Wellington Institute of Technology
Te Whare Wānanga o te Awakairangi

Heavy Vehicle Productivity Project
Emissions Monitoring Programme : October 2008

SUMMARY REPORT

Prepared for :

Ministry of Transport
PO Box 3175
Wellington

Author :
T Devos
BiosFuel Corporation

Other Principals :
Fuel Technology Ltd
Centre for Smart Product, Wellington Institute of Technology
Source Testing New Zealand Ltd

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Executive Summary

Seven trucks were emissions tested whilst operating over set routes with gross vehicle masses (GVM) of near 44 tonnes and near 50 tonnes. Analysis of the results indicated that :

- The relationships between the emission rates of any of the emissions species monitored and GVM were found to be statistically not significant.
- There were trends of decreasing emissions per T-km with increasing GVM for some emissions species, but these trends, where present, were either of small slope or of little significance, such were the low base emissions rates involved.
- There was not significant worsening of emission rates when moving from operation at 44 tonnes GVM to 50 tonnes GVM, when emissions were considered on a tonne-kilometre of freight moved basis.

1. Introduction

This report is a summary of the first stage of the “Heavy Vehicle Emissions Monitoring Programme”, one part of the Ministry of Transport’s (MOT) evaluation of the use of increased GVMs for heavy road vehicles.

This first stage of work involved repetitive exhaust emissions testing of seven heavy trucks with GVM varying from near 44 tonnes (the current maximum GVM for heavy vehicles operating on public roads apart from trial areas and under special license) to 50 tonnes (the proposed GVM limit for some roads). Six of the trucks were the same-model and operating over the same route, while the seventh was a different model truck operating on a different route.

This test work was awarded to WelTec (the principal contractor) and WelTec then engaged its associates Source Testing New Zealand (STNZ) and Bios, to carry out the mobile emissions test work on the trucks and Fuel Technology Limited to carry out a review of the results. The results of this work are presented in this Summary Report and the Main Report *“ WelTec- Ministry of Transport Heavy Vehicle Mobile Emissions Monitoring Programme October 2008”* which presents the detailed data collected.

2. Methodology:

The emissions tests were conducted over the period 16 to 29 October 2008. The tests consisted of:

- Tests on six 2005 Mercedes Benz Acto trucks. These trucks were owned and operated by Canterbury Waste Services Ltd (CWS). All trucks were fitted with the Mercedes MP2, 12 l V6 460HP engine, and all were fitted with the same design of waste carrying bins and trailer. These trucks were tested over a route from the Park House Waste Transfer Centre to the Kate Valley Landfill, a journey of approximately 74 kilometres. These trucks were mostly tested twice at each near 44 tonnes GVM and near 50 tonnes GVM. The tare weight of truck and trailer was 17.3 tonnes.

- Tests on a single Freightliner C120, B-train fuel tanker owned and operated by Alexander's Petroleum Services Ltd. This truck was fitted with a Caterpillar C15 engine. The test route was from the Shell Lyttelton Gantry to Shell Aviation Christchurch Airport, a journey of approximately 25 km. This truck was tested once at near 44 tonnes GVM and once at near 50 tonnes GVM. The tare weight of the complete unit was 17.9 tonne.
- A single test on one of the CWS trucks when it was empty (i.e., at a GVM of 17.3 tonnes, the truck's tare weight).

Further detail on the trucks tested and the test programme is provided in the report *Heavy Vehicle Mobile Emissions Monitoring Programme, October 2008.*

One of the required emissions metrics for the tests was the average mass emissions rate of the various emissions species of concern; over the routes the trucks were driven.

Emission analysers measure the concentration of various emission species and not mass flowrate. Conversion to a mass flowrate also requires the mass flow of the exhaust to be determined, which in turn requires volumetric flowrate and temperature of the exhaust to be determined. Complicating this, the emissions concentrations and the exhaust flow rates change with changes in engine load and speed. Hence emissions monitoring a truck over a set route requires the emissions concentrations and exhaust flow measurements to be captured and recorded throughout the operation of the trucks over that route. In this case a data sampling rate of every 10 seconds was used. The average mass flowrate values for individual emission species were then calculated from the combination of these various sets of data.

The determination of emissions rate thus consisted of: sampling from the exhaust, emissions concentration determination using an analyser, exhaust gas flowrate determination, continuous data capture and storage, and data download and analysis. And only the last was performed off the vehicle.

