Carbon Monoxide Automobile Emissions Measured from the Interior of a Traveling Automobile

Abstract. *During a procedure to monitor carbon monoxide (CO) concentrations inside a traveling car, it was discovered that CO emissions from individual passing vehicles produced accurately measurable increases in the CO concentration. The CO produced by individual vehicles varied by three orders of magnitude; this finding demonstrates that a relatively small number of cars can be responsible for a high percentage of total vehicle CO emissions.*

The purpose of this study was to determine the CO concentrations to which the driver of a typical passenger car was exposed while traveling under a variety of traffic conditions. The maximum concentrations of CO permitted by the Federal Ambient Air Quality Standards, (FAAQS) (*1*) set in accordance with the Clean Air Act, are 9 parts per million (ppm) for 8 hours and 35 ppm for 1 hour. While recording CO concentrations inside automobiles on lightly traveled sections of an interstate highway, I observed that CO emissions from individual passing cars produced clearly defined peaks on the strip chart recorder. Subsequent measurements on 760 vehicles showed a surprisingly wide variation in CO concentrations from 0.05 ppm to 45 ppm. Analysis of the data showed that a large proportion of the vehicles monitored produced only a small amount of the total CO, whereas a relatively small number of the total vehicles contributed almost half of the total monitored CO.

The gas filter correlation monitor used for this study was especially designed for the Environmental Protection Agency for use in modeling studies (*2*) carried out during the St. Louis Regional Air Pollution Study (*3*). The monitor is portable and can be battery-operated; hence, the monitor can readily be operated on the front passenger seat of an automobile. I determined the CO concentrations by measuring the attenuation of a focused infrared beam which makes 28 traverses of a cell 0.6 m long. This is accomplished with mirrors placed at each end of the cell. The top of the cell compartment was removed to permit an in situ measurement of the CO concentration. The time constant was set at 3 seconds. The windows of the automobile were closed, and the ventilation was forced by operating the automobile blower fan at the maximum speed. The data were recorded on a portable strip chart recorder mounted directly under the monitor so that the record could be observed and marked by the driver. Two small (15 cm in outside diameter and 51 cm long) high-pressure cylinders, one containing argon and the other containing 3.0 ppm of CO in nitrogen were placed on the floor behind the front seat. The gases in these two cylinders were used in a daily, zero and span, two-point calibration, usually carried out at a rest stop. Before and after the trip, I carried out a five-point calibration, using a gas mixture calibrated by the National Bureau of Standards. The average difference between the calibrations was 3 percent, and I estimate that the maximum measurement error is 10 percent.

The data were collected during a two-part, cross-country trip. Part 1 was from Chicago to New Orleans, 18 to 20 March 1977, and part 2 was from New Orleans to San Diego, 27 March to 2 April 1977. The expectation was that the average CO concentration would gradually increase as cities were approached, reach a maximum near the center of a city, and fall to a minimum in the rural areas. In general, this was found to be true; however, very large fluctuations occurred depending mostly on traffic density and traffic speed.

Examples of data collected on heavily traveled interstate highways are those from the Dan Ryan Expressway (I-94) in Chicago (Fig. 1a) and the San Diego Freeway (I-405) in Los Angeles (Fig. 1b). The peaks in the concentration are primarily the result of traffic slowing down as a result of congestion. When the traffic slowed to 10 miles per hour (mph) or less (1 mile = 1.6 km), the CO concentration usually exceeded 15 ppm; when it halted completely, the CO concentration was about 45 ppm.

In order to compare the CO concentration on interstate highways with that in maximum downtown traffic, I made a trip through downtown New Orleans between 1200 and 1230 C.S.T. on 23 March 1977. The traffic moved at only a few miles per hour and stopped at every traffic light. The CO concentration varied from 2 to 50 ppm, depending primarily on the number of stationary or accelerating vehicles in close vicinity to the

