1997

On-road CO, HC, NO and Opacity Measurements (Presentation)

Donald H. Stedman

Gary A. Bishop

Phillip Aldrete

7TH CRC ON-ROAD VEHICLE EMISSIONS WORKSHOP
San Diego, California
April 9-11, 1997

ON-ROAD CO, HC, NO AND OPACITY MEASUREMENTS

Donald Stedman, Gary Bishop, and Phillip Aldrete

University of Denver, Dept. of Chemistry and Biochemistry, Denver, CO 80208-2436 (P.A. Aurora Central High School)

ABSTRACT

On-road exhaust emissions measurements of 26,000 identified vehicles in Denver Colorado have been made and correlated by model year with results of the Colorado State IM240 emissions testing program. The correlation coefficients (r2) are 0.96, 0.96 and 0.97 for CO, HC and NO respectively. These results show that on-road measurements can be used to directly evaluate fleet emissions changes in a manner comparable to IM240 results. Light duty diesel vehicles showed significantly larger opacity readings than equivalent age gasoline powered vehicles. A larger data base of on-road exhaust emissions from light duty diesel vehicles was obtained in Europe. These data show that light duty diesels have much lower CO and higher opacity than the equivalent age gasoline powered fleet. Diesel HC and NO exhaust emissions are lower than pre-catalyst vehicles, but higher than catalyst equipped gasoline powered vehicles of the same age. Fleet average, light duty diesel vehicle emissions vary with age/model year much less than the gasoline powered fleet.

RESULTS AND DISCUSSION

One of the potential uses of on-road remote sensing is the development of low-cost emissions inventories for a particular location or area (1,2). The fact that on-road emissions are directly correlatable to emissions in gm/gallon of fuel sold is sometimes an advantage over VMT based modelling because VMT themselves are not as well known as fuel sales (3).

Perhaps the most accurate use of remote sensing data is to evaluate the differences between identified fleet emissions measured at the same time and place. An advantage of these studies is that observed emissions differences are independent of any uncertainty in calibration or driving mode since both fleets are measured interspersed randomly together. This method has been used to evaluate the benefits (or not) of I/M programs, and to observe differences between vehicles of the same age but different registration status (4,5,6).

Figure 1 shows the correlation between fleet average on-road emissions by model year (on the y-axis) from 26,000 vehicles measured at the ramp from Northbound I-25 to Westbound 6th Ave. in Denver in 1995-6, compared to the same average reported by the Colorado Dept. of Health and Environment from their (then new) 1995 IM240 program, using a specific data set (NONFAST.DAT) for about 40,000 vehicles which had not been allowed to obtain a FAST PASS reading. There are only a few thousand vehicles in common between the data sets. The excellent correlations observed (r^2 of 0.96, 0.97 and 0.97 for CO, HC and NO respectively) show that both testing methods are reporting the same phenomenon of average year to year emissions increase from the Colorado fleet.

Figure 2 shows the on-road data but split out between vehicles registered by the Colorado DMV as cars and trucks. The higher emissions of trucks than cars shown on-road is also observed in the IM240 database although the car/truck categorizations are slightly different. From these data it is apparent that the small effectiveness ($4\pm2\%$ for CO and zero for HC and NO) observed on-road for the Colorado I/M program (6) would be reflected in IM240 data were random IM240 testing to be carried out.

Figure 3 shows the on-road readings of average opacity by model year for the small fleet of light duty diesel vehicles observed. Apparently the on-road opacity system measures higher opacity from diesel vehicles, as expected, but the fleet is too small for the data not to show a lot of "noise". The statistics suggest that diesel opacity, like gasoline emissions, is gamma distributed, namely a few vehicles contribute most of the pollution, thus causing small data sets to show large "noise" even when averaged. For this reason to demonstrate that the opacity measurements are useful it is important to look at emissions from a much larger fleet including light duty diesel vehicles. A study sponsored by Shell Europe (discussed in more detail at this conference by A Mercer of Shell) provides such a database.

