	0.91	6.81
Carbon monoxide	1335.13	98.06	59.35	238.16	1730.71
Formaldehyde	2.07	0.14	0.10	0.41	2.72
Isomers of xylene	7.75	0.55	0.34	1.33	9.96
Lead & compounds	0.03	0.00	0.00	0.00	0.04
Oxides of nitrogen	167.76	12.58	8.27	36.63	225.24
Particulate matter ≤ 10 µm	6.63	0.46	0.31	1.30	8.70
Particulate matter ≤ 2.5 µm	6.30	0.44	0.29	1.24	8.28
Polycyclic aromatic hydrocarbons	0.45	0.03	0.02	0.07	0.57
Sulfur dioxide	3.26	0.25	0.15	0.65	4.31
Toluene	5.51	0.39	0.24	0.95	7.09
Total suspended particulates (TSP)	7.56	0.52	0.35	1.42	9.85
Total VOCs	142.11	10.06	6.22	24.36	182.75

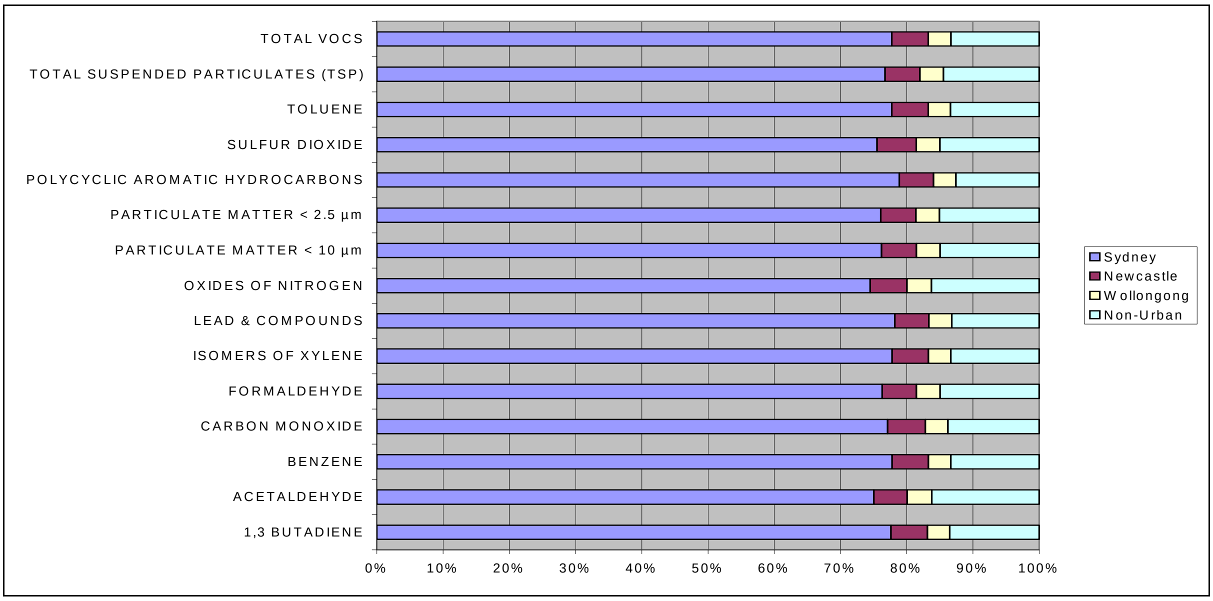

Figure 4.5: Proportion of total estimated daily emissions from on-road mobile sources in each region for a typical July weekend day

Table 4.6: Total estimated annual emissions by on-road mobile source type in the GMR

Substance	Emissions (tonnes/year)						
	Exhaust emissions – petrol passenger cars	Exhaust emissions – diesel light duty vehicles	Exhaust emissions – petrol light duty commercial vehicles	Exhaust emissions – diesel heavy duty commercial vehicles	Exhaust emissions – other vehicles	Evaporative emissions – all petrol vehicles	On-Road Mobile Total
1,3 butadiene	185.12	0.47	33.13	4.96	32.64	0.00	256.31
Acetaldehyde	261.61	23.20	46.81	440.95	46.12	0.00	818.69
Benzene	1543.59	22.54	276.22	42.62	272.14	199.02	2356.13
Carbon monoxide	413721.34	10193.65	71128.51	12424.36	51579.21	0.00	559047.07
Formaldehyde	431.85	44.86	77.28	299.53	76.14	0.00	929.65
Isomers of xylene	2302.07	13.48	411.95	42.12	405.86	268.53	3444.00
Lead & compounds	8.18	1.44	0.47	2.88	0.72	0.00	13.70
Oxides of nitrogen	49010.88	5286.69	5851.35	25288.73	3171.03	0.00	88608.69
Particulate matter ≤ 10 µm	1056.26	1105.88	61.03	1032.77	93.28	0.00	3349.22
Particulate matter ≤ 2.5 µm	971.76	1072.71	56.15	1001.78	85.82	0.00	3188.21
Polycyclic aromatic hydrocarbons (PAH)	148.78	11.63	15.28	25.92	17.90	0.00	219.51
Sulfur dioxide	821.48	317.52	63.81	425.25	31.91	0.00	1659.96
Toluene	1662.53	9.94	297.51	31.06	293.11	151.97	2446.10
Total suspended particulates (TSP)	1425.95	1116.94	82.39	1043.09	125.93	0.00	3794.30
Total VOCs	33061.68	1146.80	5916.30	3583.30	5828.85	14956.44	64493.38

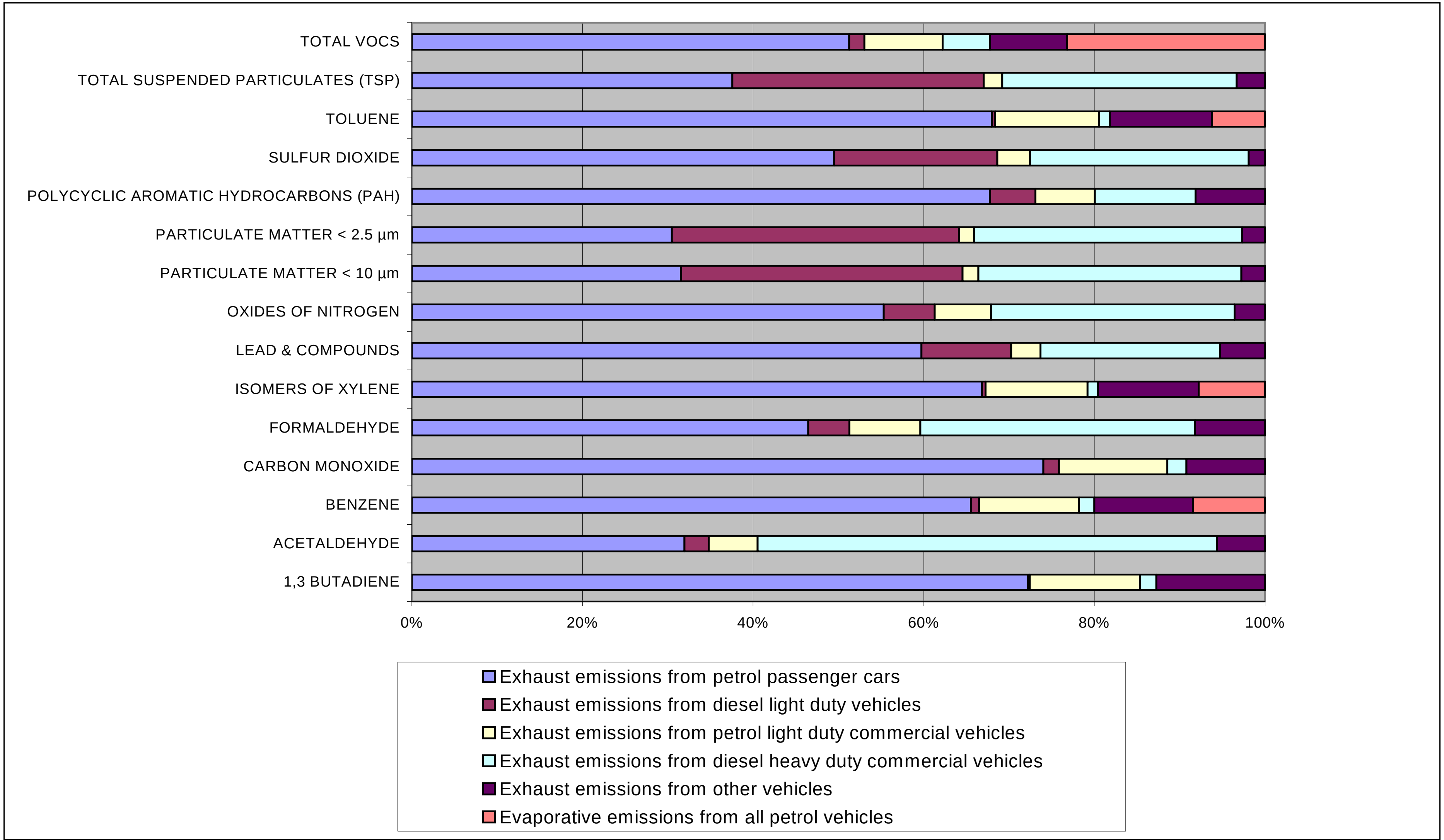

Figure 4.6: Proportion of total estimated annual emissions by on-road mobile source type in the GMR

Table 4.7: Total estimated annual emissions by on-road mobile source type in the Sydney region

Substance	Emissions (tonnes/year)						
	Exhaust emissions – petrol passenger cars	Exhaust emissions - diesel light duty vehicles	Exhaust emissions – petrol light duty commercial vehicles	Exhaust emissions – diesel heavy duty commercial vehicles	Exhaust emissions - other vehicles	Evaporative emissions – all petrol vehicles	On-Road Mobile Total
1,3 butadiene	145.95	0.39	25.91	3.59	23.20	0.00	199.04
Acetaldehyde	206.26	19.31	36.61	319.54	32.79	0.00	614.50
Benzene	1217.00	18.76	216.01	30.89	193.45	156.80	1832.90
Carbon monoxide	323953.12	7935.39	55293.61	8533.58	35554.14	0.00	431269.85
Formaldehyde	340.48	37.34	60.43	217.06	54.12	0.00	709.43
Isomers of xylene	1814.99	11.22	322.16	30.52	288.51	211.55	2678.95
Lead & compounds	6.72	1.13	0.39	1.96	0.52	0.00	10.71
Oxides of nitrogen	38175.02	4245.05	4533.89	16907.72	2134.59	0.00	65996.26
Particulate matter ≤ 10 µm	866.76	865.77	50.14	701.69	67.68	0.00	2552.05
Particulate matter ≤ 2.5 µm	797.42	839.80	46.13	680.64	62.27	0.00	2426.26
Polycyclic aromatic hydrocarbons (PAH)	120.27	9.47	12.05	18.59	12.83	0.00	173.21
Sulfur dioxide	644.96	249.06	49.67	287.86	22.22	0.00	1253.77
Toluene	1310.77	8.27	232.66	22.51	208.36	119.72	1902.29
Total suspended particulates (TSP)	1170.13	874.43	67.69	708.71	91.37	0.00	2912.33
Total VOCs	26066.45	954.65	4626.73	2596.68	4143.46	11783.08	50171.04

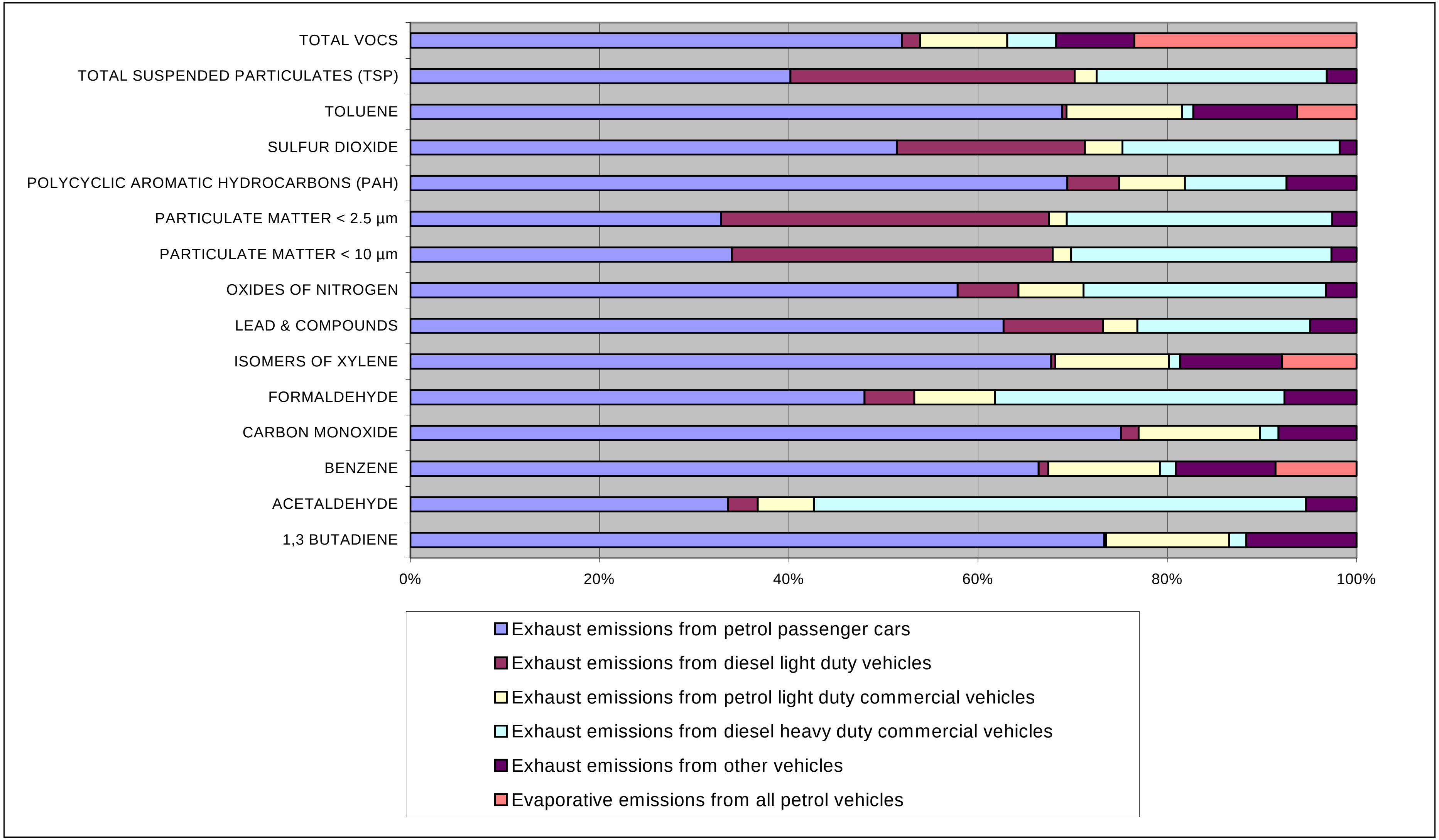

Figure 4.7: Proportion of total estimated annual emissions by on-road mobile source type in the Sydney region

