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Executive summary

The Department of Environment Regulation (DER) on-road vehicle emissions remote sensing device (RSD) was deployed for 10 days in October and November 2014 at five sites across Perth.

The RSD provides an efficient method to determine the emissions performance of a large number of vehicles in a range of locations, providing an accurate snapshot of the Perth vehicle fleet. The DER RSD (an Accuscan 4600) is the only equipment of its kind operating in Australia.

During the deployment of the RSD, over 20,000 vehicles travelled through the device, resulting in over 17,000 successful emissions tests.

This is the third report outlining results of RSD sampling in the Perth area. A number of fleet trends have been identified compared to previous sampling:

- Average emissions per vehicle are decreasing.
- Average vehicle size is increasing.
- The range of emissions remains very large with a small number of vehicles at the high emissions end of the range responsible for the largest proportion of emissions.
- There are increasing numbers of diesel passenger vehicles.
- Despite an increasing diversity of vehicle manufacturers, Toyota models continue to dominate the Perth vehicle fleet.

The adoption of increasingly stringent standards through the Australian Design Rules (ADRs) has had the greatest impact on vehicle emissions improvements. This indicates that increasing the proportion of the fleet meeting these high standards would be an efficient way to encourage further emission reductions.

Introduction

The DER CleanRun program operates an Accuscan 4600 RSD that monitors the exhaust emissions of passing vehicles. The device was deployed by DER at five sites across the Perth metropolitan area in October and November 2014. Two days of monitoring was completed at each site. The RSD was also set up at a community day in Kings Park in March 2015 to give motorists the opportunity to engage with DER staff and the RAC about their vehicle emissions.

Remote sensing of vehicle emissions provides DER with an efficient way to characterise the Perth vehicle fleet. The RSD is set up on a roadside and captures the emissions data of around 2000 vehicles per day. Photographs capture the vehicle registration number allowing vehicle registration information to be extracted from the Department of Transport database. Analysis of emissions data together with vehicle information allows DER to determine how vehicles are performing and how emissions performance changes according to age, make, model and fuel type. Access to this type of information and analysis can inform policy and add weight to decisions on vehicle regulation.

Deployment of the RSD in 2014 attracted interest from the Perth media. Articles appeared in Saturday's *The West Australian* (25 October) and the *Sunday Times* (26 October) newspapers, as well as four other suburban weekly newspapers. Channel 7's *Today Tonight* television program covered the deployment as the lead article on its 29 October 2014 program.

Background

The CleanRun RSD is an Accuscan 4600 Remote Sensing Device. The RSD was purchased in 2009 with Commonwealth funding to implement the National Environmental Protection (Diesel Vehicle Emissions) Measure. Remote sensing of vehicle emissions was undertaken in Perth in 2007[1], 2009–10 and 2014. Five sites were monitored at each of these times to allow for the analysis of trends in the vehicle fleet. During the 2009–10 RSD deployment 13 sites[2] were monitored, including the five repeat sampling sites. Additional monitoring in 2009–10 led to a significantly larger sample size for this monitoring period.

The RSD provides an efficient method to determine the emissions performance of a large number of vehicles over a large area and an accurate snapshot of the Perth vehicle fleet. The DER RSD is the only equipment of its kind operating in Australia.

Remote sensing of vehicle emissions is more common internationally where such devices are used for the validation of vehicle emissions factors (Europe, New Zealand), emission standards compliance (USA) and the detection of gross emitters (USA).

[1] 2007 RSD deployment was undertaken by the New Zealand National Institute of Water and Atmospheric Research (NIWA) as part of the Clean Air Research Program (CARP) "New Assessments of Vehicle Air Pollution and Health Effects using On-Road Remote Sensing Technology".

[2] Abernethy Rd, Belmont; Anstruther Rd, Mandurah; Bail Rd, Clayton St, Midland; Frobisher St, Osborne Park; Garling St, O'Connor; Harborne St, Wembley; Illawarra Cres, Ballajurra; Marine Pde, Cottesloe; Oats St, Carlisle; Port Kembla Dr, Spearwood; Prindiville Dr, Wangara; West Coast Dr, Sorrento.