Figure 4 shows data from one site in one city (Milan Italy) comparing CO from gasoline and diesel fleets by model year. the expected very low, unchanging with time, emissions from the diesel fleet is observed, however the modern, catalyst equipped gasoline vehicles come very close. Figure 5 shows the same data for hydrocarbons, in which the modern gasoline powered vehicles do better than the diesels. A similar picture for NO is shown by Figure 6. Again the per liter emissions from the diesel fleet are lower than their gasoline powered counterparts until the last two model years. For opacity the CO graph is effectively switched with Figure 7 showing diesels coming out higher than gasoline powered cars in all model years.

In Rotterdam the results were similar except the NO readings from all fuels were higher (the site was at higher load) and the CO, HC and opacity were all lower than Milan. In Rotterdam we were able to show, as has been shown in numerous studies elsewhere, that in real life, LPG fuelled vehicles do not appear to have lower on-road emissions that their gasoline powered counterparts. The only caveat to this conclusion concerns tailpipe HC emissions which, if mostly propane, will be measured with unit efficiency by remote sensing whereas the suite of HCs from gasoline powered cars gives lower absorption per carbon atom by a factor close to 2.5 (1).

Readers of our previous studies will not find it remarkable that we conclude from these results that on-road remote sensing is a very cost-effective method to determine fleet average emissions and to evaluate emissions reductions programs such as IM240 (which does not appear to work very well) and so-called "CLEANER BURNING" fuels which do not appear to be.

ACKNOWLEDGEMENTS

We appreciate permission from Shell to use some of their European on-road emissions data.

REFERENCES

1. "A Fuel-Based Motor Vehicle Emissions Inventory for the San Francisco Bay Area", D.R. Black, B.C. Singer, R.A. Harley, P.T. Martien and A.K. Fanai, Presented at AWMA Meeting Toronto Canada, June, 1997.

2. "A Fuel-Based Motor Vehicle Emissions Inventory", B.C. Singer and R.A. Harley, **J. Air Waste Management Assoc., 46**, 581-593, 1996.

3. "Measuring the Emissions of Passing Cars", D.H. Stedman and G.A. Bishop, **Acc. Chem. Res., 29**, 489-495, 1996.

4. "Ute Pass Carbon Monoxide Emissions Study", R.L. Ostop and L.T. Ryder, Report to the City of Colorado Springs, 1986.

5. "On-Road Evaluation of I/M Effectiveness", Y. Zhang, G.A. Bishop, S.P. Beaton, P.L. Guenther and D.H. Stedman, **Environ. Sci. Technol. 30**, 1445-1450, 1996.

6. "On-Road Evaluation of an Automobile Emission Test Program", D.H. Stedman, G.A. Bishop, P. Aldrete, and R.S. Slott, **Environ. Sci. Technol. 31**, 927-931, 1997.