Table 4.8: Total estimated annual emissions by on-road mobile source type in the Newcastle region

Substance	Emissions (tonnes/year)						
	Exhaust emissions – petrol passenger cars	Exhaust emissions - diesel light duty vehicles	Exhaust emissions - petrol light duty commercial vehicles	Exhaust emissions - diesel heavy duty commercial vehicles	Exhaust emissions - other vehicles	Evaporative emissions – all petrol vehicles	On-Road Mobile Total
1,3 butadiene	10.78	0.02	1.26	0.23	1.77	0.00	14.06
Acetaldehyde	15.23	1.02	1.79	20.48	2.50	0.00	41.02
Benzene	89.87	0.99	10.54	1.98	14.77	11.61	129.75
Carbon monoxide	24897.06	567.86	2783.93	637.87	2788.39	0.00	31675.12
Formaldehyde	25.14	1.96	2.95	13.91	4.13	0.00	48.10
Isomers of xylene	134.03	0.59	15.71	1.96	22.03	15.66	189.98
Lead & compounds	0.42	0.08	0.02	0.15	0.04	0.00	0.71
Oxides of nitrogen	2951.60	265.00	217.26	1340.23	173.14	0.00	4947.23
Particulate matter ≤ 10 µm	54.71	61.98	2.10	53.93	4.69	0.00	177.42
Particulate matter ≤ 2.5 µm	50.33	60.13	1.93	52.32	4.32	0.00	169.02
Polycyclic aromatic hydrocarbons (PAH)	8.04	0.56	0.57	1.23	0.94	0.00	11.33
Sulfur dioxide	51.49	18.50	2.64	23.71	1.78	0.00	98.11
Toluene	96.80	0.43	11.35	1.44	15.91	8.86	134.79
Total suspended particulates (TSP)	73.85	62.60	2.83	54.47	6.34	0.00	200.11
Total VOCs	1924.95	50.18	225.66	166.43	316.42	872.12	3555.75

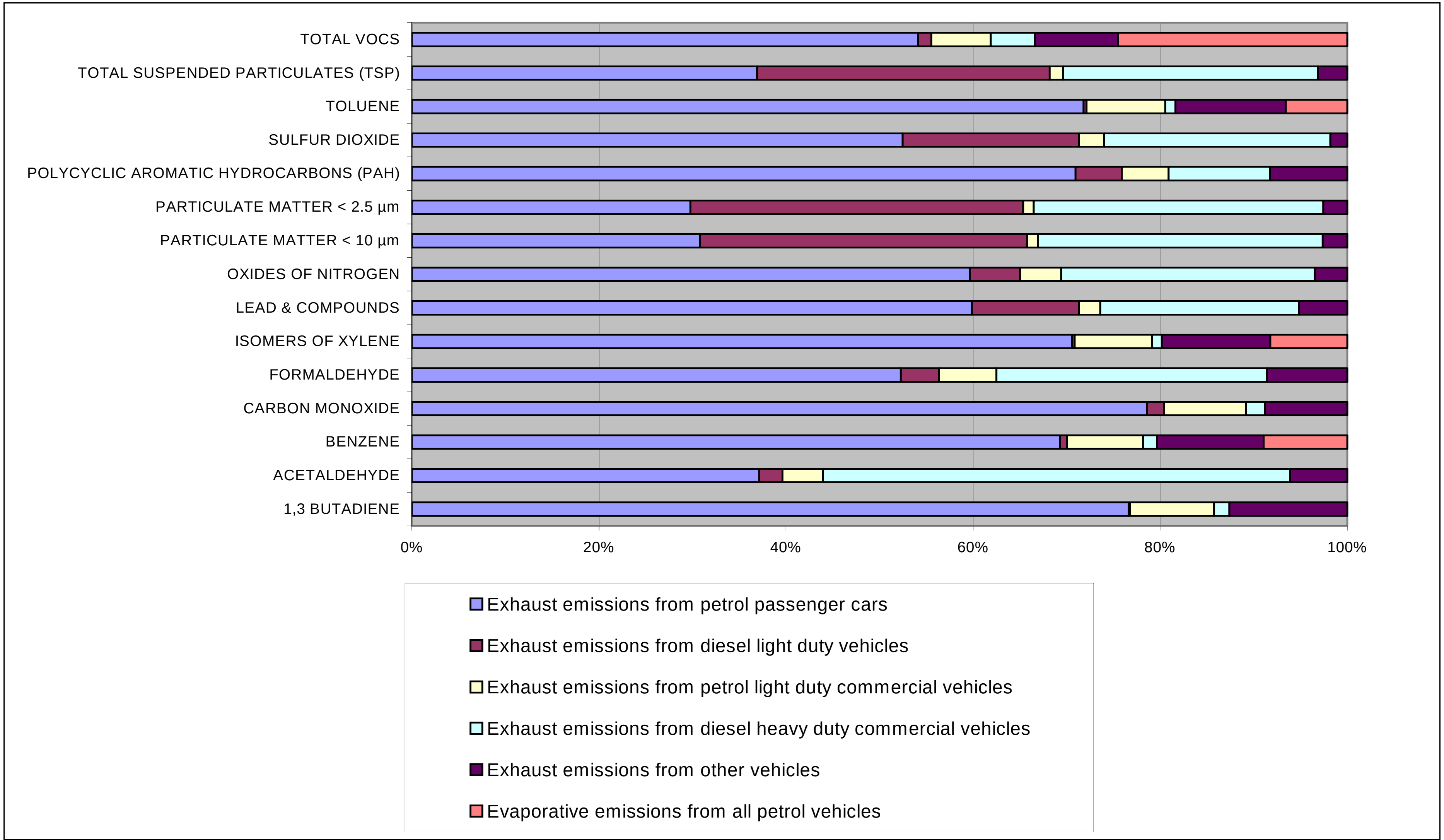

Figure 4.8: Proportion of total estimated annual emissions by on-road mobile source type in the Newcastle region

Table 4.9: Total estimated annual emissions by on-road mobile source type in the Wollongong region

Substance	Emissions (tonnes/year)						
	Exhaust emissions - petrol passenger cars	Exhaust emissions - diesel light duty vehicles	Exhaust emissions – petrol light duty commercial vehicles	Exhaust emissions - diesel heavy duty commercial vehicles	Exhaust emissions - other vehicles	Evaporative emissions – all petrol vehicles	On-Road Mobile Total
1,3 butadiene	6.35	0.01	0.94	0.20	1.16	0.00	8.66
Acetaldehyde	8.97	0.69	1.33	17.93	1.63	0.00	30.56
Benzene	52.92	0.67	7.86	1.73	9.64	6.74	79.57
Carbon monoxide	14415.00	346.52	2049.71	513.07	1848.33	0.00	19172.63
Formaldehyde	14.80	1.34	2.20	12.18	2.70	0.00	33.22
Isomers of xylene	78.92	0.40	11.73	1.71	14.37	9.09	116.23
Lead & compounds	0.27	0.05	0.01	0.12	0.03	0.00	0.47
Oxides of nitrogen	1742.61	169.66	163.51	1067.05	112.45	0.00	3255.29
Particulate matter ≤ 10 µm	34.44	37.63	1.70	41.73	3.50	0.00	119.00
Particulate matter ≤ 2.5 µm	31.68	36.50	1.56	40.48	3.22	0.00	113.45
Polycyclic aromatic hydrocarbons (PAH)	4.93	0.37	0.43	1.05	0.65	0.00	7.43
Sulfur dioxide	29.38	10.97	1.93	15.94	1.22	0.00	59.45
Toluene	56.99	0.30	8.47	1.26	10.38	5.15	82.55
Total suspended particulates (TSP)	46.49	38.00	2.29	42.15	4.73	0.00	133.67
Total VOCs	1133.42	34.33	168.45	145.68	206.43	506.53	2194.83

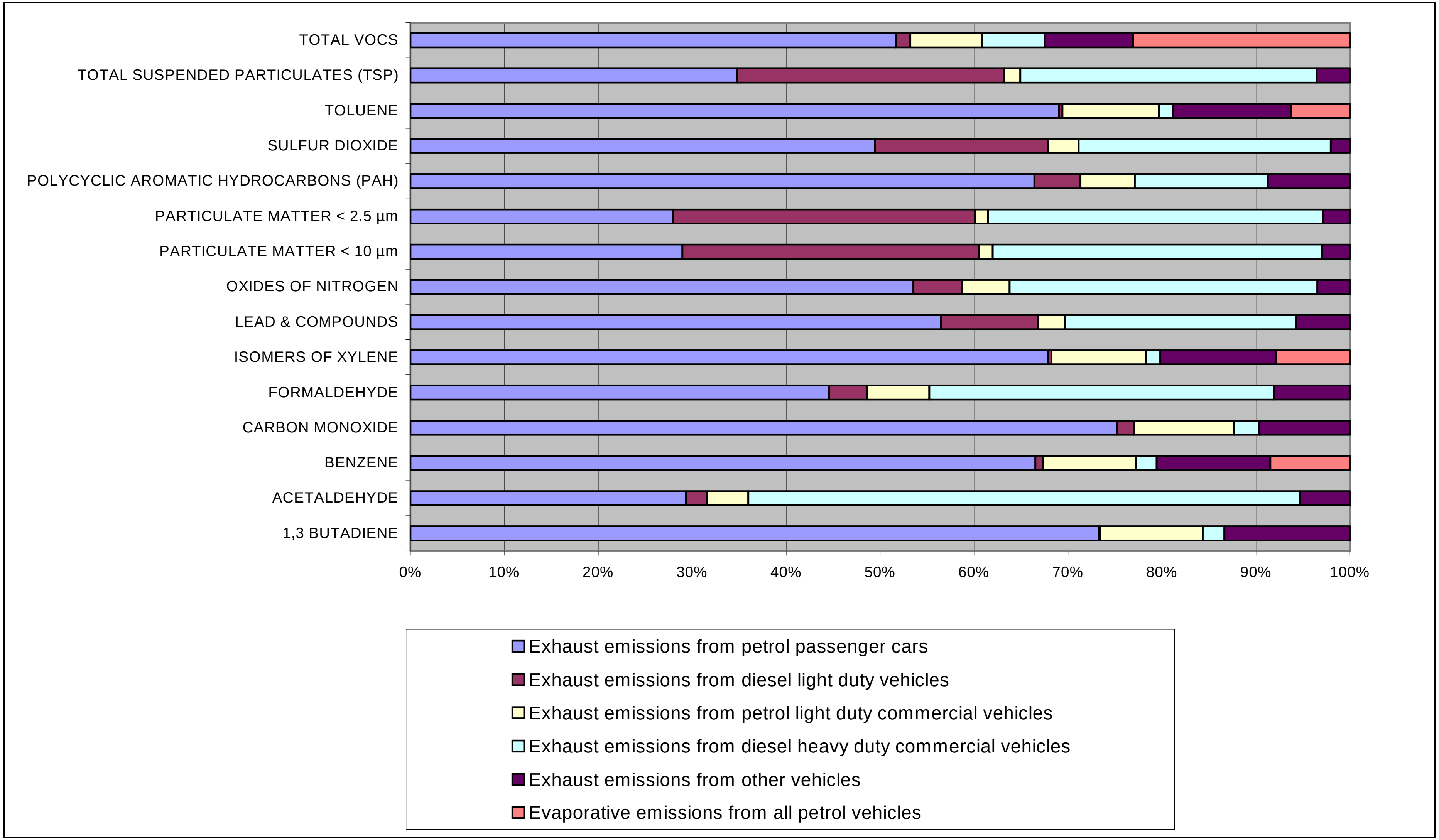

Figure 4.9: Proportion of total estimated annual emissions by on-road mobile source type in the Wollongong region

Table 4.10: Total estimated annual emissions by on-road mobile source type in the Non-Urban region