The exhaust emissions so monitored were:

- Carbon dioxide (CO_2).
- Carbon monoxide (CO).
- Sulphur dioxide (SO_2).
- Nitric oxide (NO), nitrogen dioxide (NO_2), total oxides of nitrogen ($NO + NO_2$).
- Hydrocarbons[1] (HC). and
- Oxygen (O_2, used for data correction).

Further detail on the emissions-related methodology, data verification, and the conversion of data and correction factors used, is provided in the report *Heavy Vehicle Mobile*

[1] Reported in terms of propane-equivalent emissions in the report *Heavy Vehicle Mobile Emissions Monitoring Programme, October 2008* but converted to hexane-equivalent values for this report (a more common unit for automotive applications) by dividing the propane-equivalent values by a factor of 2.

Emissions Monitoring Programme, October 2008. The resulting processed data is also listed in that report.
Note that it has been assumed that the drivers drove their respective trucks in the same manner, regardless of load, although it is conceivable that travel times could be extended when hauling heavier loads. A check on the travel times (based on the recording sample times for each test) found that there was no significant difference between the mean of the travel times for the near 44 tonnes GVM tests and the near 50 tonnes GVM tests, although there was found to be reasonable scatter in the test run times for both 44 and 50 tonnes GVM tests. Run time through the tests would be difficult to control as traffic and road conditions would be expected to vary during the day and through the week. This could be responsible for some of the scatter found in the results.

3. Analysis of Data

The results of this test programme need to be put into perspective. They are the results from testing two different vehicle types on two different routes, and it is difficult to extrapolate these results to the national heavy vehicle fleet – the responses could be quite different for different vehicles and different routes. However, the results do provide a useful indication of what some of the responses might be.

Note that corrected values for emission rates have been used in the following analysis. However, the reference to "corrected" has been removed to make the report easier to read.

CO_2
Exhaust CO_2 is formed from the combustion of fuel carbon and air. The fraction of fuel carbon that is not released as CO_2 is extremely small and for this reason corrected CO_2 emission is a good indicator of fuel consumption of the engine (to the point that the emission of CO_2 is used to calculate drive cycle fuel consumption in many of the internationally recognised fuel economy tests). Following on from this, plotting CO_2 versus GVM provides an indication of the change in fuel consumption with change in load.

Figure 1 provides this plot for the trucks tested, with the individual trucks given as different colours so as to check for trends on an individual truck basis.

Linear trend lines are also provided for individual trucks.

As can be seen, the results are scattered.

There are many reasons why there is such scatter, including differences in road and traffic conditions, as has been mentioned.

The scatter indicates that the relationship between fuel economy (as measured by CO_2) and truck GVM is statistically not significant when considered in the absence of other variables.