Fleet testing in Australia such as for the national in-service emissions study (NISE1 and 2) is undertaken using a dynamometer. Dynamometer testing involves a vehicle being driven through a set drive cycle while exhaust emissions are tested in a controlled environment. A selection of vehicles are run through the drive cycle and the results are extrapolated over the fleet. Dynamometer testing is an expensive and labour intensive process resulting in a smaller number of overall tests and difficulty in obtaining a random sample of the vehicle fleet.[3]

Vehicle emissions testing

In 2014, the same five sites (Oats Street, Carlisle; Harborne Street, Wembley; Marine Parade, Cottesloe; West Coast Drive, Sorrento; and Prindiville Drive, Wangara) were monitored as in 2007 and 2009–10. This allows for trend analysis of fleet emissions over time. A map of sampling sites is attached at Appendix A. The sites conform to the following essential criteria for effective use of the RSD:

- single lane road with median strip;
- slight incline to ensure positive engine load; and
- adequate vehicle traffic to ensure the target number of samples are possible.

Vehicle numbers and successful tests demonstrate that some sites are more efficient than others. Prindiville Drive was the most successful test site with the highest overall number of valid samples. Harborne Street was the least successful site with the second lowest number of valid samples and the lowest percentage of valid samples (Table 1).

Table 1. Vehicle emission samples

Sites	Number of vehicles	Number of valid samples	Percentage of valid samples %
Oats Street	5188	4035	77.8
Harborne Street	6025	3477	57.7
Marine Parade	3071	2516	81.9
West Coast Drive	7340	4549	62.0
Prindiville Drive	6653	5343	80.3
Totals	**28,277**	**19,920**	**70.4**

Successful site selection depends on traffic volumes and road gradient. Prindiville Drive in Wangara is an important feeder road into a busy light industrial area with an up-hill gradient. Harborne Street in Wembley is a busy road in a suburban area, however the slight gradient fails to keep drivers accelerating through the equipment. Marine Parade in Cottesloe has a road gradient that ensures a high valid sample rate but the traffic volume on a weekday is low.

[3] National In-Service Emissions Study (1996) (NISE1) and (2009) (NISE2) available at: http://www.infrastructure.gov.au/roads/environment/emission/str_national-in-service.aspx

Remote sensing of vehicle emissions

The RSD measures the following exhaust pollutants:

- carbon monoxide (CO);
- nitrogen oxide (NO);
- hydrocarbons (HC); and
- particulates (UV smoke).

The RSD measures exhaust gases by sampling the gas conditions in the air in front of the vehicle (taken as the ambient condition or baseline) then sampling the gas conditions at the rear of the vehicle. The difference between the two conditions represents the emissions of the vehicle.

The RSD source/detector is set up on a roadside to project light (infrared and ultra violet) across the road to a reflector cube (Figure 1.). The light reflected back to the RSD is partly absorbed by the vehicle exhaust and allows the emissions to be calculated.

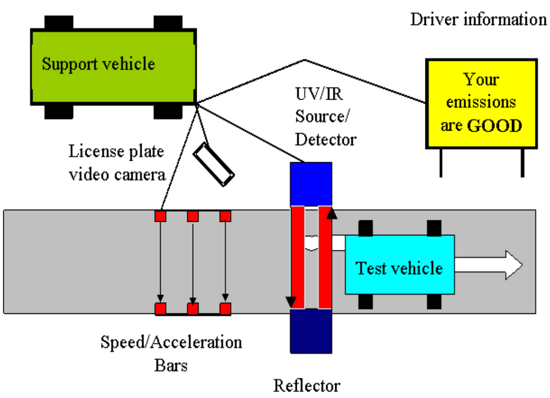

Figure 1. Schematic diagram of the RSD monitoring equipment[4] (left) and RSD source/detector and reflector in operation[5] (right)

A valid sample is captured by the RSD when a vehicle passes the accelerator bars triggering the source/detector to take the initial sample. The vehicle must be under load in order to emit detectable exhaust gases. The vehicle specific power (VSP) is calculated by the RSD using the vehicle acceleration, velocity and road gradient. If the vehicle VSP is positive, and the RSD successfully measures the before and after gas conditions, the test is valid and assigned a V sample flag in the data log.

On triggering the source/detector to take the initial sample, a camera records the rear registration plate of the vehicle. This allows the specific vehicle information (but no personal information) to be entered into the data log after the sampling.