Substance	Emissions (tonnes/year)						
	Exhaust emissions - petrol passenger cars	Exhaust emissions - diesel light duty vehicles	Exhaust emissions – petrol light duty commercial vehicles	Exhaust emissions – diesel heavy duty commercial vehicles	Exhaust emissions - other vehicles	Evaporative emissions – all petrol vehicles	On-Road Mobile Total
1,3 butadiene	22.04	0.04	5.01	0.93	6.51	0.00	34.54
Acetaldehyde	31.15	2.18	7.09	83.00	9.20	0.00	132.62
Benzene	183.81	2.12	41.81	8.02	54.28	23.88	313.91
Carbon monoxide	50456.15	1343.88	11001.26	2739.84	11388.35	0.00	76929.48
Formaldehyde	51.42	4.21	11.70	56.38	15.18	0.00	138.90
Isomers of xylene	274.12	1.27	62.35	7.93	80.95	32.22	458.84
Lead & compounds	0.78	0.18	0.05	0.66	0.13	0.00	1.81
Oxides of nitrogen	6141.65	606.99	936.69	5973.73	750.85	0.00	14409.90
Particulate matter ≤ 10 µm	100.35	140.50	7.09	235.41	17.40	0.00	500.75
Particulate matter ≤ 2.5 µm	92.32	136.28	6.52	228.35	16.01	0.00	479.48
Polycyclic aromatic hydrocarbons (PAH)	15.54	1.23	2.24	5.05	3.49	0.00	27.55
Sulfur dioxide	95.64	38.99	9.57	97.74	6.69	0.00	248.63
Toluene	197.97	0.93	45.03	5.85	58.46	18.24	326.47
Total suspended particulates (TSP)	135.48	141.90	9.57	237.76	23.49	0.00	548.20
Total VOCs	3936.86	107.64	895.46	674.53	1162.55	1794.71	8571.75

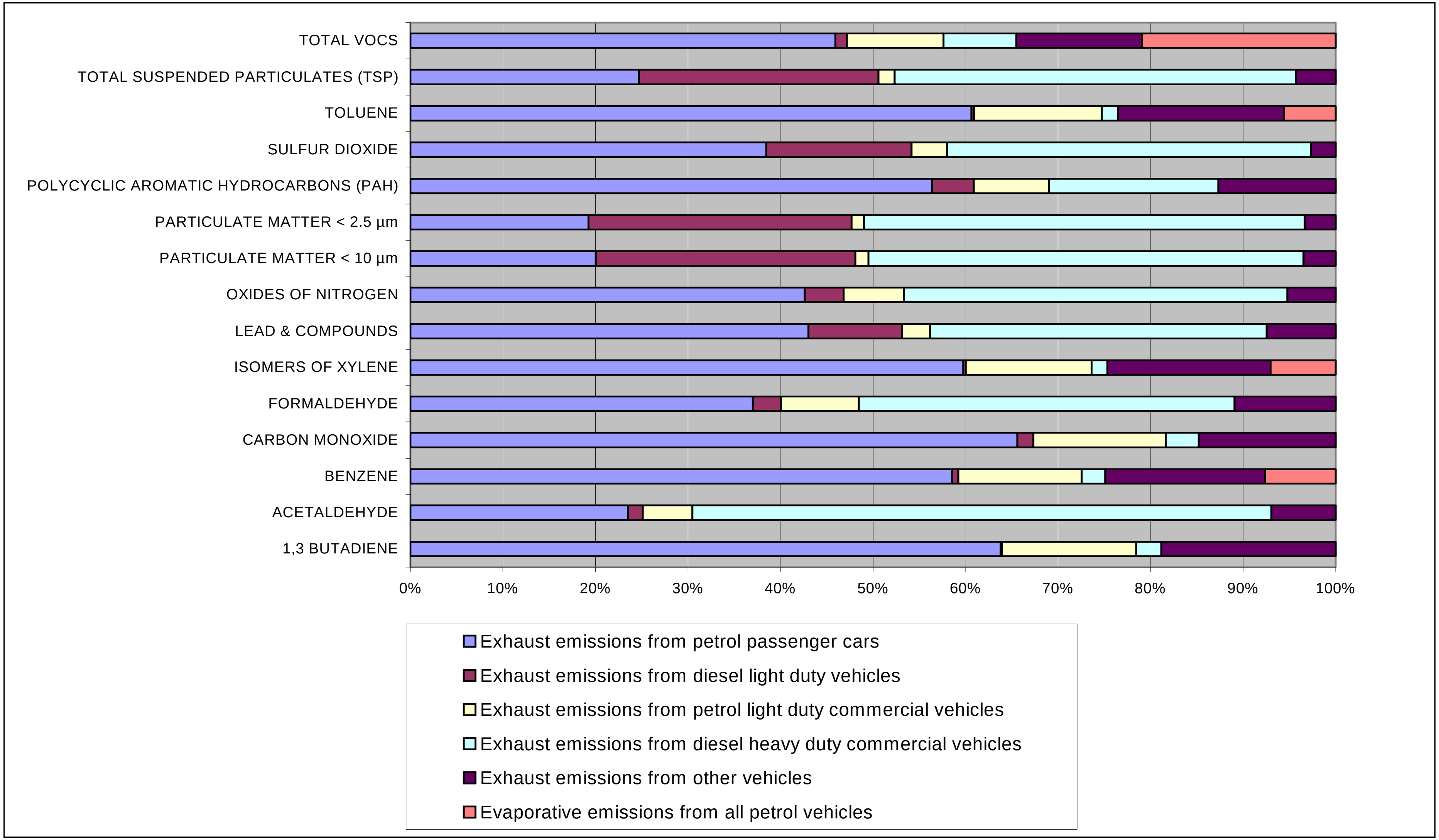

Figure 4.10: Proportion of total estimated annual emissions by on-road mobile source type in the Non-Urban region

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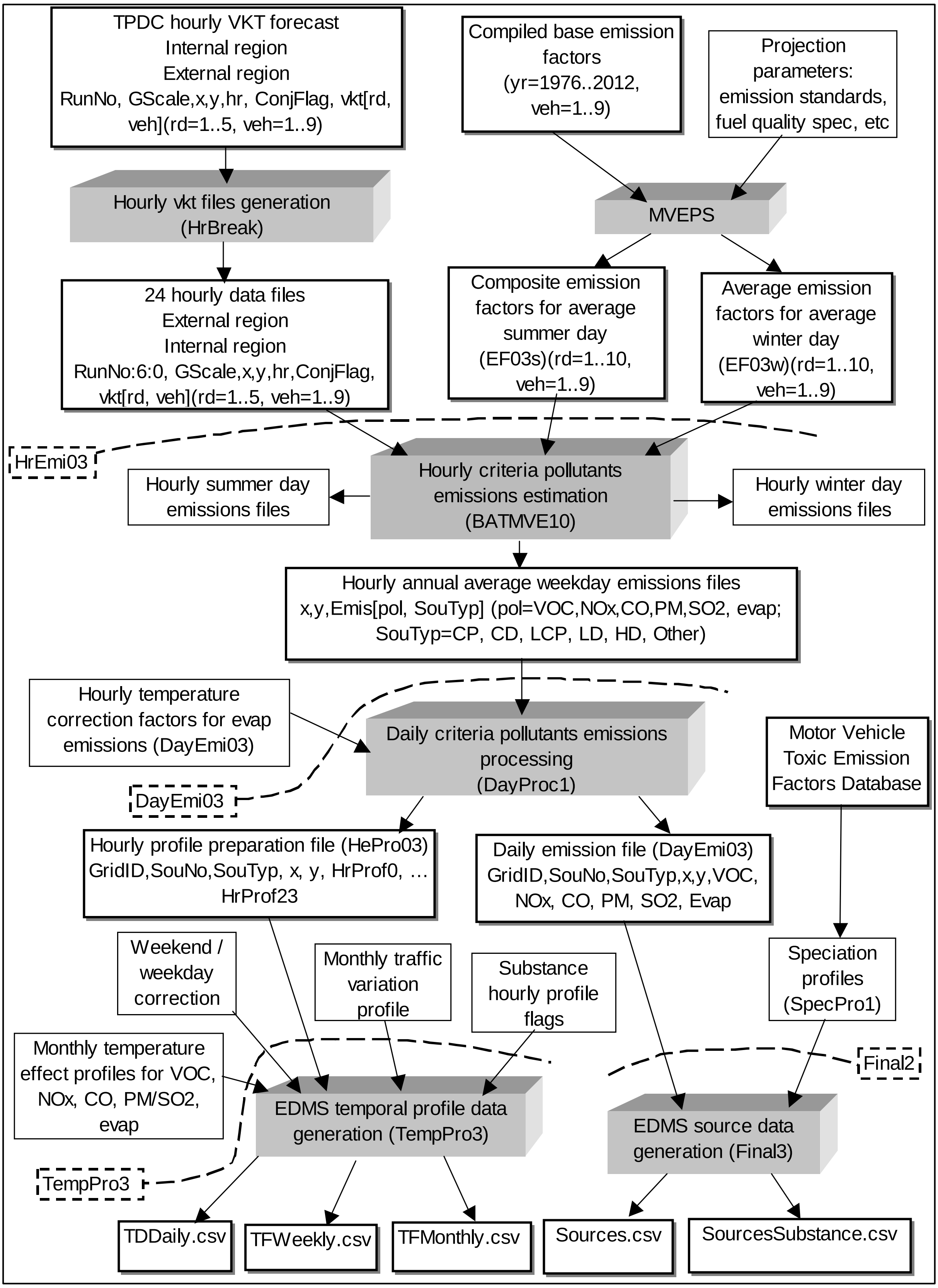
Appendix A: Flowchart for On-Road Mobile Data Generation



Appendix B: Future Emission Projections for GMR

Future year emissions are calculated using the same methodology as for the base year but with VKT forecasts for future years, as well as base emission factors developed for a future vehicle emission standards improvement scenario. As the emission scenario is largely based on assumptions about perceived future policy and technology development, a high level of uncertainty exists. Therefore the future emission projections presented here mirror current mandated vehicle emission and fuel standards.

B1. Major Assumptions for Future Emission Scenario

National current and future emission standards are given in Table B1. The future emission projections were developed on the basis of the following assumptions:

1. A quite recent drive cycle comparative study[1] has shown that for the emission test procedures of EURO II and EURO III, each will yield higher emission results than that using the test procedures of its predecessor's standards. This is interpreted as a progressive tightening in testing stringency and presumably this will achieve future reductions in in-service emissions, regardless of emission limits. It is assumed that this effect can be quantified by modification factors, which can be derived from available emission data.

2. It is assumed that in-service conformity checking measures incorporated in the original EURO III (and beyond) will not be effectively implemented under Australian conditions, implying that durability will remain unchecked at least under EURO II and III. The EURO III in-service conformity requirement has therefore no bearing on changing NO_x emission deterioration behaviour.

3. It is generally assumed that the emission levels of CO, VOC and NO_x for a new car are initially about 50% of the relevant emission limits under EURO II, and III standards.

4. The trend of steady improvement in CO emission deterioration performance as suggested by emission data is assumed to continue through EURO II (2004) and to EURO III (2006).

5. As existing data suggest that the decreasing trend in VOC emission deterioration rate is about to reach a plateau, it is assumed that the level of VOC emission deterioration under EURO II and III will not change dramatically, except for limited improvement already captured by Assumption 1 (tightening testing procedures).

6. Data show that in-service emission performance of NO_x has shown little improvement. As EURO II has no initiative to control in-service performance relative to pre-EURO standards, it is assumed that the level of NO_x emission deterioration under EURO II stays the same as the pre-EURO level, and under EURO III a small improvement was assumed and embodied by adjustment for changes in testing procedures (i.e. assumption 1).

7. There are no emission test data available for petrol light duty commercial vehicles. However, most of them are currently un-regulated for emissions, which leads to the assumption that the current emission levels of these vehicles are very high – close to the uncontrolled level of passenger cars. The adoption of EURO II (2004) will for the first time bring them under regulation. A significant reduction is therefore expected after EURO II comes into force. For NO_x, it is assumed that under EURO II new vehicle emission level is about 90% of the emission limit while keeping deterioration unchanged (Note that even under this assumption a big reduction will be achieved relative to the high pre-EURO level). Under EURO III, it is assumed that new vehicle level will be

[1] Cycle comparative study by Ford Australia as sponsored by the Federal Government for national emission standards review in 1998/99. Dataset of the study was provided by Jon Real of the then Federal Office of Road Safety.

50% of the limit, and deterioration will be half of that of EURO II. For CO and VOC under EURO II and III, the same assumptions as for NO_x are used.

8. For heavy duty commercial vehicles (mostly being diesel vehicles), emission deterioration is assumed to be insignificant and is thus not taken into account.

9. Emissions factors for diesel light duty vehicles in the current fleet were developed from DNEPM data (refer to Section 3.2.1). No deterioration is assumed due to limitation of the data.

10. As discussed previously, it is assumed that a significant proportion of imported diesel vehicles are certified under the current emission standards of the origin countries which are more stringent than Australian ones. Specifically, it is assumed that 50% of vehicles are EURO II compliant in 1997 and 20% of vehicles are already EURO III compliant in 2001. This assumption implies that the overall emission performance of heavy diesel fleet will be somewhat better than what is legally required.

11. For evaporative emissions, it is tentatively assumed at this stage there is no significant impact from changes in emission standards. This assumption tends to be quite conservative (i.e. having a tendency of overestimating evaporative emissions for the future years). EURO III does have a tighten-up of evaporative emission testing procedure e.g. 24-hr diurnal test replacing 1-hr diurnal test. However, it is very difficult to estimate the real effect of these procedural changes on emissions without emission test data.

12. As EURO IV for light duty vehicles (possibly in 2009/10) and EURO V for heavy duty vehicles (possibly in 2010/11) were not officially promulgated by the Federal Government as Australian standards when this inventory was developed, they have not been included in the projection.