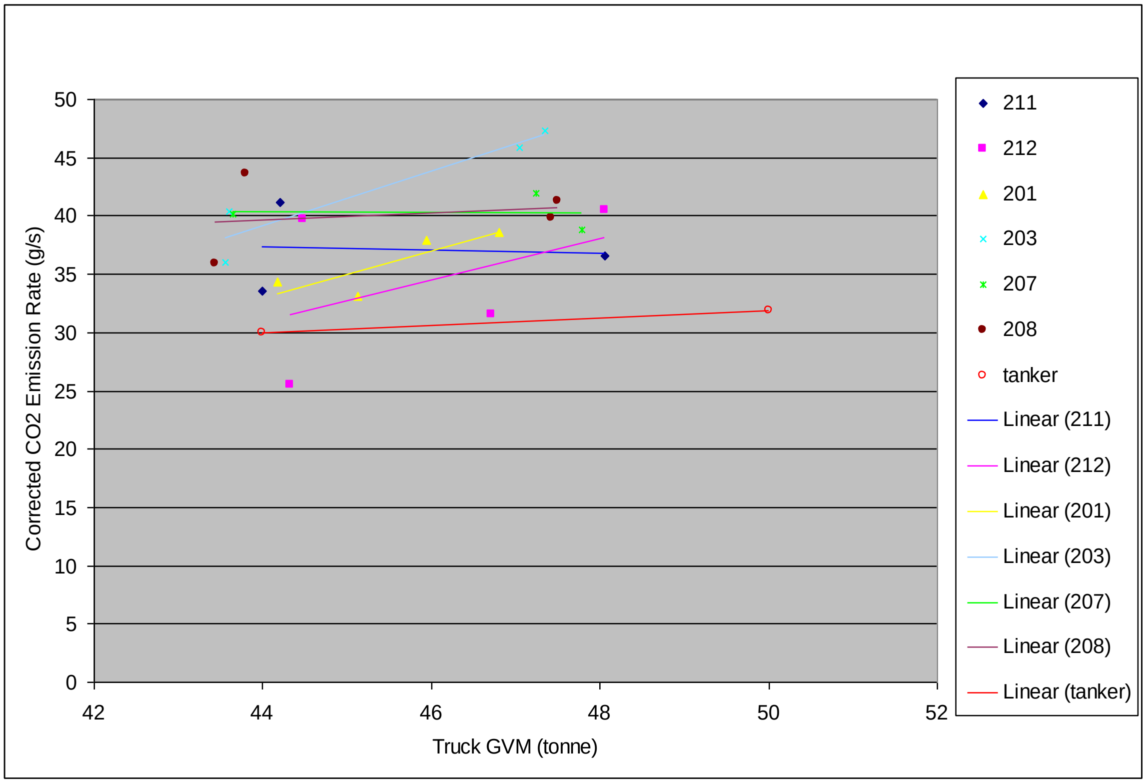

Figure 1: CO_2 vs Truck GVM for the Various Trucks in the Trial

Despite this lack of statistical significance, there is an overall trend[2] of increasing fuel consumption with increasing GVM (as the majority of the trend lines are positively sloped), which is as expected (as moving a heavier load is expected to consume more fuel). The CO_2 emissions per T-km of freight carried (ie, considering the load only and not the mass of the truck unit) is arguably of more relevance. This metric allows a comparison of the fuel consumed to move the same unit of goods.

Figure 2 provides this comparison, being a plot of CO_2 per T-km (for the freight component only) versus GVM for the CWS trucks.

For Figure 2, the data has been considered as one data so as to provide a trend line for the set.

Note that the data for the tanker has been removed from this analysis as the indicated time to complete the test route varied significantly between the tests conducted and suggested that the truck was not driven in a comparable manner.

[2] But, repeating, one that is statistically not significant.

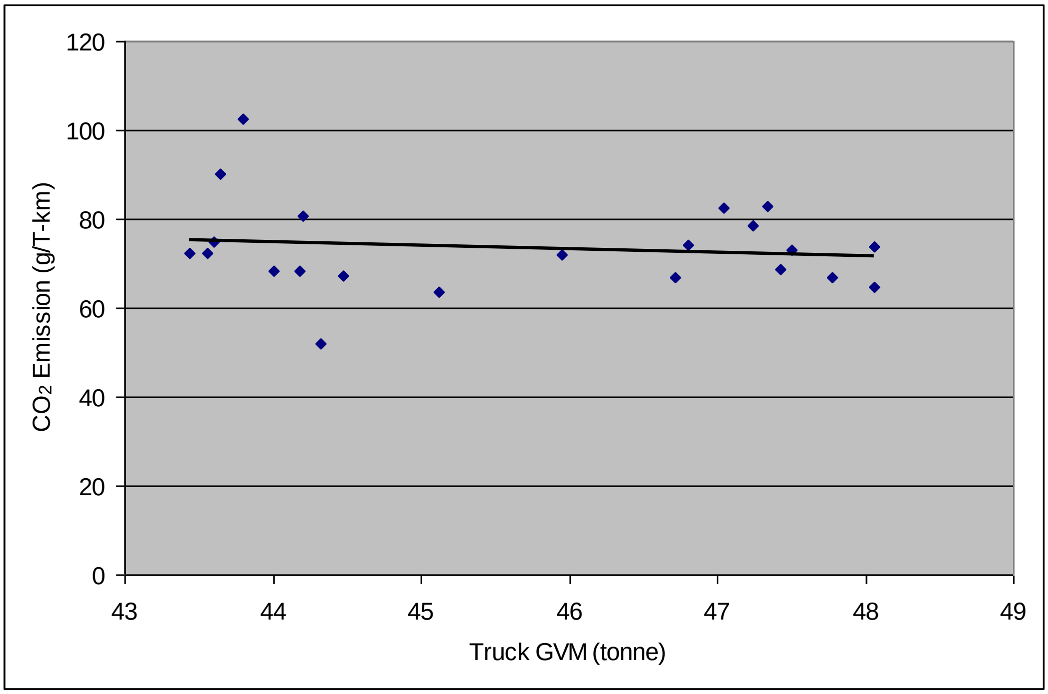

Figure 2: CO_2 Emissions per Tonne-Kilometre
Versus Truck GVM for the CWS Trucks.