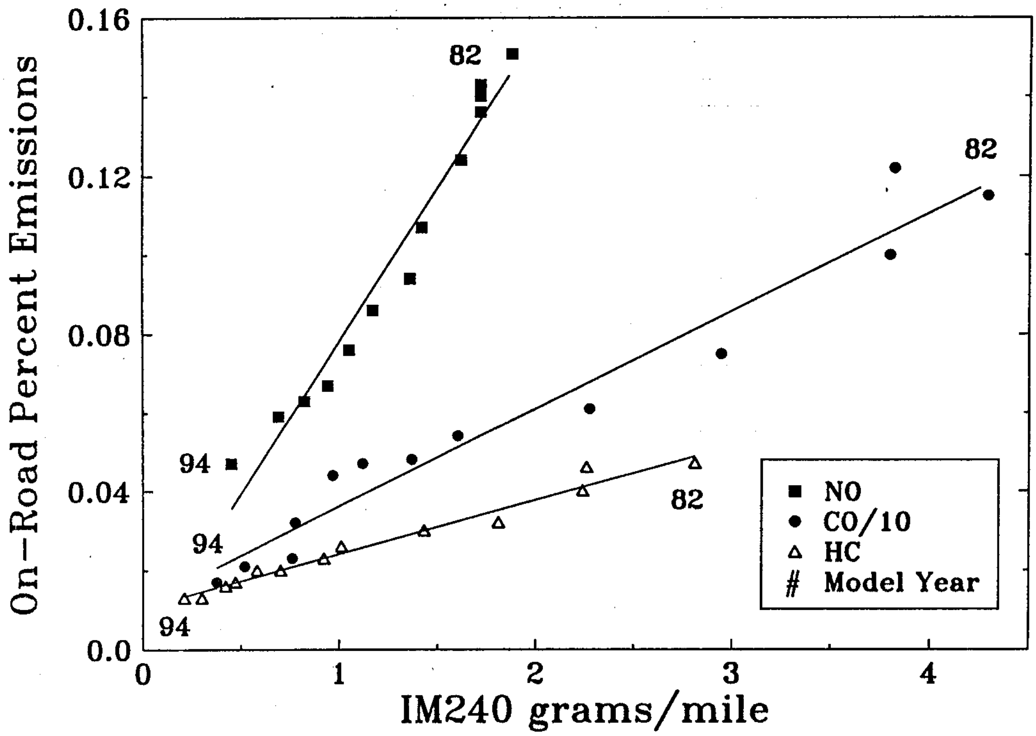

Figure 1. Correlation between fleet average on-road emissions by model year from vehicles measured at the ramp from Northbound I-25 to Westbound 6th Ave. in Denver in 1995-6 to Colorado IM240 data.

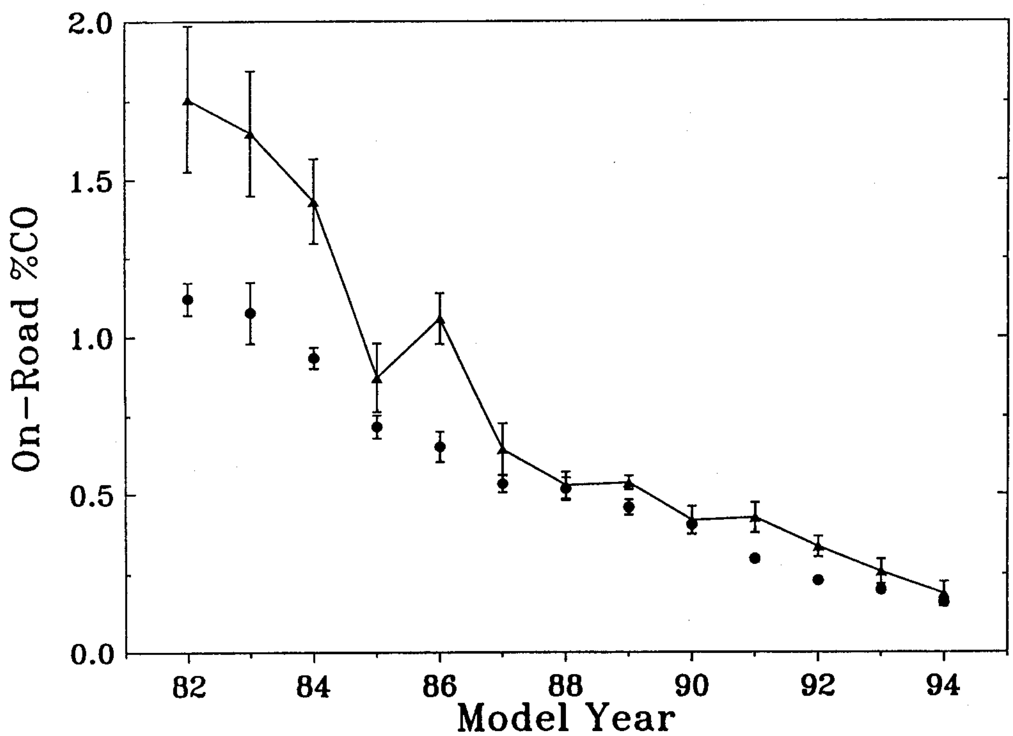

Figure 2. The same on-road data but split out between vehicles registered by the Colorado DMV as cars and trucks.