Table B1. National emission standards

I	1978	ADR27 for light duty petrol vehicles (LDV)
	1986	ADR37/00 for light duty petrol vehicles
	1996	ADR70 for diesel vehicles
	1997–1999	ADR37/01 for light duty petrol vehicles
II	2002–03	ADR80/01 as EURO III for heavy duty vehicles with 500ppm diesel sulfur content
	2003–04	ADR79/01 as EURO II for light duty vehicles
	2005–06	ADR79/01 as EURO III for light duty vehicles
	2006–07	ADR80/01 as EURO IV for heavy duty vehicles wit 50ppm diesel sulfur content
III	2009–10 ?	Proposed adoption of EURO IV for light duty vehicles
	2010–11 ?	Proposed adoption of EURO V for heavy duty vehicles

B2. Results of Projection

Emission projections for VOC, NO_x, CO and PM_{10} are presented in Figures B1 to B4 as well as Tables B2 to B5, respectively.

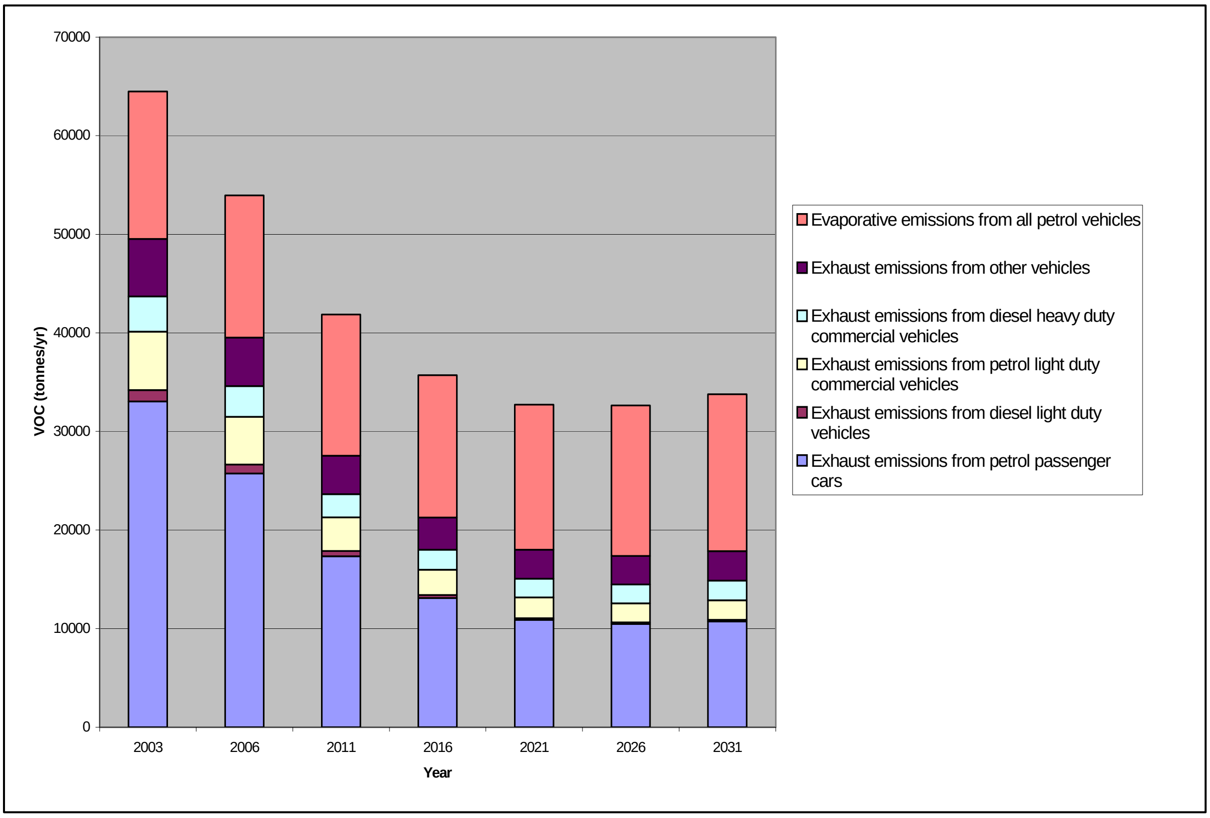


Figure B1. VOC emission projections for the GMR

Table B2. VOC emission projections (tonnes/yr) from different mobiles sources in the GMR

Year	Exhaust emissions - petrol passenger cars	Exhaust emissions - diesel light duty vehicles	Exhaust emissions - petrol light duty commercial vehicles	Exhaust emissions - diesel heavy duty commercial vehicles	Exhaust emissions - other vehicles	Evaporative emissions - all petrol vehicles	Total
2003	33062	1147	5916	3583	5829	14956	65216
2006	25739	913	4826	3119	4919	14438	54652
2011	17340	543	3413	2347	3895	14339	42569
2016	13113	303	2576	2013	3260	14453	36415
2021	10896	174	2093	1898	2940	14723	33436
2026	10481	136	1956	1906	2901	15253	33369
2031	10742	137	1984	2003	2999	15899	34531

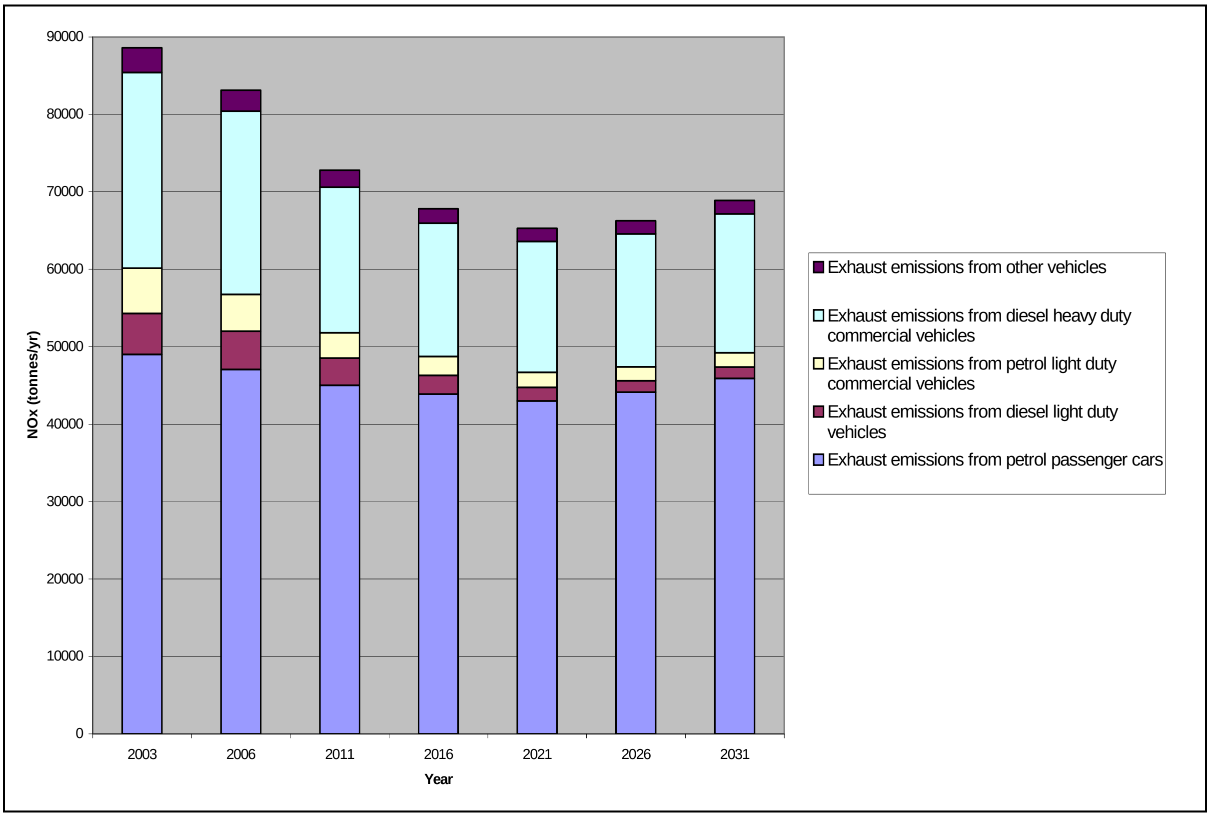


Figure B2. NO_x emission projections for the GMR

Table B3. NO_x emission projections (tonnes/yr) from different mobiles sources in the GMR

Year	Exhaust emissions - petrol passenger cars	Exhaust emissions - diesel light duty vehicles	Exhaust emissions - petrol light duty commercial vehicles	Exhaust emissions - diesel heavy duty commercial vehicles	Exhaust emissions - other vehicles	Total
2003	49011	5287	5851	25289	3171	88609
2006	47074	4939	4753	23659	2713	83138
2011	45019	3526	3271	18801	2195	72812
2016	43887	2428	2414	17233	1860	67822
2021	43010	1742	1939	16921	1693	65305
2026	44150	1455	1797	17190	1679	66271
2031	45921	1469	1817	17948	1740	68895

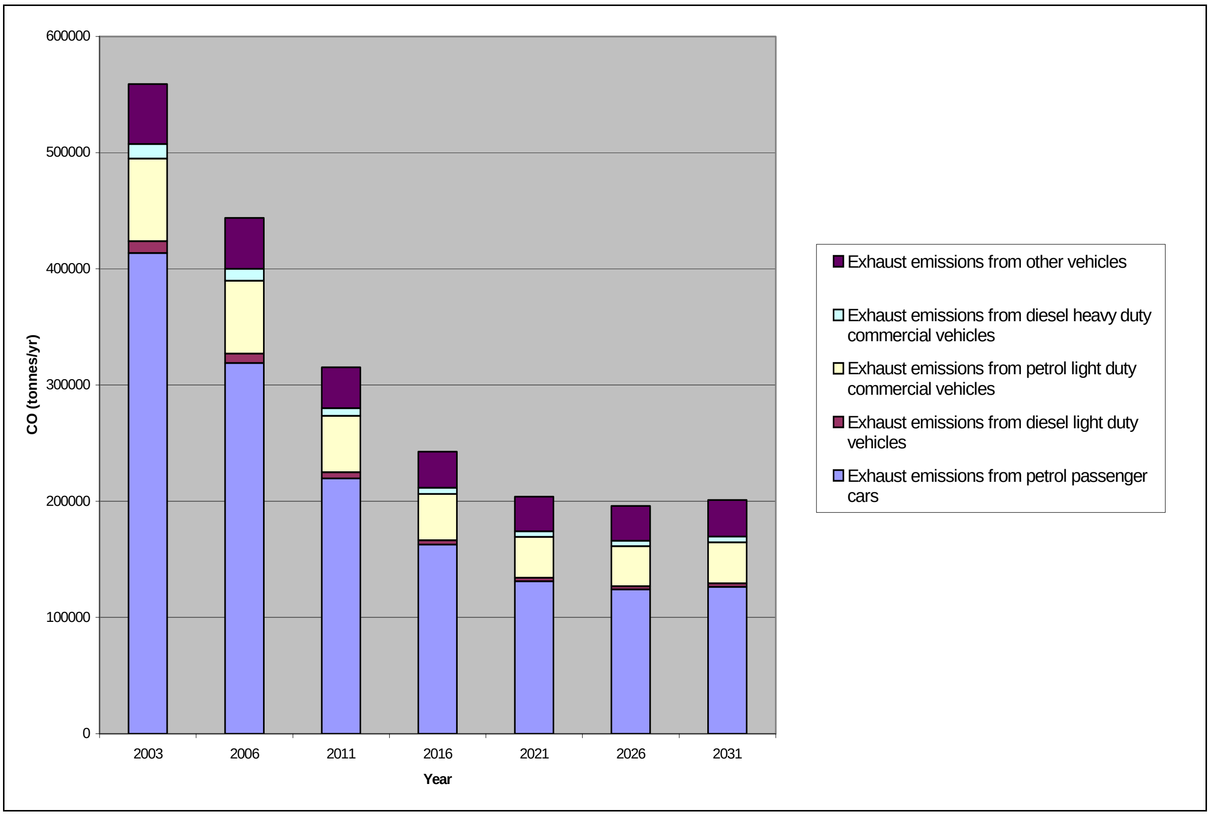


Figure B3. CO emission projections for the GMR

Table B4. CO emission projections (tonnes/yr) from different mobiles sources in the GMR

Year	Exhaust emissions - petrol passenger cars	Exhaust emissions - diesel light duty vehicles	Exhaust emissions - petrol light duty commercial vehicles	Exhaust emissions - diesel heavy duty commercial vehicles	Exhaust emissions - other vehicles	Total
2003	413721	10194	71129	12424	51579	559047
2006	318949	8217	62732	10182	43648	443728
2011	219639	5359	48645	6694	34951	315288
2016	162863	3713	39802	5308	31087	242774
2021	131276	2971	35252	4843	29693	204036
2026	124250	2838	34175	4800	30027	196090
2031	126479	2936	35204	4999	31340	200958