Again, the scatter of results shown in Figure 2 indicates that the relationship between CO_2 emission (or fuel consumed) per T-km of freight movement and GVM, is statistically not significant when only these variables are compared. However, there is a trend of slightly decreasing CO_2 per T-km with increasing GVM (a trend of around a 5% decrease in CO_2 in moving from 44 tonnes GVM to 50 tonnes).

CO

A similar course of analysis was conducted for the other emission species. Figure 3 is a plot of CO emissions per T-km versus GVM. A y-axis scale of 0 to 1 g/T-km has been deliberately chosen to make the reader aware of the absolute value of the HC emissions – it is very small which is in keeping with the inherent emissions performance of a diesel engine. Again, scatter in the data indicates that the relationship between CO emission per T-km and GVM is statistically not significant. A decreasing linear trend line illustrates a trend of decreasing CO emission per T-km with increasing GVM (at around a 20% decrease in CO emission per T-km in moving from 44 tonnes GVM to 50 tonnes, but this is also relatively insignificant as the levels of emission are already low).

NOx

Figure 4 is a plot of NOx emissions per T-km versus GVM, using a y-axis scale of 0 to 1 g/T-km. There is scatter in the data indicating that there is no statistically significant relationship when only NOx and GVM are compared. A small slope in the trend line indicates a trend of slight decreasing NOx emission with increased GVM (but of no significance).

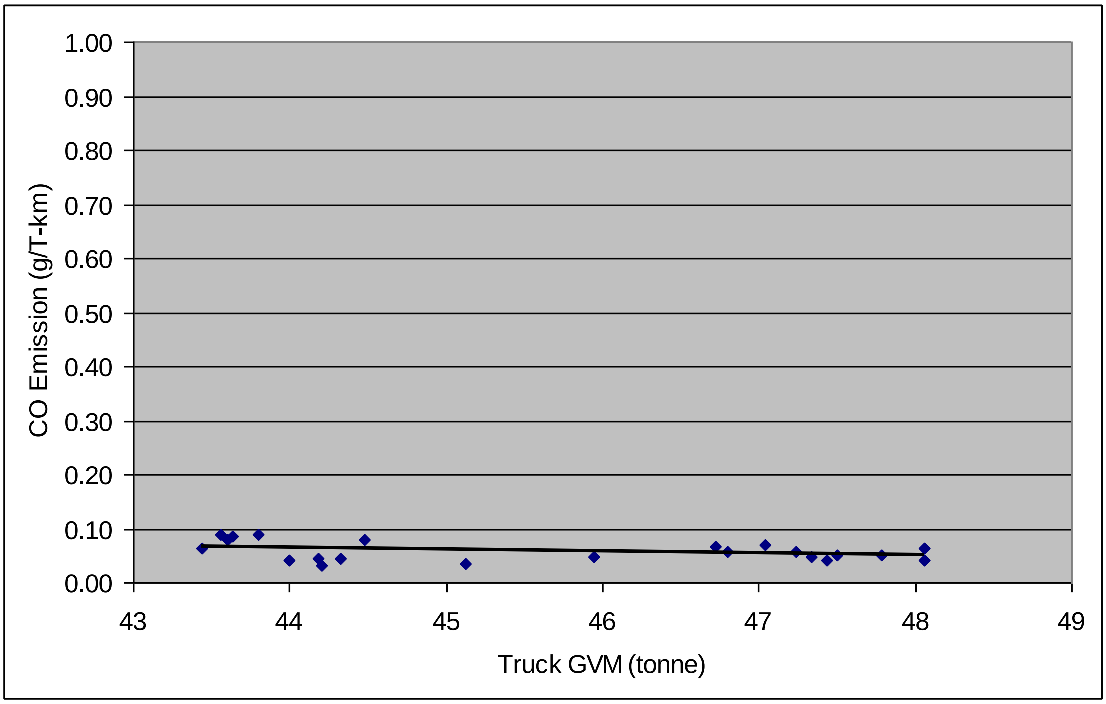

Figure 3: CO Emissions per Tonne-Kilometre Versus Truck GVM for the Various CWS Trucks.