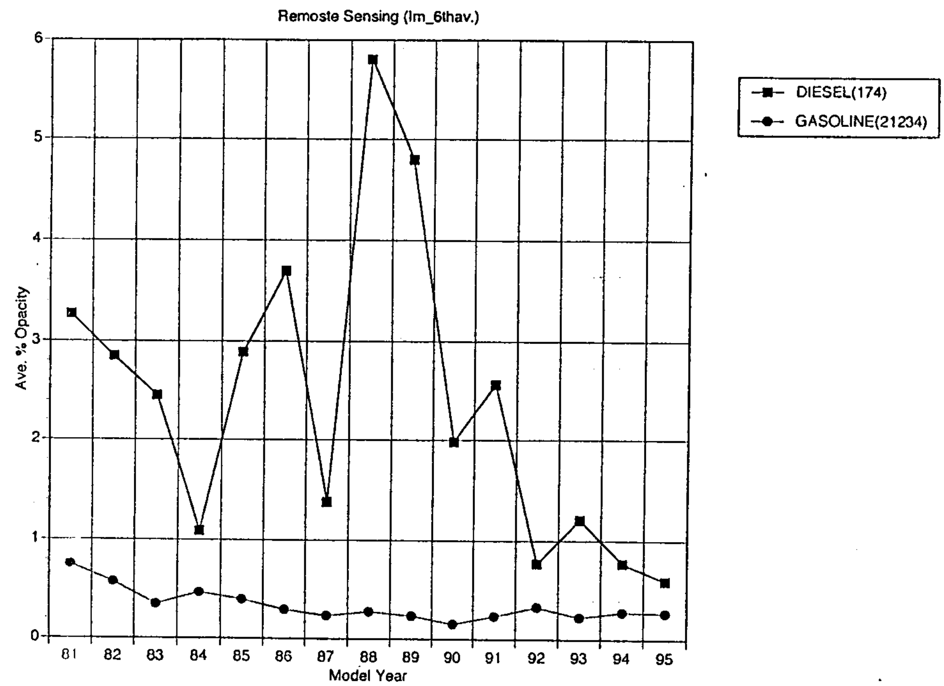

Figure 3. On-road readings of average opacity by model year showing the small fleet of light duty diesel vehicles observed, together with the gasoline powered fleet.