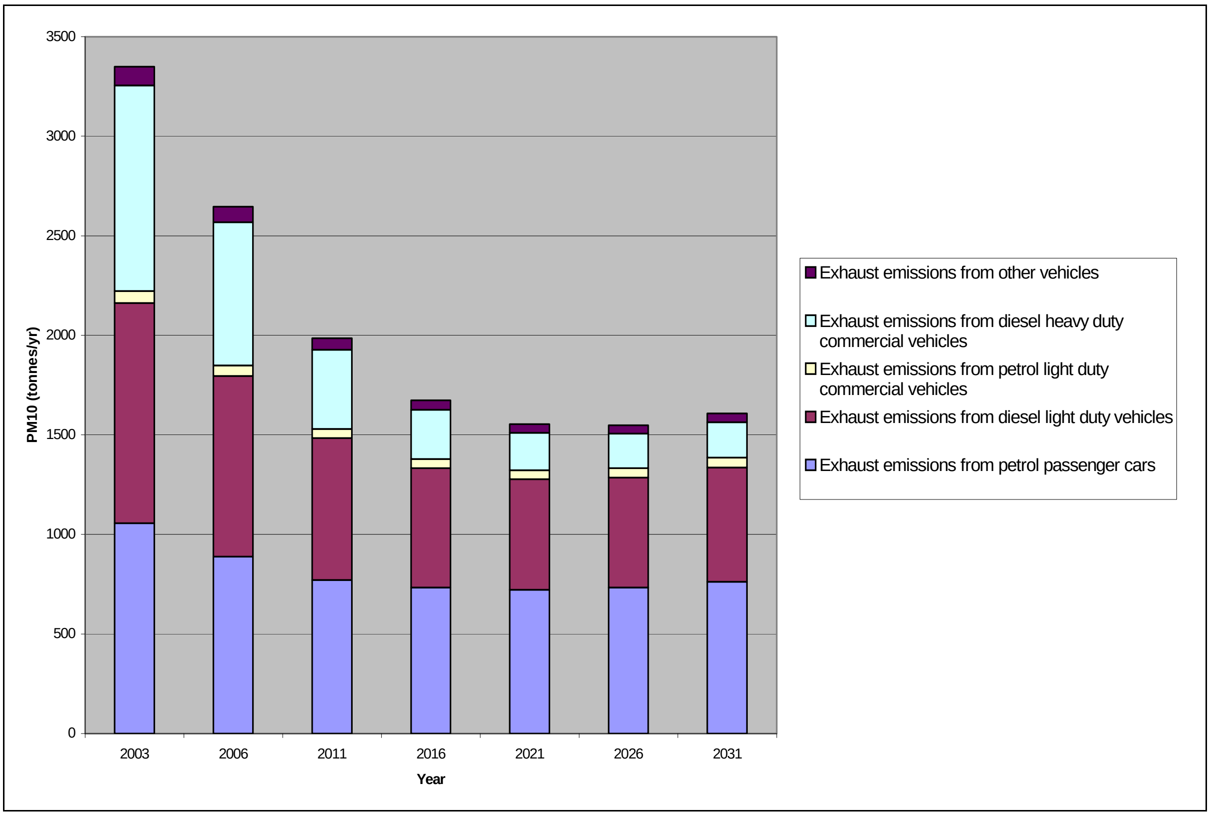


Figure B4. PM_{10} emission projections for the GMR

Table B5. PM_{10} emission projections (tonnes/yr) from different mobiles sources in the GMR

Year	Exhaust emissions - petrol passenger cars	Exhaust emissions - diesel light duty vehicles	Exhaust emissions - petrol light duty commercial vehicles	Exhaust emissions - diesel heavy duty commercial vehicles	Exhaust emissions - other vehicles	Total
2003	1056	1106	61	1033	93	3349
2006	889	907	53	720	78	2646
2011	771	713	46	397	59	1986
2016	733	600	45	248	48	1674
2021	723	554	45	189	43	1554
2026	733	553	47	173	43	1549
2031	763	574	49	177	44	1608

Appendix C: Total Annual Emissions for all Substances from On-Road Mobile Sources in GMR for 2003 (tonnes)

Substance ID	Substance name	Exhaust emissions – petrol passenger cars	Exhaust emissions – diesel light duty vehicles	Exhaust emissions – petrol light duty commercial vehicles	Exhaust emissions – diesel heavy duty commercial vehicles	Exhaust emissions – other vehicles	Evaporative emissions – all petrol vehicles	Total emissions
1	OXIDES OF NITROGEN	$4.90 \times 10^{+04}$	$5.29 \times 10^{+03}$	$5.85 \times 10^{+03}$	$2.53 \times 10^{+04}$	$3.17 \times 10^{+03}$	0	$8.86 \times 10^{+04}$
2	SULFUR DIOXIDE	$8.21 \times 10^{+02}$	$3.18 \times 10^{+02}$	$6.38 \times 10^{+01}$	$4.25 \times 10^{+02}$	$3.19 \times 10^{+01}$	0	$1.66 \times 10^{+03}$
3	LEAD	$8.18 \times 10^{+00}$	$1.44 \times 10^{+00}$	4.73×10^{-01}	$2.88 \times 10^{+00}$	7.23×10^{-01}	0	$1.37 \times 10^{+01}$
4	PARTICULATE MATTER ≤ 10 µm	$1.06 \times 10^{+03}$	$1.11 \times 10^{+03}$	$6.10 \times 10^{+01}$	$1.03 \times 10^{+03}$	$9.33 \times 10^{+01}$	0	$3.35 \times 10^{+03}$
5	PARTICULATE MATTER ≤ 2.5 µm	$9.72 \times 10^{+02}$	$1.07 \times 10^{+03}$	$5.61 \times 10^{+01}$	$1.00 \times 10^{+03}$	$8.58 \times 10^{+01}$	0	$3.19 \times 10^{+03}$
8	ARSENIC	0	1.84×10^{-02}	0	0	0	0	1.84×10^{-02}
11	BORON	0	0	0	$1.34 \times 10^{+00}$	0	0	$1.34 \times 10^{+00}$
12	CALCIUM	$2.61 \times 10^{+00}$	8.18×10^{-01}	1.51×10^{-01}	$1.82 \times 10^{+00}$	2.31×10^{-01}	0	$5.64 \times 10^{+00}$
13	CHLORINE	$1.84 \times 10^{+01}$	$1.71 \times 10^{+01}$	$1.06 \times 10^{+00}$	$1.58 \times 10^{+01}$	$1.62 \times 10^{+00}$	0	$5.40 \times 10^{+01}$
16	CHROMIUM	6.69×10^{-02}	1.84×10^{-02}	3.87×10^{-03}	4.54×10^{-02}	5.91×10^{-03}	0	1.41×10^{-01}
19	COPPER	1.45×10^{-01}	3.32×10^{-02}	8.39×10^{-03}	7.06×10^{-02}	1.28×10^{-02}	0	2.70×10^{-01}
27	MANGANESE	9.51×10^{-02}	7.13×10^{-01}	5.49×10^{-03}	1.24×10^{-01}	8.40×10^{-03}	0	9.46×10^{-01}
28	MERCURY	2.11×10^{-02}	7.37×10^{-03}	1.22×10^{-03}	2.07×10^{-02}	1.87×10^{-03}	0	5.22×10^{-02}
30	NICKEL	5.55×10^{-02}	1.11×10^{-02}	3.20×10^{-03}	2.24×10^{-02}	4.90×10^{-03}	0	9.70×10^{-02}
36	DIOXINS & FURANS	3.78×10^{-06}	5.98×10^{-06}	2.18×10^{-07}	7.48×10^{-06}	3.34×10^{-07}	0	1.78×10^{-05}
37	TOTAL PAH	$1.49 \times 10^{+02}$	$1.16 \times 10^{+01}$	$1.53 \times 10^{+01}$	$2.59 \times 10^{+01}$	$1.79 \times 10^{+01}$	0	$2.20 \times 10^{+02}$
38	SELENIUM	1.41×10^{-02}	1.84×10^{-02}	8.14×10^{-04}	3.10×10^{-02}	1.24×10^{-03}	0	6.56×10^{-02}
40	VOLATILE ORGANIC COMPOUNDS	$3.31 \times 10^{+04}$	$1.15 \times 10^{+03}$	$5.92 \times 10^{+03}$	$3.58 \times 10^{+03}$	$5.83 \times 10^{+03}$	$1.50 \times 10^{+04}$	$6.45 \times 10^{+04}$
41	ZINC	$1.25 \times 10^{+01}$	$1.17 \times 10^{+01}$	7.23×10^{-01}	$1.11 \times 10^{+01}$	$1.10 \times 10^{+00}$	0	$3.71 \times 10^{+01}$
42	NITROGEN DIOXIDE	$2.45 \times 10^{+03}$	$2.64 \times 10^{+02}$	$2.93 \times 10^{+02}$	$1.26 \times 10^{+03}$	$1.59 \times 10^{+02}$	0	$4.43 \times 10^{+03}$
43	NITRIC OXIDE	$3.04 \times 10^{+04}$	$3.28 \times 10^{+03}$	$3.63 \times 10^{+03}$	$1.57 \times 10^{+04}$	$1.96 \times 10^{+03}$	0	$5.49 \times 10^{+04}$
45	VANADIUM	7.39×10^{-02}	2.95×10^{-02}	4.27×10^{-03}	2.27×10^{-02}	6.53×10^{-03}	0	1.37×10^{-01}
46	TOTAL SUSPENDED PARTICULATE	$1.43 \times 10^{+03}$	$1.12 \times 10^{+03}$	$8.24 \times 10^{+01}$	$1.04 \times 10^{+03}$	$1.26 \times 10^{+02}$	0	$3.79 \times 10^{+03}$

Substance ID	Substance name	Exhaust emissions – petrol passenger cars	Exhaust emissions – diesel light duty vehicles	Exhaust emissions – petrol light duty commercial vehicles	Exhaust emissions – diesel heavy duty commercial vehicles	Exhaust emissions – other vehicles	Evaporative emissions – all petrol vehicles	Total emissions
47	METHANE	$2.54 \times 10^{+03}$	0	$4.55 \times 10^{+02}$	0	$4.48 \times 10^{+02}$	0	$3.44 \times 10^{+03}$
48	CARBON MONOXIDE	$4.14 \times 10^{+05}$	$1.02 \times 10^{+04}$	$7.11 \times 10^{+04}$	$1.24 \times 10^{+04}$	$5.16 \times 10^{+04}$	0	$5.59 \times 10^{+05}$
49	FORMALDEHYDE	$4.32 \times 10^{+02}$	$4.49 \times 10^{+01}$	$7.73 \times 10^{+01}$	$3.00 \times 10^{+02}$	$7.61 \times 10^{+01}$	0	$9.30 \times 10^{+02}$
51	METHYL ALCOHOL	0	0	0	0	0	$1.04 \times 10^{+02}$	$1.04 \times 10^{+02}$
83	ACETYLENE	$7.65 \times 10^{+02}$	$2.85 \times 10^{+01}$	$1.37 \times 10^{+02}$	$8.92 \times 10^{+01}$	$1.35 \times 10^{+02}$	$3.38 \times 10^{+01}$	$1.19 \times 10^{+03}$
84	ETHYLENE	$2.54 \times 10^{+03}$	$5.31 \times 10^{+01}$	$4.54 \times 10^{+02}$	$1.66 \times 10^{+02}$	$4.47 \times 10^{+02}$	$9.04 \times 10^{+01}$	$3.75 \times 10^{+03}$
85	ETHANE	$7.42 \times 10^{+02}$	0	$1.33 \times 10^{+02}$	0	$1.31 \times 10^{+02}$	$4.47 \times 10^{+01}$	$1.05 \times 10^{+03}$
88	ACETALDEHYDE	$2.62 \times 10^{+02}$	$2.32 \times 10^{+01}$	$4.68 \times 10^{+01}$	$4.41 \times 10^{+02}$	$4.61 \times 10^{+01}$	0	$8.19 \times 10^{+02}$
91	ETHYL ALCOHOL	$1.04 \times 10^{+03}$	0	$1.86 \times 10^{+02}$	0	$1.83 \times 10^{+02}$	$2.68 \times 10^{+03}$	$4.09 \times 10^{+03}$
141	1-PROPYNE	$1.48 \times 10^{+01}$	0	$2.65 \times 10^{+00}$	0	$2.61 \times 10^{+00}$	0	$2.01 \times 10^{+01}$
142	1,2-PROPADIENE	$2.59 \times 10^{+01}$	0	$4.64 \times 10^{+00}$	0	$4.57 \times 10^{+00}$	0	$3.51 \times 10^{+01}$
144	PROPYLENE	$1.01 \times 10^{+03}$	$4.84 \times 10^{+00}$	$1.81 \times 10^{+02}$	$1.51 \times 10^{+01}$	$1.78 \times 10^{+02}$	$3.73 \times 10^{+01}$	$1.43 \times 10^{+03}$
145	PROPANE	$6.04 \times 10^{+01}$	0	$1.08 \times 10^{+01}$	0	$1.06 \times 10^{+01}$	$2.16 \times 10^{+02}$	$2.97 \times 10^{+02}$
147	ACROLEIN	$6.58 \times 10^{+01}$	$1.15 \times 10^{+01}$	$1.18 \times 10^{+01}$	$3.61 \times 10^{+01}$	$1.16 \times 10^{+01}$	0	$1.37 \times 10^{+02}$
148	ACETONE	$1.70 \times 10^{+02}$	0	$3.05 \times 10^{+01}$	0	$3.00 \times 10^{+01}$	0	$2.31 \times 10^{+02}$
151	PROPIONALDEHYDE	$2.22 \times 10^{+01}$	0	$3.98 \times 10^{+00}$	0	$3.92 \times 10^{+00}$	0	$3.01 \times 10^{+01}$
201	1,3-BUTADIENE	$1.85 \times 10^{+02}$	4.73×10^{-01}	$3.31 \times 10^{+01}$	$4.96 \times 10^{+00}$	$3.26 \times 10^{+01}$	0	$2.56 \times 10^{+02}$
203	2-BUTYNE	$3.33 \times 10^{+01}$	0	$5.96 \times 10^{+00}$	0	$5.87 \times 10^{+00}$	0	$4.52 \times 10^{+01}$
207	1-BUTENE	$9.02 \times 10^{+02}$	0	$1.61 \times 10^{+02}$	0	$1.59 \times 10^{+02}$	$1.52 \times 10^{+02}$	$1.38 \times 10^{+03}$
209	CIS-2-BUTENE	$1.59 \times 10^{+02}$	0	$2.85 \times 10^{+01}$	0	$2.81 \times 10^{+01}$	$1.34 \times 10^{+02}$	$3.50 \times 10^{+02}$
210	TRANS-2-BUTENE	$1.83 \times 10^{+02}$	$3.23 \times 10^{+00}$	$3.27 \times 10^{+01}$	$1.01 \times 10^{+01}$	$3.22 \times 10^{+01}$	$2.74 \times 10^{+02}$	$5.35 \times 10^{+02}$
211	N-BUTANE	$9.20 \times 10^{+02}$	$2.38 \times 10^{+01}$	$1.65 \times 10^{+02}$	$7.43 \times 10^{+01}$	$1.62 \times 10^{+02}$	$2.52 \times 10^{+03}$	$3.86 \times 10^{+03}$
212	ISOBUTANE	$4.23 \times 10^{+02}$	0	$7.57 \times 10^{+01}$	0	$7.46 \times 10^{+01}$	$8.42 \times 10^{+02}$	$1.42 \times 10^{+03}$
219	CROTONALDEHYDE	$1.48 \times 10^{+01}$	0	$2.65 \times 10^{+00}$	0	$2.61 \times 10^{+00}$	0	$2.01 \times 10^{+01}$
224	BUTYRALDEHYDE	$2.59 \times 10^{+01}$	$8.07 \times 10^{+00}$	$4.64 \times 10^{+00}$	$2.52 \times 10^{+01}$	$4.57 \times 10^{+00}$	0	$6.84 \times 10^{+01}$