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[4] Bluett, J., Dey, K., Fisher, G. (2008) *Assessing Vehicle Air Pollution Emissions*. Prepared for the Department of the Environment, Water, Heritage and the Arts by the National Institute of Water and Atmospheric Research Ltd (New Zealand)

[5] Department of Environment Conservation (2011) *CleanRun Remote Sensing Program: Final Report*. (unpublished report)

The RSD is capable of monitoring vehicles with a rear exhaust within one metre of the ground, which restricts analysis to vehicles with this configuration. This means heavy duty vehicles that operate vertical exhausts cannot be sampled. Vehicles towing trailers are also excluded.

The CleanRun smart sign provides immediate feedback to the driver about the emissions performance of the vehicle. The display reads:

Your emissions are GOOD = saving money

Your emissions are FAIR = costing money

Your emissions are POOR = losing money

Cut points entered into the RSD are used to determine the good, fair or poor results of the vehicle. Without specific vehicle regulations for emissions, cut points are based on the average emissions performance of the fleet. The worst 10 per cent of vehicles (those with the highest emissions) are classed as poor. Emissions results between 10 and 50 per cent are classed as fair and the top 50 per cent (those with the lowest emissions) are classed as good. Using the two days of testing at Oats Street, Carlisle, cut points for each emissions category were determined for the remainder of the deployment (Table 2).

Table 2. Smart sign cut points

Emission category	Poor	Fair	Good
Carbon monoxide (CO) %	>1.873	0.554 – 1.873	<0.554
Hydrocarbons (HC) ppm	>556	195 - 556	<195
Nitrogen oxide (NO) ppm	>2050	1370 - 2050	<1370
UV smoke (PM) %	>0.15	0.05 – 0.15	<0.05

Interpreting emission results[6]

Individual vehicle emissions are comprised of the by-products of fuel combustion within the vehicle engine. In an ideal engine where all fuel is completely combusted, vehicle emissions would be made up of carbon dioxide (CO_2) and water. In a real world engine, the combustion by-products (exhaust) are made up of oxygen (O_2), carbon dioxide (CO_2), carbon monoxide (CO), hydrocarbons (HC), nitrogen oxides (NOx) and water.

The RSD measures and reports gas results using two methods and reporting units. CO and UV smoke are both reported as a percentage using different calculation techniques. CO is reported as a percentage of total exhaust volume. By comparing the percentage volume of CO (where a good result is less than 0.554 per cent) to the percentage volume of CO_2 (which should be in the order of 14.7 per cent), an understanding of the air fuel mix in the engine can be determined. A high CO reading (over one per cent) indicates an engine running rich, with a high fuel to O_2 ratio.

UV smoke is a measurement of opacity rather than a proportion of particles in the exhaust. A high UV smoke reading (greater than 0.15 per cent opacity) indicates the

[6] Information for this section is summarised from: Environmental Systems Products Holdings Inc. (2006) RSD4600 Operators Manual, Ch 1.

presence of particles in the vehicle exhaust. The Emissions profile section reports CO and UV smoke together for convenience although the calculations are independent of each other.

NO and HC are reported as concentrations in parts per million (ppm). They are calculated in a similar fashion to CO in that they are initially calculated as a ratio to CO_2 and then their concentrations determined by the combustion equation below.

$CHx + N_2 + O_2 \rightarrow CO_2 + CO + CHx + NO_2$

The ratio of fuel (CHx) to O_2 is assumed to be 1:2 and the ratio of CO_2 to CO, HC and NO is measured as 1:3, 1:4 and 1:5 respectively. The fuel ratio is assumed to be 1:2 or CH_2. The calculations also assume that nitrogen makes up 79 per cent of ambient air and that 14.8 kilograms of air is required to burn one kilogram of fuel.

Fleet profile

Assessment of the Perth fleet requires individual vehicle licensing information. This information is held by the WA Department of Transport (DoT). At the completion of the RSD monitoring deployment the DoT provides vehicle information to be matched to the emissions data collected. Vehicle data include vehicle make, model, weight, type, year of manufacture, number of cylinders, fuel type, and family vehicle flag. No personal information associated with the vehicle is provided.

In 2014 the total number of vehicles in WA was 2,142,307, or 840 vehicles per 1000 people[7]. Approximately 98 per cent of those vehicles are registered in the metropolitan area[8]. The average age of passenger cars sampled by the RSD in WA is eight years old, the same as in 2009–10. ABS census data from 2014 age the WA passenger fleet at 9.9 years (10.3 years for all vehicles including heavy trucks and motor cycles).

Diesel vehicles have increased as a proportion of the fleet in WA from nine per cent in 2007 and 16 per cent in 2009–10 to 23 per cent in 2014. This is consistent with ABS data for WA diesel vehicles in 2014 at 22 per cent.