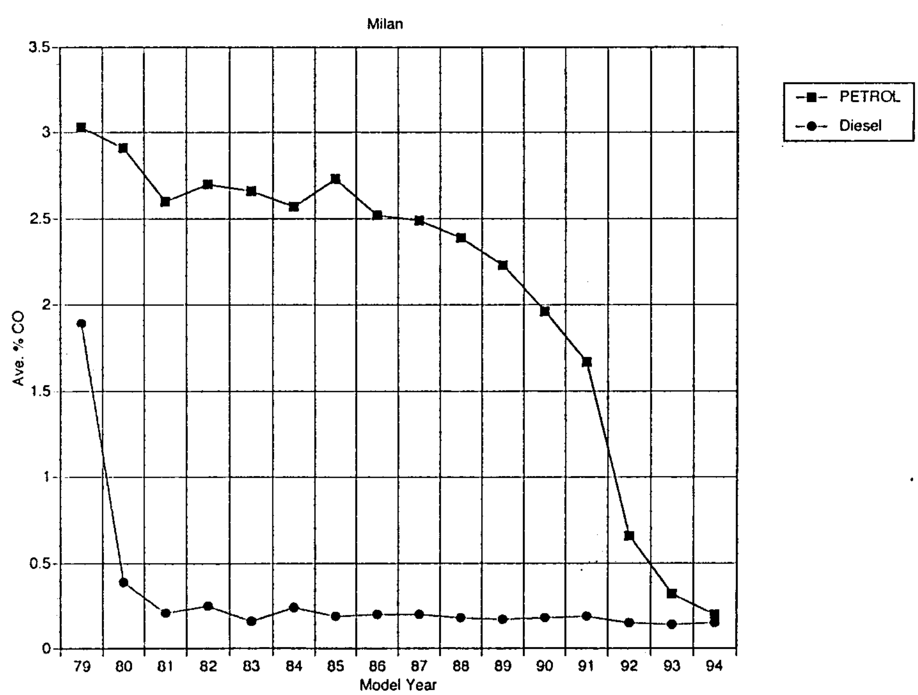

Figure 4. Data from the single measurement site in Milan Italy comparing on-road CO emissions from gasoline and diesel fleets by model year.

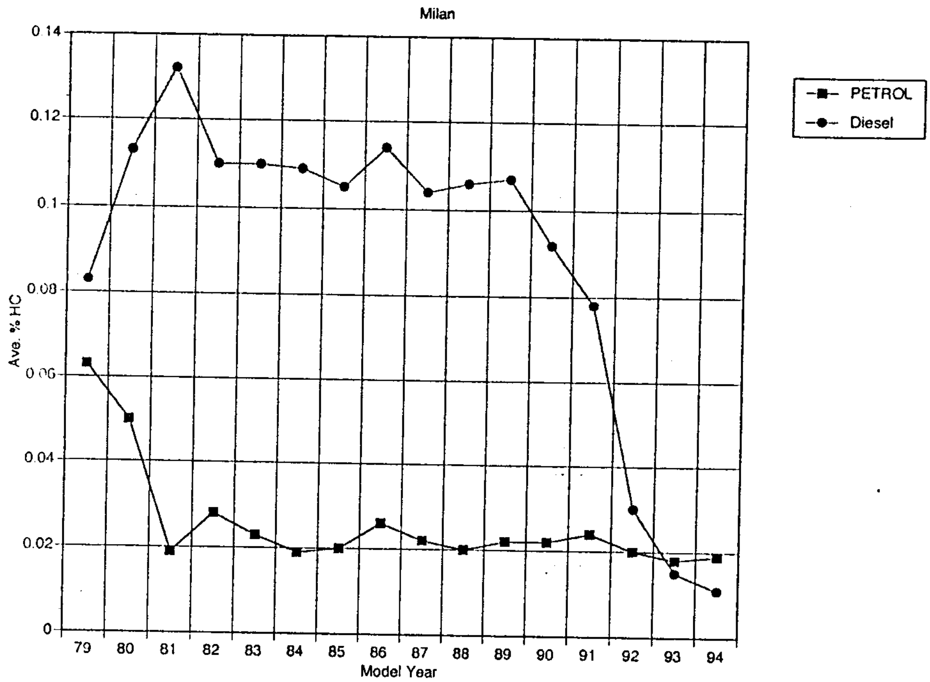

Figure 5. Same as Fig. 4 but for hydrocarbons.