Substance ID	Substance name	Exhaust emissions – petrol passenger cars	Exhaust emissions – diesel light duty vehicles	Exhaust emissions – petrol light duty commercial vehicles	Exhaust emissions – diesel heavy duty commercial vehicles	Exhaust emissions – other vehicles	Evaporative emissions – all petrol vehicles	Total emissions
287	ISOPRENE	$7.03 \times 10^{+01}$	0	$1.26 \times 10^{+01}$	0	$1.24 \times 10^{+01}$	$5.19 \times 10^{+01}$	$1.47 \times 10^{+02}$
288	CYCLOPENTENE	$3.70 \times 10^{+00}$	$1.30 \times 10^{+00}$	6.63×10^{-01}	$4.07 \times 10^{+00}$	6.53×10^{-01}	$4.27 \times 10^{+01}$	$5.31 \times 10^{+01}$
292	CYCLOPENTANE	$1.26 \times 10^{+02}$	0	$2.25 \times 10^{+01}$	0	$2.22 \times 10^{+01}$	$5.07 \times 10^{+01}$	$2.21 \times 10^{+02}$
293	1-PENTENE	$1.28 \times 10^{+02}$	0	$2.29 \times 10^{+01}$	0	$2.26 \times 10^{+01}$	$9.62 \times 10^{+01}$	$2.70 \times 10^{+02}$
294	3-METHYL-1-BUTENE	$1.85 \times 10^{+01}$	9.93×10^{-01}	$3.31 \times 10^{+00}$	$3.10 \times 10^{+00}$	$3.26 \times 10^{+00}$	$1.26 \times 10^{+01}$	$4.17 \times 10^{+01}$
295	2-METHYL-2-BUTENE	$2.37 \times 10^{+02}$	0	$4.24 \times 10^{+01}$	0	$4.18 \times 10^{+01}$	$3.30 \times 10^{+02}$	$6.51 \times 10^{+02}$
296	2-METHYL-1-BUTENE	$7.40 \times 10^{+01}$	0	$1.33 \times 10^{+01}$	0	$1.31 \times 10^{+01}$	$1.57 \times 10^{+02}$	$2.58 \times 10^{+02}$
297	CIS-2-PENTENE	$9.03 \times 10^{+01}$	0	$1.62 \times 10^{+01}$	0	$1.59 \times 10^{+01}$	$1.04 \times 10^{+02}$	$2.26 \times 10^{+02}$
298	TRANS-2-PENTENE	$1.45 \times 10^{+02}$	0	$2.59 \times 10^{+01}$	0	$2.55 \times 10^{+01}$	$1.91 \times 10^{+02}$	$3.87 \times 10^{+02}$
299	2,2-DIMETHYLPROPANE	$3.70 \times 10^{+00}$	0	6.63×10^{-01}	0	6.53×10^{-01}	$8.37 \times 10^{+00}$	$1.34 \times 10^{+01}$
300	N-PENTANE	$9.26 \times 10^{+02}$	$1.15 \times 10^{+01}$	$1.66 \times 10^{+02}$	$3.61 \times 10^{+01}$	$1.63 \times 10^{+02}$	$7.04 \times 10^{+02}$	$2.01 \times 10^{+03}$
301	2-METHYL-BUTANE	$2.53 \times 10^{+03}$	$1.61 \times 10^{+00}$	$4.52 \times 10^{+02}$	$5.04 \times 10^{+00}$	$4.46 \times 10^{+02}$	$2.23 \times 10^{+03}$	$5.66 \times 10^{+03}$
356	BENZENE	$1.54 \times 10^{+03}$	$2.25 \times 10^{+01}$	$2.76 \times 10^{+02}$	$4.26 \times 10^{+01}$	$2.72 \times 10^{+02}$	$1.99 \times 10^{+02}$	$2.36 \times 10^{+03}$
359	CYCLOHEXENE	$3.70 \times 10^{+00}$	0	6.63×10^{-01}	0	6.53×10^{-01}	$7.54 \times 10^{+01}$	$8.04 \times 10^{+01}$
360	1-METHYLCYCLOPENTENE	$8.15 \times 10^{+01}$	0	$1.46 \times 10^{+01}$	0	$1.44 \times 10^{+01}$	$4.19 \times 10^{+01}$	$1.52 \times 10^{+02}$
368	METHYLCYCLOPENTANE	$4.10 \times 10^{+02}$	$3.85 \times 10^{+00}$	$7.34 \times 10^{+01}$	$1.20 \times 10^{+01}$	$7.23 \times 10^{+01}$	$9.12 \times 10^{+01}$	$6.63 \times 10^{+02}$
369	CYCLOHEXANE	$1.11 \times 10^{+02}$	$1.30 \times 10^{+00}$	$1.99 \times 10^{+01}$	$4.07 \times 10^{+00}$	$1.96 \times 10^{+01}$	$2.65 \times 10^{+01}$	$1.82 \times 10^{+02}$
371	1-HEXENE	$5.77 \times 10^{+01}$	0	$1.03 \times 10^{+01}$	0	$1.02 \times 10^{+01}$	$4.01 \times 10^{+01}$	$1.18 \times 10^{+02}$
372	4-METHYL-1-PENTENE	$1.85 \times 10^{+01}$	0	$3.31 \times 10^{+00}$	0	$3.26 \times 10^{+00}$	$1.67 \times 10^{+01}$	$4.18 \times 10^{+01}$
373	3-METHYL-1-PENTENE	$7.40 \times 10^{+00}$	0	$1.33 \times 10^{+00}$	0	$1.31 \times 10^{+00}$	0	$1.00 \times 10^{+01}$
374	TRANS-3-HEXENE	$3.70 \times 10^{+00}$	0	6.63×10^{-01}	0	6.53×10^{-01}	$2.51 \times 10^{+01}$	$3.01 \times 10^{+01}$
375	TRANS-2-HEXENE	$3.70 \times 10^{+00}$	9.93×10^{-01}	6.63×10^{-01}	$3.10 \times 10^{+00}$	6.53×10^{-01}	$5.02 \times 10^{+01}$	$5.94 \times 10^{+01}$
379	2-METHYL-2-PENTENE	$3.70 \times 10^{+00}$	$1.30 \times 10^{+00}$	6.63×10^{-01}	$4.07 \times 10^{+00}$	6.53×10^{-01}	$3.52 \times 10^{+01}$	$4.56 \times 10^{+01}$
383	2-METHYL-1-PENTENE	$5.00 \times 10^{+01}$	0	$8.94 \times 10^{+00}$	0	$8.81 \times 10^{+00}$	$8.37 \times 10^{+01}$	$1.51 \times 10^{+02}$
385	CIS-2-HEXENE	$1.85 \times 10^{+01}$	6.20×10^{-01}	$3.31 \times 10^{+00}$	$1.94 \times 10^{+00}$	$3.26 \times 10^{+00}$	$3.01 \times 10^{+01}$	$5.78 \times 10^{+01}$

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387	2,2-DIMETHYLBUTANE	$1.66 \times 10^{+02}$	$1.92 \times 10^{+00}$	$2.96 \times 10^{+01}$	$6.01 \times 10^{+00}$	$2.92 \times 10^{+01}$	$2.26 \times 10^{+02}$	$4.58 \times 10^{+02}$
388	2-METHYLPENTANE	$1.04 \times 10^{+03}$	$5.77 \times 10^{+00}$	$1.85 \times 10^{+02}$	$1.80 \times 10^{+01}$	$1.83 \times 10^{+02}$	$4.23 \times 10^{+02}$	$1.85 \times 10^{+03}$
389	N-HEXANE	$5.07 \times 10^{+02}$	0	$9.08 \times 10^{+01}$	0	$8.94 \times 10^{+01}$	$2.01 \times 10^{+02}$	$8.89 \times 10^{+02}$
390	2,3-DIMETHYLBUTANE	$3.57 \times 10^{+02}$	$3.54 \times 10^{+00}$	$6.39 \times 10^{+01}$	$1.11 \times 10^{+01}$	$6.29 \times 10^{+01}$	$2.75 \times 10^{+02}$	$7.73 \times 10^{+02}$
391	3-METHYLPENTANE	$6.13 \times 10^{+02}$	$4.16 \times 10^{+00}$	$1.10 \times 10^{+02}$	$1.30 \times 10^{+01}$	$1.08 \times 10^{+02}$	$3.26 \times 10^{+02}$	$1.17 \times 10^{+03}$
482	TOLUENE	$2.71 \times 10^{+03}$	$9.98 \times 10^{+00}$	$4.85 \times 10^{+02}$	$5.02 \times 10^{+01}$	$4.78 \times 10^{+02}$	$5.23 \times 10^{+02}$	$4.26 \times 10^{+03}$
493	METHYLCYCLOHEXANE	$1.81 \times 10^{+02}$	$3.23 \times 10^{+00}$	$3.25 \times 10^{+01}$	$1.01 \times 10^{+01}$	$3.20 \times 10^{+01}$	$3.35 \times 10^{+01}$	$2.93 \times 10^{+02}$
496	ETHYLCYCLOPENTANE	$4.07 \times 10^{+01}$	0	$7.29 \times 10^{+00}$	0	$7.18 \times 10^{+00}$	0	$5.52 \times 10^{+01}$
509	1-HEPTENE	$3.70 \times 10^{+00}$	0	6.63×10^{-01}	0	6.53×10^{-01}	$4.19 \times 10^{+00}$	$9.20 \times 10^{+00}$
535	3,3-DIMETHYLPENTANE	0	0	0	0	0	$5.02 \times 10^{+00}$	$5.02 \times 10^{+00}$
537	2,4-DIMETHYLPENTANE	$2.78 \times 10^{+02}$	0	$4.97 \times 10^{+01}$	0	$4.90 \times 10^{+01}$	$9.73 \times 10^{+01}$	$4.74 \times 10^{+02}$
540	N-HEPTANE	$2.64 \times 10^{+02}$	$2.92 \times 10^{+00}$	$4.73 \times 10^{+01}$	$9.11 \times 10^{+00}$	$4.66 \times 10^{+01}$	$6.96 \times 10^{+01}$	$4.40 \times 10^{+02}$
541	2,3-DIMETHYLPENTANE	$3.85 \times 10^{+02}$	$2.54 \times 10^{+00}$	$6.89 \times 10^{+01}$	$7.95 \times 10^{+00}$	$6.79 \times 10^{+01}$	$1.44 \times 10^{+02}$	$6.76 \times 10^{+02}$
542	3-METHYLHEXANE	$3.87 \times 10^{+02}$	$1.92 \times 10^{+00}$	$6.92 \times 10^{+01}$	$6.01 \times 10^{+00}$	$6.81 \times 10^{+01}$	$8.03 \times 10^{+01}$	$6.12 \times 10^{+02}$
543	2-METHYLHEXANE	$3.57 \times 10^{+02}$	$3.54 \times 10^{+00}$	$6.39 \times 10^{+01}$	$1.11 \times 10^{+01}$	$6.30 \times 10^{+01}$	$9.55 \times 10^{+01}$	$5.94 \times 10^{+02}$
544	BENZALDEHYDE	$4.07 \times 10^{+01}$	0	$7.29 \times 10^{+00}$	0	$7.18 \times 10^{+00}$	0	$5.52 \times 10^{+01}$
593	STYRENE	$1.26 \times 10^{+02}$	0	$2.25 \times 10^{+01}$	0	$2.22 \times 10^{+01}$	$5.34 \times 10^{+00}$	$1.76 \times 10^{+02}$
594	ETHYLBENZENE	$4.81 \times 10^{+02}$	$2.92 \times 10^{+00}$	$8.60 \times 10^{+01}$	$9.11 \times 10^{+00}$	$8.48 \times 10^{+01}$	$1.03 \times 10^{+02}$	$7.67 \times 10^{+02}$
596	M-XYLENE	$1.66 \times 10^{+03}$	$9.94 \times 10^{+00}$	$2.98 \times 10^{+02}$	$3.11 \times 10^{+01}$	$2.93 \times 10^{+02}$	$1.52 \times 10^{+02}$	$2.45 \times 10^{+03}$
597	O-XYLENE	$6.40 \times 10^{+02}$	$3.54 \times 10^{+00}$	$1.14 \times 10^{+02}$	$1.11 \times 10^{+01}$	$1.13 \times 10^{+02}$	$1.17 \times 10^{+02}$	$9.98 \times 10^{+02}$
617	ETHYLCYCLOHEXANE	0	0	0	0	0	$1.67 \times 10^{+00}$	$1.67 \times 10^{+00}$
641	2,4,4-TRIMETHYL-1-PENTENE	$9.63 \times 10^{+01}$	0	$1.72 \times 10^{+01}$	0	$1.70 \times 10^{+01}$	$7.54 \times 10^{+00}$	$1.38 \times 10^{+02}$
659	2,2,4-TRIMETHYLPENTANE	$9.59 \times 10^{+02}$	$7.69 \times 10^{+00}$	$1.72 \times 10^{+02}$	$2.40 \times 10^{+01}$	$1.69 \times 10^{+02}$	$2.29 \times 10^{+02}$	$1.56 \times 10^{+03}$
660	2,2-DIMETHYLHEXANE	$5.92 \times 10^{+01}$	0	$1.06 \times 10^{+01}$	0	$1.04 \times 10^{+01}$	$4.19 \times 10^{+00}$	$8.45 \times 10^{+01}$
662	N-OCTANE	$1.20 \times 10^{+02}$	$1.61 \times 10^{+00}$	$2.14 \times 10^{+01}$	$5.04 \times 10^{+00}$	$2.11 \times 10^{+01}$	$2.73 \times 10^{+01}$	$1.96 \times 10^{+02}$