Family vehicles have increased as a proportion of surveyed vehicles in 2014—63 per cent compared to 60 per cent in 2009–10 (Table 3). In 2009–10 eight sites were monitored in addition to the five repeat monitoring sites. Commercial vehicles may have been over represented in these areas.

Table 3. Vehicle purpose (commercial/family)

	Family %	Commercial %	Other %
2007	58.66	36.79	4.54
2009–10	59.52	37.05	3.42
2014	63.31	33.46	3.22

The most popular vehicle makes have been stable between sampled years with Toyota the most popular vehicle manufacturer in 2009–10 and 2014. Vehicles from manufacturers outside of the top six are increasing in popularity with a larger proportion of these vehicles represented in the fleet—34 per cent in 2014 compared to 27 per cent in 2009–10 (Figure 2).

[7] ABS (2014) Motor Vehicle Census. http://www.abs.gov.au/ausstats/abs@.nsf/mf/9309.0 accessed 15/06/2015.
[8] DER, (in review), Perth Vehicle Emissions Inventory 2011-2012

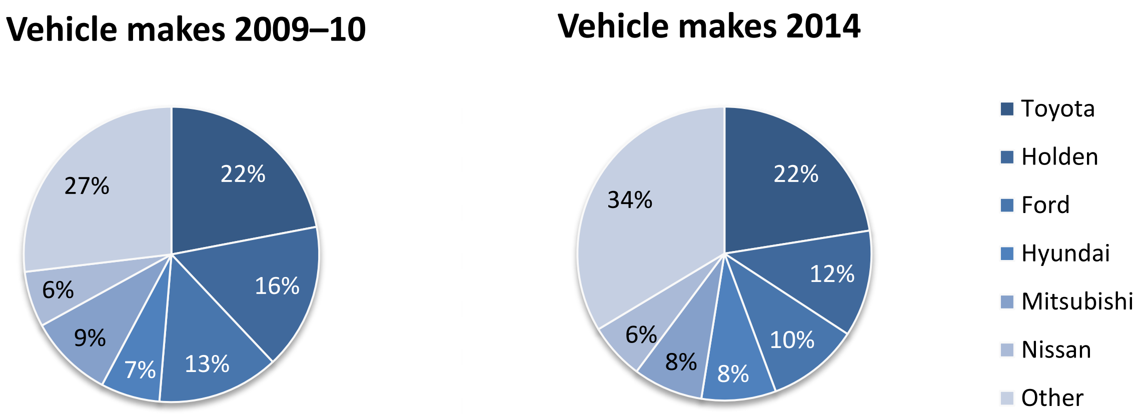

Figure 2. Six most popular vehicle makes 2009–10 and 2014.

Large vehicles continue to dominate the WA fleet. Small cars (defined for the purposes of this study as a sedan or hatch with four cylinders) were a smaller proportion of the fleet in 2014 than 2009–10. Average weights have increased from 1470kg in 2007 to 1706kg in 2014, although the bulk of the fleet (middle 50 per cent) is within the 1100kg to 1850kg range across the three sample periods. Advances in emissions technology offset this impact to an extent but a larger, heavier car will always require more energy than a smaller car with the same technology.

Emissions profile

Average emissions per vehicle have reduced significantly between 2009–10 and 2014. Improvements range from a 19 per cent reduction in UV smoke to a 35 per cent reduction in hydrocarbon concentrations. The progressive introduction of Australian Design Rules (ADRs) for new vehicles and aligning ADR emission standards with European emission standards results in newer, cleaner vehicles making up a larger proportion of the fleet. In 2007 the newest vehicles in the fleet met ADR 70/0; in 2014 the newest vehicles meet ADR 79/03. Although the average vehicle age is stable at eight years, an eight-year-old car in 2014 meets ADR 70/01. An eight-year-old car in 2007 would only meet ADR 37/01 (Figure 3). In 2014 the largest group of vehicles complied with ADR 79/02 which took effect in 2008. This places the single largest group of vehicles between two and six years old. The proportion of new vehicles is significantly larger than in previous testing years, which had a greater spread across the age range. The unprecedented high number of new car sales in WA since 2005 (over 8,000 new car sales per month), peaking in 2008 and again in 2013, may be responsible for this trend[9].