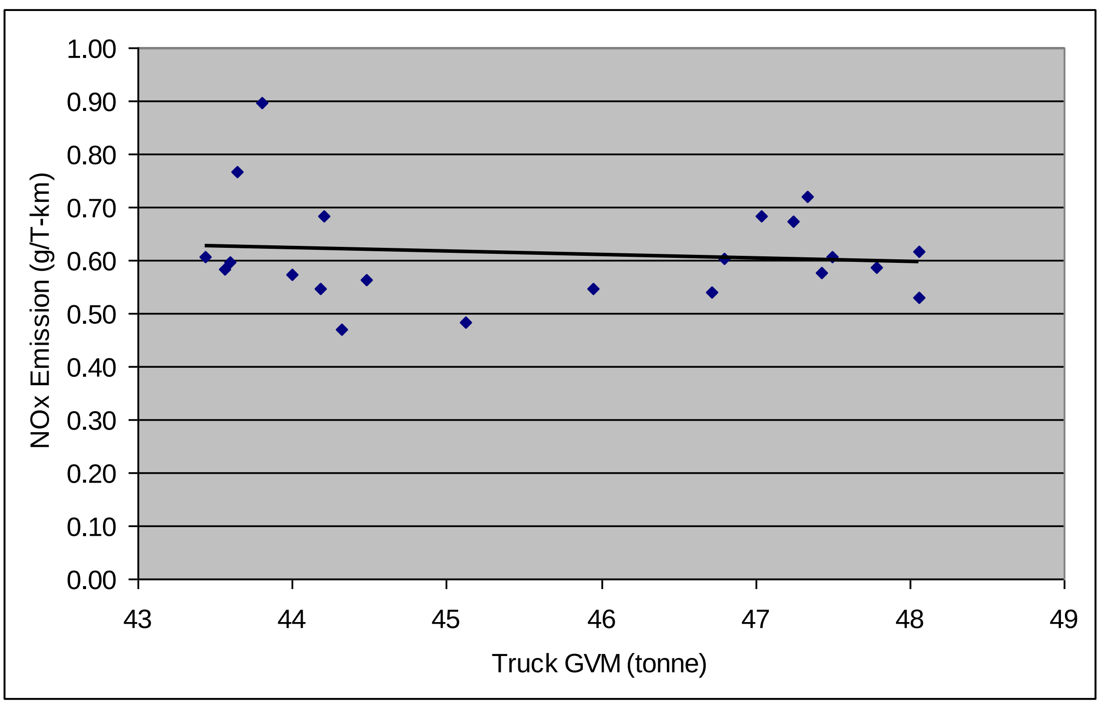

Figure 4: NOx Emissions per Tonne-Kilometre Versus Truck GVM for the Various CWS Trucks.

SO_2

Figure 5 is a plot of SO_2 emissions per T-km versus GVM, using a y-axis scale of 0 to 0.2 g/T-km (noting a finer scale has been used on this occasion in recognition of the capability of the measurement equipment and the greater concern of this emissions species compared to the other species considered). The relationship of SO_2 per T-km and GVM appears to be statistically not significant and there does not appear to be any significant trend either.