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667	2,3,4-TRIMETHYLPENTANE	$3.59 \times 10^{+02}$	$1.92 \times 10^{+00}$	$6.43 \times 10^{+01}$	$6.01 \times 10^{+00}$	$6.33 \times 10^{+01}$	$1.20 \times 10^{+02}$	$6.15 \times 10^{+02}$
669	2,3-DIMETHYLHEXANE	$1.81 \times 10^{+02}$	9.93×10^{-01}	$3.25 \times 10^{+01}$	$3.10 \times 10^{+00}$	$3.20 \times 10^{+01}$	$1.59 \times 10^{+01}$	$2.66 \times 10^{+02}$
670	2,4-DIMETHYLHEXANE	$2.55 \times 10^{+02}$	3.11×10^{-01}	$4.57 \times 10^{+01}$	9.71×10^{-01}	$4.50 \times 10^{+01}$	$2.26 \times 10^{+01}$	$3.70 \times 10^{+02}$
671	4-METHYLHEPTANE	$5.55 \times 10^{+01}$	0	$9.94 \times 10^{+00}$	0	$9.79 \times 10^{+00}$	$1.00 \times 10^{+01}$	$8.53 \times 10^{+01}$
672	3-METHYLHEPTANE	$2.04 \times 10^{+02}$	0	$3.64 \times 10^{+01}$	0	$3.59 \times 10^{+01}$	$6.62 \times 10^{+01}$	$3.42 \times 10^{+02}$
673	2,5-DIMETHYLHEXANE	$1.44 \times 10^{+02}$	3.11×10^{-01}	$2.58 \times 10^{+01}$	9.71×10^{-01}	$2.55 \times 10^{+01}$	$1.09 \times 10^{+01}$	$2.08 \times 10^{+02}$
674	2-METHYLHEPTANE	$1.88 \times 10^{+02}$	6.20×10^{-01}	$3.36 \times 10^{+01}$	$1.94 \times 10^{+00}$	$3.31 \times 10^{+01}$	$6.07 \times 10^{+01}$	$3.17 \times 10^{+02}$
740	INDAN	$4.81 \times 10^{+01}$	0	$8.61 \times 10^{+00}$	0	$8.49 \times 10^{+00}$	$5.02 \times 10^{+00}$	$7.03 \times 10^{+01}$
743	N-PROPYLBENZENE	$1.27 \times 10^{+02}$	6.20×10^{-01}	$2.27 \times 10^{+01}$	$1.94 \times 10^{+00}$	$2.24 \times 10^{+01}$	$2.32 \times 10^{+01}$	$1.98 \times 10^{+02}$
745	1,3,5-TRIMETHYLBENZENE	$2.42 \times 10^{+02}$	$1.61 \times 10^{+00}$	$4.34 \times 10^{+01}$	$5.04 \times 10^{+00}$	$4.27 \times 10^{+01}$	$3.21 \times 10^{+01}$	$3.67 \times 10^{+02}$
746	1,2,3-TRIMETHYLBENZENE	$2.36 \times 10^{+02}$	0	$4.22 \times 10^{+01}$	0	$4.16 \times 10^{+01}$	$1.88 \times 10^{+01}$	$3.38 \times 10^{+02}$
747	O-ETHYLTOLUENE	$1.81 \times 10^{+02}$	0	$3.25 \times 10^{+01}$	0	$3.20 \times 10^{+01}$	$1.78 \times 10^{+01}$	$2.64 \times 10^{+02}$
748	M-ETHYLTOLUENE	$5.21 \times 10^{+02}$	0	$9.32 \times 10^{+01}$	0	$9.19 \times 10^{+01}$	$6.84 \times 10^{+01}$	$7.75 \times 10^{+02}$
749	P-ETHYLTOLUENE	$2.63 \times 10^{+02}$	0	$4.70 \times 10^{+01}$	0	$4.63 \times 10^{+01}$	$6.11 \times 10^{+01}$	$4.17 \times 10^{+02}$
750	1,2,4-TRIMETHYLBENZENE	$7.41 \times 10^{+02}$	0	$1.33 \times 10^{+02}$	0	$1.31 \times 10^{+02}$	$8.60 \times 10^{+01}$	$1.09 \times 10^{+03}$
794	1-NONENE	$1.67 \times 10^{+02}$	0	$2.98 \times 10^{+01}$	0	$2.94 \times 10^{+01}$	$3.35 \times 10^{+00}$	$2.29 \times 10^{+02}$
811	2,2,5-TRIMETHYLHEXANE	$1.74 \times 10^{+02}$	0	$3.11 \times 10^{+01}$	0	$3.07 \times 10^{+01}$	$1.09 \times 10^{+01}$	$2.47 \times 10^{+02}$
814	2,3,5-TRIMETHYLHEXANE	$3.33 \times 10^{+01}$	0	$5.96 \times 10^{+00}$	0	$5.87 \times 10^{+00}$	$2.51 \times 10^{+00}$	$4.77 \times 10^{+01}$
817	N-NONANE	$4.45 \times 10^{+01}$	9.93×10^{-01}	$7.97 \times 10^{+00}$	$3.10 \times 10^{+00}$	$7.85 \times 10^{+00}$	$9.10 \times 10^{+00}$	$7.36 \times 10^{+01}$
824	2,4-DIMETHYLHEPTANE	$3.70 \times 10^{+00}$	0	6.63×10^{-01}	0	6.53×10^{-01}	$1.67 \times 10^{+00}$	$6.69 \times 10^{+00}$
827	3-METHYLOCTANE	$3.33 \times 10^{+01}$	0	$5.96 \times 10^{+00}$	0	$5.87 \times 10^{+00}$	$4.19 \times 10^{+00}$	$4.93 \times 10^{+01}$
828	4-METHYLOCTANE	$1.33 \times 10^{+02}$	0	$2.39 \times 10^{+01}$	0	$2.35 \times 10^{+01}$	$4.19 \times 10^{+00}$	$1.85 \times 10^{+02}$
829	2,3-DIMETHYLHEPTANE	0	0	0	0	0	$1.67 \times 10^{+00}$	$1.67 \times 10^{+00}$
837	3,5-DIMETHYLHEPTANE	$3.33 \times 10^{+01}$	0	$5.96 \times 10^{+00}$	0	$5.87 \times 10^{+00}$	$2.51 \times 10^{+00}$	$4.77 \times 10^{+01}$
884	NAPHTHALENE	$1.44 \times 10^{+02}$	$3.03 \times 10^{+00}$	$1.47 \times 10^{+01}$	$6.21 \times 10^{+00}$	$1.73 \times 10^{+01}$	0	$1.85 \times 10^{+02}$

Substance ID	Substance name	Exhaust emissions – petrol passenger cars	Exhaust emissions – diesel light duty vehicles	Exhaust emissions – petrol light duty commercial vehicles	Exhaust emissions – diesel heavy duty commercial vehicles	Exhaust emissions – other vehicles	Evaporative emissions – all petrol vehicles	Total emissions
885	METHYLINDENE	$1.11 \times 10^{+01}$	0	$1.99 \times 10^{+00}$	0	$1.96 \times 10^{+00}$	0	$1.51 \times 10^{+01}$
900	(1-METHYLPROPYL)BENZENE	$3.67 \times 10^{+02}$	0	$6.56 \times 10^{+01}$	0	$6.46 \times 10^{+01}$	0	$4.97 \times 10^{+02}$
907	1,2 DIETHYLBENZENE	$7.40 \times 10^{+00}$	0	$1.33 \times 10^{+00}$	0	$1.31 \times 10^{+00}$	0	$1.00 \times 10^{+01}$
908	1,3-DIETHYLBENZENE (META)	$1.48 \times 10^{+01}$	0	$2.65 \times 10^{+00}$	0	$2.61 \times 10^{+00}$	$4.19 \times 10^{+00}$	$2.43 \times 10^{+01}$
909	1,4-DIMETHYL-2-ETHYLBENZENE	0	0	0	0	0	$3.35 \times 10^{+00}$	$3.35 \times 10^{+00}$
910	1,3-DIMETHYL-2-ETHYLBENZENE	0	0	0	0	0	$1.67 \times 10^{+00}$	$1.67 \times 10^{+00}$
911	1,2,3,4-TETRAMETHYLBENZENE	$4.44 \times 10^{+01}$	0	$7.95 \times 10^{+00}$	0	$7.83 \times 10^{+00}$	$1.67 \times 10^{+00}$	$6.19 \times 10^{+01}$
915	1,3-DIMETHYL-4-ETHYLBENZENE	0	0	0	0	0	$3.35 \times 10^{+00}$	$3.35 \times 10^{+00}$
918	1,2-DIMETHYL-4-ETHYLBENZENE	0	0	0	0	0	$5.02 \times 10^{+00}$	$5.02 \times 10^{+00}$
983	N-DECANE	$4.94 \times 10^{+01}$	0	$8.83 \times 10^{+00}$	0	$8.70 \times 10^{+00}$	$1.67 \times 10^{+00}$	$6.86 \times 10^{+01}$
1001	2,4-DIMETHYLOCTANE	$2.15 \times 10^{+02}$	0	$3.84 \times 10^{+01}$	0	$3.79 \times 10^{+01}$	0	$2.91 \times 10^{+02}$
1067	1-METHYL NAPHTHALENE	0	9.00×10^{-01}	0	$2.35 \times 10^{+00}$	0	0	$3.25 \times 10^{+00}$
1068	2-METHYLNAPHTHALENE	0	2.57×10^{-01}	0	5.16×10^{-01}	0	0	7.73×10^{-01}
1129	N-UNDECANE	$3.83 \times 10^{+01}$	0	$6.85 \times 10^{+00}$	0	$6.74 \times 10^{+00}$	$1.67 \times 10^{+00}$	$5.35 \times 10^{+01}$
1168	ACENAPHTHYLENE	0	2.29×10^{-01}	0	6.24×10^{-01}	0	0	8.53×10^{-01}
1169	BIPHENYL	0	3.11×10^{-01}	0	6.23×10^{-01}	0	0	9.34×10^{-01}
1170	ACENAPHTHENE	0	9.51×10^{-02}	0	2.08×10^{-01}	0	0	3.03×10^{-01}
1206	N-DODECANE	$3.33 \times 10^{+01}$	$3.12 \times 10^{+00}$	$5.96 \times 10^{+00}$	$9.75 \times 10^{+00}$	$5.87 \times 10^{+00}$	0	$5.80 \times 10^{+01}$
1257	FLUORENE	$2.75 \times 10^{+00}$	1.79×10^{-01}	2.82×10^{-01}	5.14×10^{-01}	3.30×10^{-01}	0	$4.05 \times 10^{+00}$
1298	ANTHRACENE	1.86×10^{-01}	2.49×10^{-02}	1.91×10^{-02}	9.11×10^{-02}	2.24×10^{-02}	0	3.43×10^{-01}
1299	PHENANTHRENE	$1.32 \times 10^{+00}$	3.32×10^{-01}	1.36×10^{-01}	7.91×10^{-01}	1.59×10^{-01}	0	$2.74 \times 10^{+00}$
1327	2-METHYLPHENANTHRENE	1.03×10^{-02}	9.98×10^{-01}	1.05×10^{-03}	$3.04 \times 10^{+00}$	1.23×10^{-03}	0	$4.05 \times 10^{+00}$
1328	2-METHYLANTHRACENE	8.30×10^{-02}	4.75×10^{-02}	8.52×10^{-03}	9.54×10^{-02}	9.98×10^{-03}	0	2.44×10^{-01}
1329	1-METHYLPHENANTHRENE	6.59×10^{-02}	5.41×10^{-02}	6.77×10^{-03}	1.28×10^{-01}	7.93×10^{-03}	0	2.63×10^{-01}
1330	3-METHYLPHENANTHRENE	0	7.77×10^{-02}	0	1.97×10^{-01}	0	0	2.75×10^{-01}