[9] ABS (2015) Sales of New Motor Vehicles by State, Type, All Series. http://www.abs.gov.au/AUSSTATS/abs@.nsf/DetailsPage/9314.0May%202015?OpenDocument

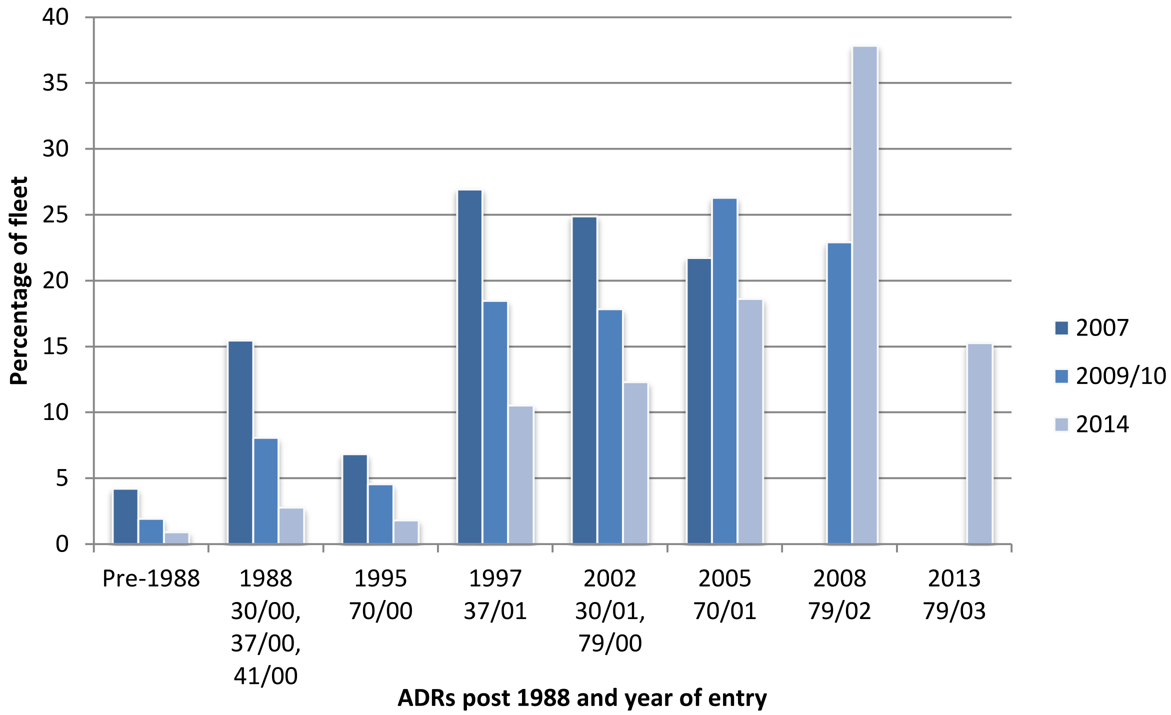

Figure 3. Australian Design Rule of fleet population

The range of vehicle emissions returned by the RSD extends from very low emission vehicles below the detection limit of the equipment to the highest emissions attributable to a small proportion of the fleet. Allocating vehicle emissions to percentile ranges demonstrates that the highest emitters (gross polluting vehicles) account for the vast majority of vehicle emissions (assuming that all vehicles travel over the same distance) (Figure 4).