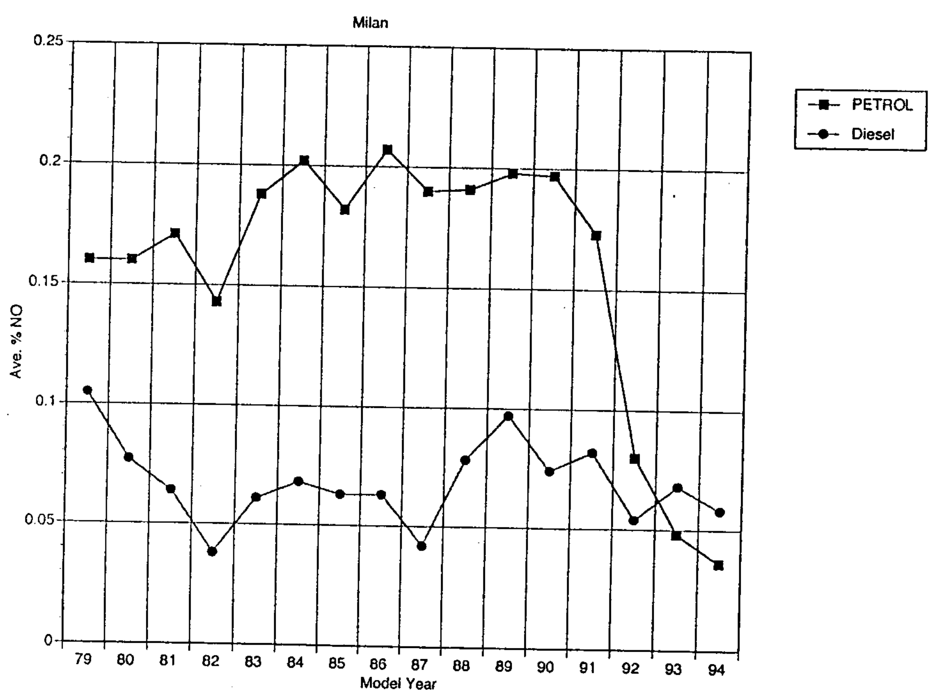

Figure 6. Same as Fig. 4 but for NO.

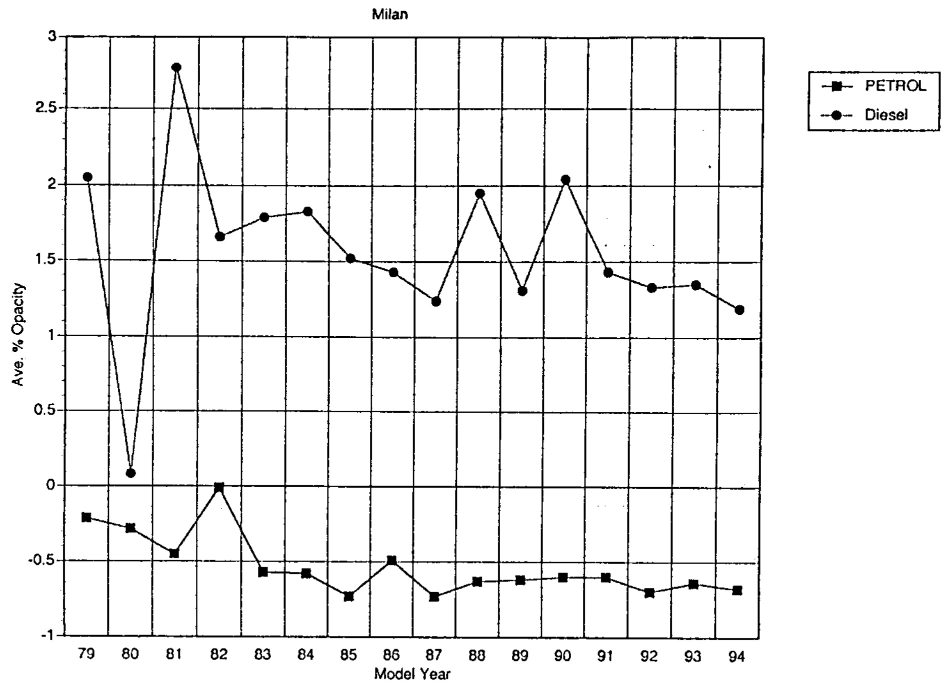

Figure 7. Same as Fig. 4 but for opacity.