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1331	9-METHYLPHENANTHRENE	0	5.86×10^{-02}	0	1.49×10^{-01}	0	0	2.08×10^{-01}
1356	PYRENE	1.98×10^{-01}	1.29×10^{-01}	2.04×10^{-02}	6.45×10^{-01}	2.38×10^{-02}	0	$1.02 \times 10^{+00}$
1358	FLUORANTHENE	2.77×10^{-01}	9.95×10^{-02}	2.84×10^{-02}	3.87×10^{-01}	3.33×10^{-02}	0	8.25×10^{-01}
1386	BENZO[GHI]FLUORANTHENE	3.54×10^{-02}	1.64×10^{-02}	3.63×10^{-03}	4.01×10^{-02}	4.26×10^{-03}	0	9.98×10^{-02}
1387	BENZO(C)PHENANTHRENE	0	1.13×10^{-02}	0	1.50×10^{-03}	0	0	1.28×10^{-02}
1388	CHRYSENE	6.54×10^{-02}	5.06×10^{-02}	6.72×10^{-03}	4.48×10^{-02}	7.87×10^{-03}	0	1.75×10^{-01}
1389	CYCLOPENTA[CD]PYRENE	2.32×10^{-02}	1.74×10^{-02}	2.38×10^{-03}	3.00×10^{-02}	2.79×10^{-03}	0	7.58×10^{-02}
1390	BENZO(A)ANTHRACENE	3.75×10^{-02}	8.41×10^{-02}	3.85×10^{-03}	4.10×10^{-02}	4.52×10^{-03}	0	1.71×10^{-01}
1404	BENZO(A)PYRENE	1.36×10^{-02}	5.46×10^{-02}	1.40×10^{-03}	6.57×10^{-02}	1.64×10^{-03}	0	1.37×10^{-01}
1405	BENZO(B)FLUORANTHENE	3.95×10^{-02}	5.08×10^{-02}	4.06×10^{-03}	2.73×10^{-02}	4.75×10^{-03}	0	1.26×10^{-01}
1406	BENZO(E)PYRENE	1.10×10^{-02}	2.49×10^{-02}	1.13×10^{-03}	1.02×10^{-02}	1.32×10^{-03}	0	4.85×10^{-02}
1407	PERYLENE	1.22×10^{-03}	6.83×10^{-04}	1.25×10^{-04}	2.13×10^{-03}	1.47×10^{-04}	0	4.31×10^{-03}
1408	BENZO(K)FLUORANTHENE	3.95×10^{-02}	5.22×10^{-02}	4.06×10^{-03}	2.24×10^{-02}	4.75×10^{-03}	0	1.23×10^{-01}
1418	INDENO(1,2,3-CD)PYRENE	1.14×10^{-02}	7.42×10^{-02}	1.17×10^{-03}	4.24×10^{-02}	1.38×10^{-03}	0	1.31×10^{-01}
1420	BENZO(G,H,I)PERYLENE	3.39×10^{-02}	7.66×10^{-02}	3.48×10^{-03}	6.84×10^{-02}	4.07×10^{-03}	0	1.86×10^{-01}
1421	DIBENZ(A,H)ANTHRACENE	4.58×10^{-03}	7.72×10^{-02}	4.70×10^{-04}	3.17×10^{-02}	5.51×10^{-04}	0	1.14×10^{-01}
1427	CORONENE	0	3.36×10^{-04}	0	6.74×10^{-04}	0	0	1.01×10^{-03}
1447	METHYLANTHRACENES	0	4.26×10^{-02}	0	8.55×10^{-02}	0	0	1.28×10^{-01}
1449	METHYLINDANS	$9.26 \times 10^{+01}$	0	$1.66 \times 10^{+01}$	0	$1.63 \times 10^{+01}$	$3.35 \times 10^{+00}$	$1.29 \times 10^{+02}$
1462	DIMETHYLHEXADIENE	$1.11 \times 10^{+01}$	0	$1.99 \times 10^{+00}$	0	$1.96 \times 10^{+00}$	0	$1.51 \times 10^{+01}$
1475	NONADIENE	$3.70 \times 10^{+00}$	0	6.63×10^{-01}	0	6.53×10^{-01}	0	$5.02 \times 10^{+00}$
1516	METHYLPYRENES	0	2.46×10^{-02}	0	4.94×10^{-02}	0	0	7.40×10^{-02}
1529	METHYLBUTADIENE	$5.55 \times 10^{+01}$	0	$9.94 \times 10^{+00}$	0	$9.79 \times 10^{+00}$	$6.70 \times 10^{+00}$	$8.20 \times 10^{+01}$
1537	C6H8 ISOMER	$3.70 \times 10^{+00}$	0	6.63×10^{-01}	0	6.53×10^{-01}	0	$5.02 \times 10^{+00}$
1610	METHYLNAPHTHALENES	0	$1.70 \times 10^{+00}$	0	$3.42 \times 10^{+00}$	0	0	$5.13 \times 10^{+00}$

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1619	DIMETHYLCYCLOPENTANE	$8.15 \times 10^{+01}$	0	$1.46 \times 10^{+01}$	0	$1.44 \times 10^{+01}$	$3.27 \times 10^{+01}$	$1.43 \times 10^{+02}$
1638	ETHYLMETHYLCYCLOHEXANES	$7.40 \times 10^{+00}$	0	$1.33 \times 10^{+00}$	0	$1.31 \times 10^{+00}$	0	$1.00 \times 10^{+01}$
1654	DIMETHYLBUTENE	$7.40 \times 10^{+00}$	0	$1.33 \times 10^{+00}$	0	$1.31 \times 10^{+00}$	$2.51 \times 10^{+00}$	$1.25 \times 10^{+01}$
1667	C2 MW 178 PAH	0	1.72×10^{-01}	0	3.46×10^{-01}	0	0	5.18×10^{-01}
1668	C3 MW 178 PAH	0	1.33×10^{-01}	0	2.66×10^{-01}	0	0	3.99×10^{-01}
1683	C4 OLEFINS	$6.91 \times 10^{+02}$	0	$1.24 \times 10^{+02}$	0	$1.22 \times 10^{+02}$	$6.54 \times 10^{+02}$	$1.59 \times 10^{+03}$
1692	M,P-ETHYLTOLUENES	$3.77 \times 10^{+02}$	0	$6.74 \times 10^{+01}$	0	$6.64 \times 10^{+01}$	$2.50 \times 10^{+01}$	$5.36 \times 10^{+02}$
1694	TRIMETHYLPENTANE	0	0	0	0	0	$6.03 \times 10^{+01}$	$6.03 \times 10^{+01}$
1709	METHYLPHENANTHRENES	0	8.31×10^{-02}	0	1.67×10^{-01}	0	0	2.50×10^{-01}
1721	C8 ALKANES	$8.29 \times 10^{+02}$	0	$1.48 \times 10^{+02}$	0	$1.46 \times 10^{+02}$	$8.84 \times 10^{+01}$	$1.21 \times 10^{+03}$
1735	TRIMETHYLCYCLOHEXANES	$7.40 \times 10^{+00}$	0	$1.33 \times 10^{+00}$	0	$1.31 \times 10^{+00}$	0	$1.00 \times 10^{+01}$
1736	TRIMETHYLCYCLOPENTANE	$5.92 \times 10^{+01}$	0	$1.06 \times 10^{+01}$	0	$1.04 \times 10^{+01}$	$4.19 \times 10^{+00}$	$8.45 \times 10^{+01}$
1746	METHYLPENTENES	$8.89 \times 10^{+01}$	0	$1.59 \times 10^{+01}$	0	$1.57 \times 10^{+01}$	$1.45 \times 10^{+03}$	$1.57 \times 10^{+03}$
1747	METHYLHEXENES	$7.40 \times 10^{+01}$	0	$1.33 \times 10^{+01}$	0	$1.31 \times 10^{+01}$	$3.01 \times 10^{+01}$	$1.30 \times 10^{+02}$
1748	DIMETHYLPENTANE	$7.40 \times 10^{+00}$	0	$1.33 \times 10^{+00}$	0	$1.31 \times 10^{+00}$	$6.70 \times 10^{+00}$	$1.67 \times 10^{+01}$
1752	C1 MW 228 PAH	0	8.89×10^{-03}	0	1.79×10^{-02}	0	0	2.68×10^{-02}
1765	C8H14	$3.70 \times 10^{+00}$	0	6.63×10^{-01}	0	6.53×10^{-01}	0	$5.02 \times 10^{+00}$
1767	C2 ALKYL INDAN	$7.40 \times 10^{+00}$	0	$1.33 \times 10^{+00}$	0	$1.31 \times 10^{+00}$	0	$1.00 \times 10^{+01}$
1786	DIMETHYLHEXANES	$1.22 \times 10^{+02}$	0	$2.19 \times 10^{+01}$	0	$2.15 \times 10^{+01}$	$4.19 \times 10^{+00}$	$1.70 \times 10^{+02}$
1787	DIMETHYLOCTANES	$4.81 \times 10^{+01}$	0	$8.61 \times 10^{+00}$	0	$8.49 \times 10^{+00}$	0	$6.52 \times 10^{+01}$
1794	ISOMERS OF HEPTANE	0	0	0	0	0	$1.67 \times 10^{+00}$	$1.67 \times 10^{+00}$
1800	C7 OLEFINS	$3.70 \times 10^{+00}$	0	6.63×10^{-01}	0	6.53×10^{-01}	$3.35 \times 10^{+00}$	$8.37 \times 10^{+00}$
1857	4-NITROBIPHENYL	0	3.71×10^{-04}	0	7.45×10^{-04}	0	0	1.12×10^{-03}
1865	PHOSPHORUS	$4.14 \times 10^{+00}$	$3.18 \times 10^{+00}$	2.39×10^{-01}	$3.28 \times 10^{+00}$	3.66×10^{-01}	0	$1.12 \times 10^{+01}$
1879	2,3,7,8-TCDD	1.16×10^{-07}	1.88×10^{-07}	7.00×10^{-09}	2.27×10^{-07}	1.00×10^{-08}	0	5.48×10^{-07}

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1880	1,2,3,7,8-PeCDD	6.34×10^{-07}	1.06×10^{-06}	3.70×10^{-08}	1.36×10^{-06}	5.60×10^{-08}	0	3.15×10^{-06}
1881	1,2,3,4,7,8-HxCDD	2.54×10^{-07}	3.98×10^{-07}	1.50×10^{-08}	4.96×10^{-07}	2.20×10^{-08}	0	1.18×10^{-06}
1882	1,2,3,7,8,9-HxCDD	8.98×10^{-07}	1.47×10^{-06}	5.20×10^{-08}	1.88×10^{-06}	7.90×10^{-08}	0	4.38×10^{-06}
1883	1,2,3,6,7,8-HxCDD	1.07×10^{-06}	1.85×10^{-06}	6.20×10^{-08}	2.40×10^{-06}	9.40×10^{-08}	0	5.47×10^{-06}
1884	1,2,3,4,6,7,8-HpCDD	5.04×10^{-06}	8.62×10^{-06}	2.91×10^{-07}	1.12×10^{-05}	4.45×10^{-07}	0	2.55×10^{-05}
1885	OCDD	2.14×10^{-06}	3.13×10^{-06}	1.24×10^{-07}	3.76×10^{-06}	1.89×10^{-07}	0	9.35×10^{-06}
1886	2,3,7,8-TCDF	2.31×10^{-06}	3.98×10^{-06}	1.34×10^{-07}	5.18×10^{-06}	2.04×10^{-07}	0	1.18×10^{-05}
1887	1,2,3,7,8-PeCDF	3.85×10^{-06}	5.63×10^{-06}	2.22×10^{-07}	6.75×10^{-06}	3.40×10^{-07}	0	1.68×10^{-05}
1888	2,3,4,7,8-PeCDF	3.38×10^{-06}	5.07×10^{-06}	1.95×10^{-07}	6.16×10^{-06}	2.99×10^{-07}	0	1.51×10^{-05}
1889	1,2,3,4,7,8-HxCDF	3.68×10^{-06}	6.05×10^{-06}	2.12×10^{-07}	7.72×10^{-06}	3.25×10^{-07}	0	1.80×10^{-05}
1890	1,2,3,7,8,9-HxCDF	1.69×10^{-07}	2.43×10^{-07}	1.00×10^{-08}	3.00×10^{-07}	1.50×10^{-08}	0	7.36×10^{-07}
1891	1,2,3,6,7,8-HxCDF	2.98×10^{-06}	4.86×10^{-06}	1.72×10^{-07}	6.16×10^{-06}	2.63×10^{-07}	0	1.44×10^{-05}
1892	2,3,4,6,7,8-HxCDF	2.84×10^{-06}	4.83×10^{-06}	1.64×10^{-07}	6.24×10^{-06}	2.51×10^{-07}	0	1.43×10^{-05}
1893	1,2,3,4,6,7,8-HpCDF	1.40×10^{-05}	2.47×10^{-05}	8.12×10^{-07}	3.24×10^{-05}	1.24×10^{-06}	0	7.32×10^{-05}
1894	1,2,3,4,7,8,9-HpCDF	2.36×10^{-06}	4.22×10^{-06}	1.36×10^{-07}	5.60×10^{-06}	2.08×10^{-07}	0	1.25×10^{-05}
1895	OCDF	1.18×10^{-05}	1.73×10^{-05}	6.81×10^{-07}	2.07×10^{-05}	1.04×10^{-06}	0	5.15×10^{-05}
1919	1,6-DINITROPYRENE	0	0	0	0	0	0	0
1920	1,8-DINITROPYRENE	0	0	0	0	0	0	0
1922	6-NITROCHRYSENE	0	4.61×10^{-05}	0	9.25×10^{-05}	0	0	1.39×10^{-04}
1923	2-NITROFLUORENE	0	3.04×10^{-05}	0	6.10×10^{-05}	0	0	9.14×10^{-05}
1924	1-NITROPYRENE	0	5.13×10^{-04}	0	1.03×10^{-03}	0	0	1.54×10^{-03}
1936	BROMINE	$1.72 \times 10^{+00}$	7.37×10^{-02}	9.93×10^{-02}	7.75×10^{-02}	1.52×10^{-01}	0	$2.12 \times 10^{+00}$
1993	BENZO(J)FLUORANTHENE	0	0	0	0	0	0	0
1997	SULFATES	$2.64 \times 10^{+02}$	$2.32 \times 10^{+01}$	$1.53 \times 10^{+01}$	$2.53 \times 10^{+01}$	$2.33 \times 10^{+01}$	0	$3.51 \times 10^{+02}$