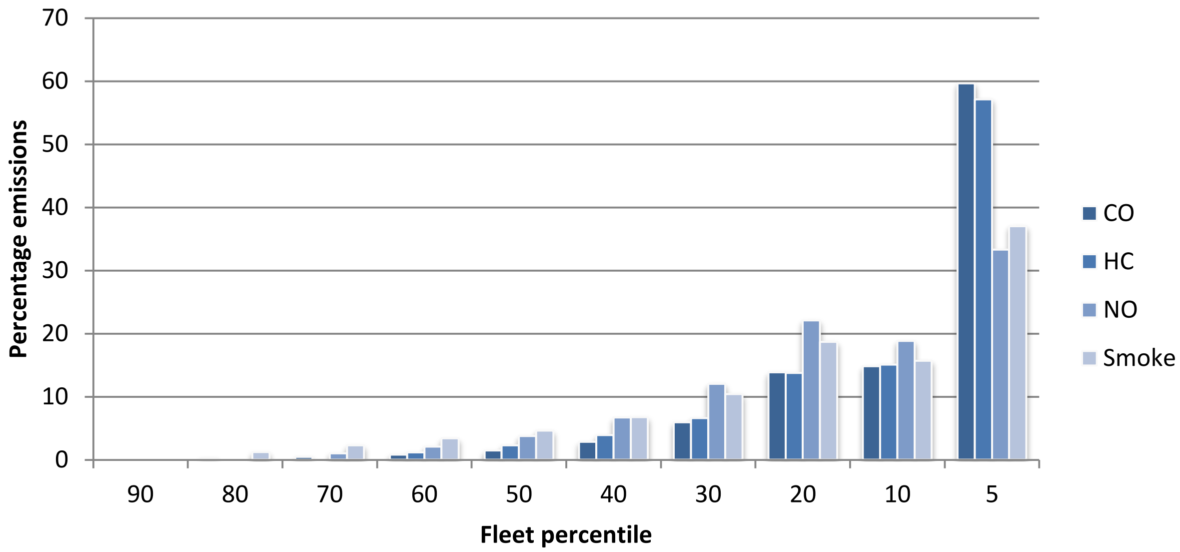

Figure 4. Fleet emissions by percentile range. The worst 5% of the fleet are responsible for 59% of CO, 57% of HC, 32% of NO and 36% of smoke (particulates)

Fleet percentile does not take into account the distance travelled per vehicle. For the 2011–12 Perth Vehicle Emissions Inventory (PVEI)[10], calculations of vehicle kilometres travelled (VKT) were assigned to each vehicle age range or ADR in order to calculate a total emissions load to the Perth air shed. The vehicle emissions model used in the PVEI indicates that although older vehicles are high emitters, there are fewer of them and they have a lower VKT. The significantly greater population of newer model cars are therefore responsible for the majority of emissions.

However, one high polluting vehicle in the worst cohort of vehicles emits many hundreds or even thousands of times more emissions than a new, well maintained vehicle. Removing these high emitting vehicles from circulation would have a positive impact on vehicle emissions.

Fuel use

Average emissions by fuel type show the types of pollutants emitted by various fuels. For example, Figures 5 and 6 indicate that LPG powered vehicles emit much greater amounts of CO, HC and NO than either petrol or diesel vehicles. LPG vehicles only made up three per cent of the vehicle fleet in 2014 (Figure 7). Petrol vehicles emit greater amounts of CO, while UV smoke and NO emissions are higher in diesel vehicles.

Analysis of fuel emissions data indicates that fuel type has an impact on whether a vehicle is awarded a good, fair or poor result by the CleanRun smart sign. Only 37 per cent of diesel vehicles were classed as good for UV smoke emissions while 45 per cent were classed as fair and 18 per cent were poor. In contrast, petrol vehicle UV smoke results were 87 per cent good, 9.1 per cent fair and 3.9 per cent poor.