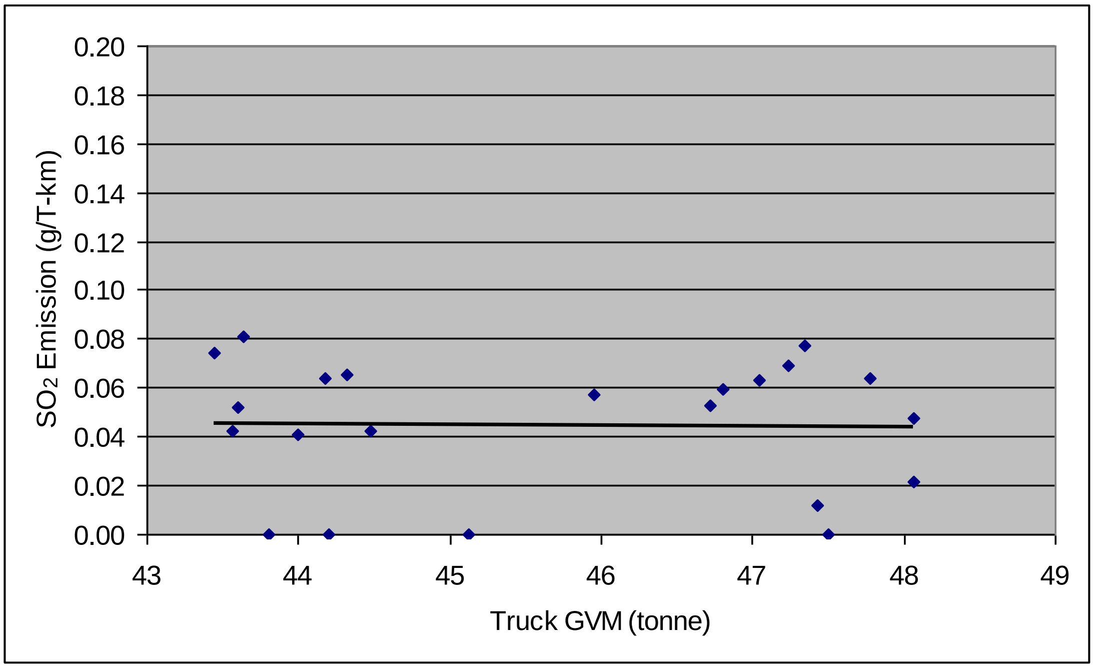

Figure 5: SO_2 Emissions per Tonne-Kilometre Versus Truck GVM for the CWS Trucks.

HC

Figure 6 is a plot of HC emissions per T-km versus GVM, using a y-axis scale of 0 to 0.2 g/T-km (noting that a finer scale has been used on this occasion simply in order to detect a difference). For the purposes of this study, all results were found to be near-zero and no change was found in moving from 44 tonnes GVM to 50 tonnes.

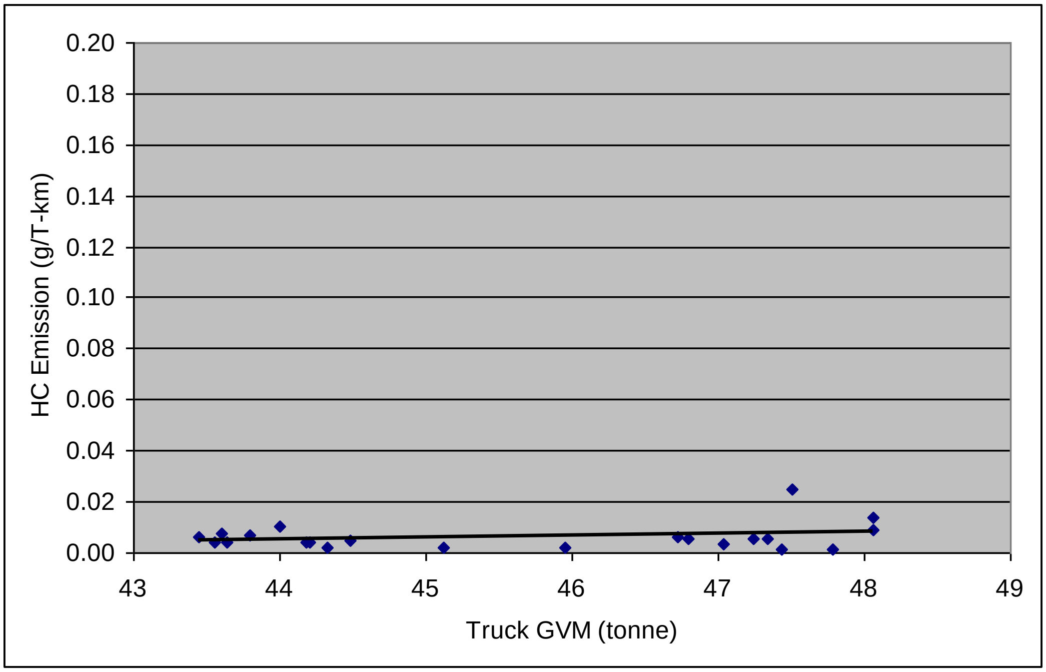

Figure 6: HC Emissions per Tonne-Kilometre
Versus Truck GVM for the CWS Trucks.

4. Conclusions

Analysis of results from emissions testing seven trucks at near 44 tonnes GVM and near 50 tonnes GVM has found:

- The relationships between the emission rates of any of the emissions species monitored and GVM were found to be statistically not significant.
- There were trends of decreasing emissions per T-km with increasing GVM for some emissions species, but these trends, where present, were either of small slope or of little significance, such were the low base emissions rates involved.

More accurately, the results of testing six trucks did not indicate any significant worsening of emission rates when moving from operation at 44 tonnes GVM to 50 tonnes GVM, when emissions were considered on a T-km of freight movement basis.

5. Recommendation

Note that care is required if extrapolating from these results as the base data is from testing only two different types of vehicles over two different routes. Different vehicle models and types are expected to respond differently. A more robust analysis would be achieved through a technical appraisal and modelling of the expected performance of the fleet for different duties and drive cycles, and verifying and calibrating this model with a limited, structured test programme.