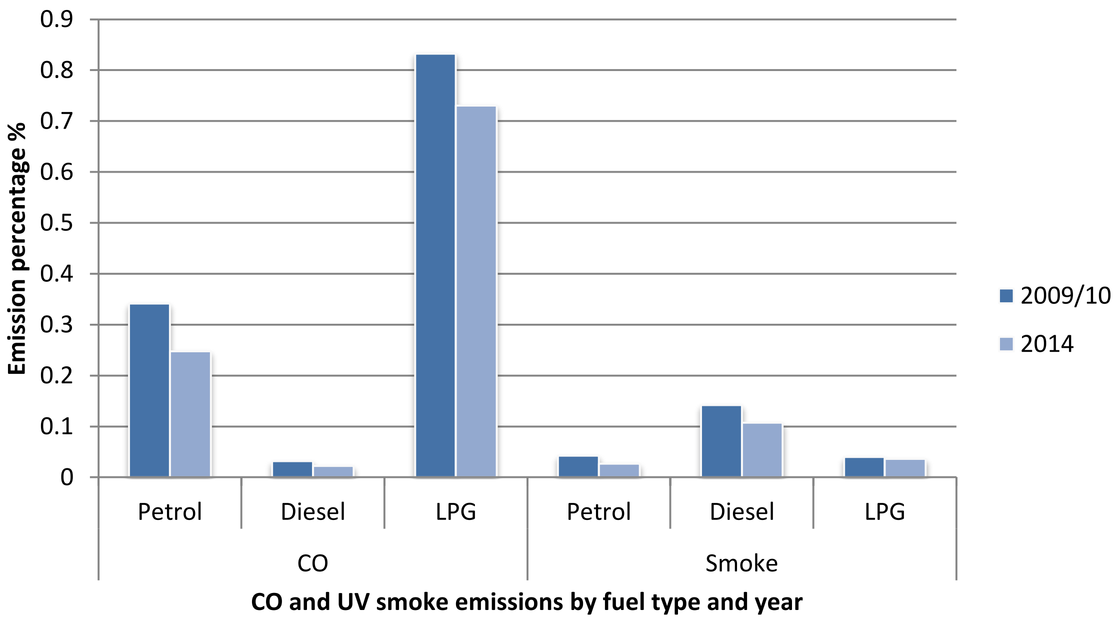

Figure 5. Emission averages by fuel type 2009–10 and 2014. Note: CO and smoke measured as a percentage of the vehicle exhaust

[10] DER, (in review), Perth Vehicle Emissions Inventory 2011-12

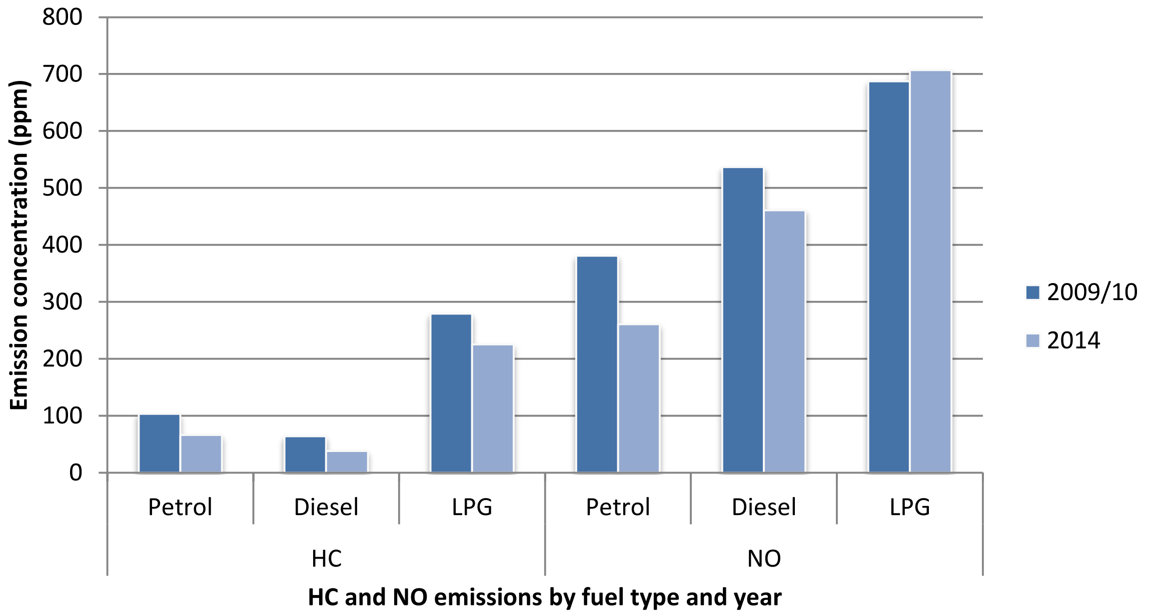

Figure 6. Emission averages by fuel type 2009–10 and 2014. Note: HC and NO measured as concentration in ppm

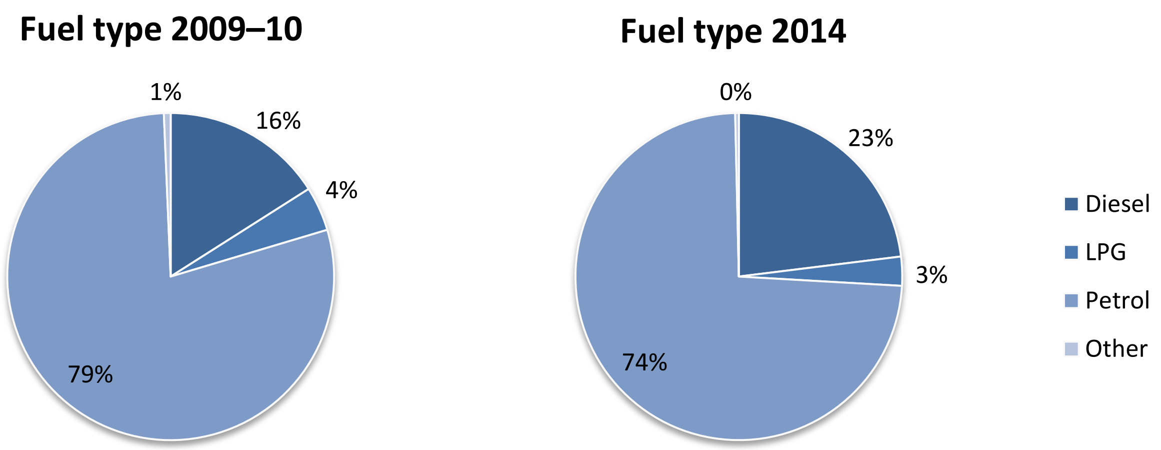

Figure 7. Vehicle fuel type 2009–10 and 2014

Manufacturers

The most popular vehicle manufacturers make use of different engine and emissions technologies. The size, weight and fuel type of a vehicle also impacts on fuel efficiency and emissions. The average emissions of the top six vehicle manufacturers indicates that the most popular make (Toyota) has lower average emissions than the other vehicle makes, despite the popularity of large Toyota models such as Landcruiser and Hilux (Figure 8). The proportion of diesel vehicles within each manufacturer's vehicle fleet may impact on average emission results. Of the top six vehicle makes, Nissan had the highest proportion of diesel vehicles at 36 per cent and the highest average smoke emissions. The cut point for vehicles to be awarded 'good' as they are tested for smoke by the RSD is 0.05 per cent; only two vehicle manufacturers are in this category.

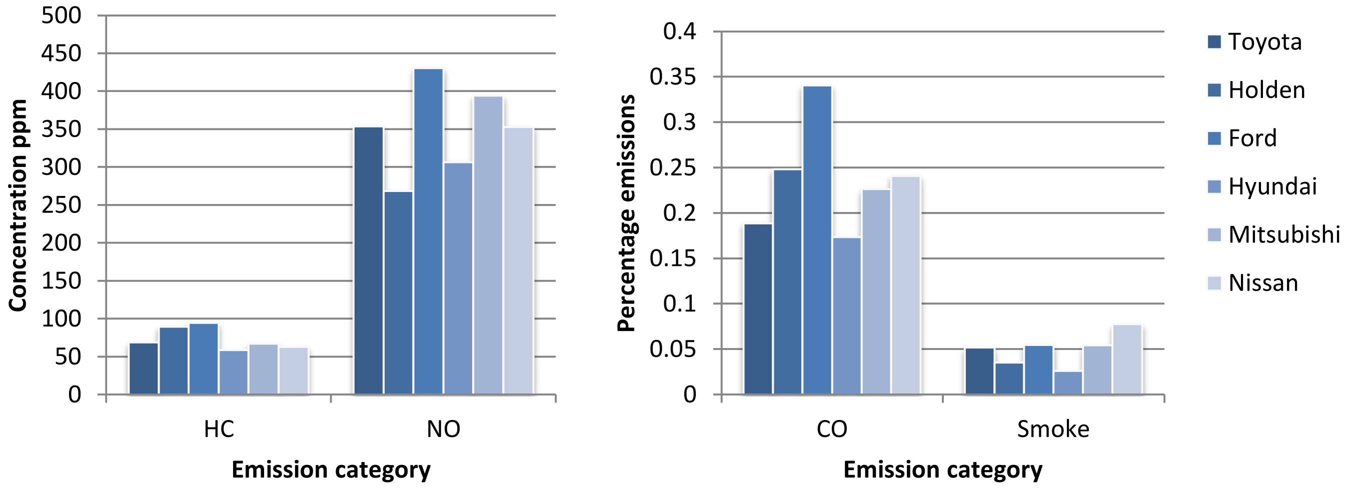

Figure 8. 2014 emissions averages by popular vehicle manufacturer

Conclusion

As older vehicles are removed from the Perth vehicle fleet and new vehicles conform to more stringent ADR standards, the average emissions of the fleet are improving. Only repeat monitoring of emissions performance, vehicle population and the average distance travelled (VKT) can provide an indication of whether emissions performance is keeping pace with vehicle population growth. There are a number of trends identified by the 2014 emissions monitoring including:

- increasing vehicle size;
- increasing proportion of diesel passenger vehicles;
- increasing diversity in vehicle manufacturers in the fleet; and
- decreasing average emissions per vehicle.

Appendix A: RSD monitoring site locations