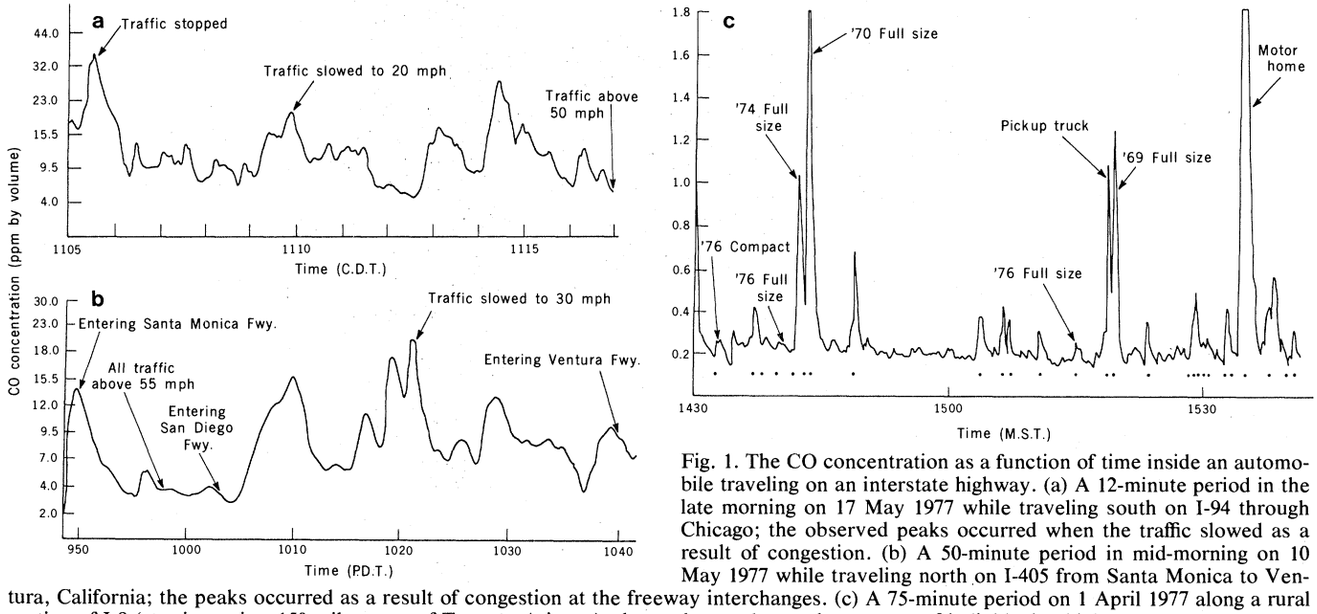

Fig. 1. The CO concentration as a function of time inside an automobile traveling on an interstate highway. (a) A 12-minute period in the late morning on 17 May 1977 while traveling south on I-94 through Chicago; the observed peaks occurred when the traffic slowed as a result of congestion. (b) A 50-minute period in mid-morning on 10 May 1977 while traveling north on I-405 from Santa Monica to Ventura, California; the peaks occurred as a result of congestion at the freeway interchanges. (c) A 75-minute period on 1 April 1977 along a rural section of I-8 (starting point, 150 miles west of Tucson, Arizona); the peaks are due to the passage of individual vehicles.

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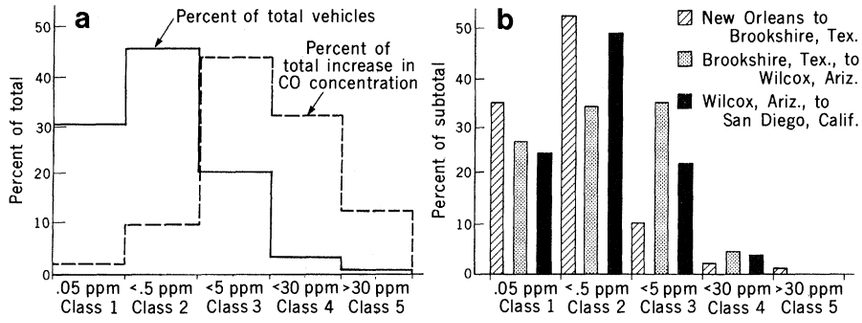

Fig. 2. Data summary of 760 vehicles monitored on I-8 from New Orleans to San Diego (28 March to 2 April 1977): (a) distribution of vehicles and CO emission by class; (b) distribution of vehicles by class for three subgroups of the total sample.

monitoring vehicle. The results of these experiments correlated with the expectations.

The surprising results occurred along the rural, rather than the urban, portions of the route. The strip chart used for recording the rural data required that the sensitivity and chart speed be adjusted to accommodate the maximum CO concentration and the traffic density. As a result of the attention required to make these adjustments, the speed of the monitoring vehicle was somewhat slower than normal. Thus, many of the other vehicles on the highway were passing at their normal cruising speed of about 60 mph. I noticed that the CO concentration in the instrumented vehicle would increase abruptly a few seconds after the passage of some but not all vehicles. I decided to monitor the increase in CO concentration due to the passage of single vehicles in a uniformly controlled manner. The procedure that I adopted was to drive the monitoring vehicle at about 52 mph so that most of the other traffic passed with a differential speed of from 3 to 10 mph. The usual pattern of the passing vehicles after passing was to return to the traveling lane about 50 feet ahead of the monitoring vehicle. If for some reason the passing vehicle remained in the passing lane and there was no other vehicle approaching, then I also moved the monitoring vehicle into the passing lane. A sample recording of some of the data collected by this technique is shown in Fig. 1c. A few of the peaks that were positively identified with a given vehicle are noted.

The monitoring procedure described above was developed during the trip from Chicago to New Orleans and was used during the trip from New Orleans to San Diego to collect the data summarized in Fig. 2. The only vehicles included in the tabulation were those that passed singly with sufficient distance between the other vehicles to permit a clear identification of the peak in the monitored CO concentration with the passing vehicle. In order for this condition to hold, the traffic density had to be sufficiently low. Hence virtually all the data were collected in rural areas, usually 20 miles or more from a metropolitan area.

While recording the data, I observed that heavily loaded vehicles produced high CO concentrations. Also, whenever a grade was being ascended, the CO concentrations increased. In order to determine the effect of a steep grade, I followed a truck over the Sierra Nevada mountains. The CO concentrations increased and decreased by more than one order of magnitude, depending on the grade. The CO concentration inside the monitoring vehicle reached 50 ppm on the most severe part of the grade and remained over 25 ppm for ½ hour. Clearly, under some circumstances the potential to exceed the FAAQS exists.

I monitored a total of 760 vehicles by this technique on part 2 of the trip. These were divided into five classes based on the maximum increase in CO concentration measured inside the monitoring vehicle. The classes were as follows: class 1, maximum increase less than 0.05 ppm; these vehicles were all 1975, 1976, or 1977 models lightly loaded (less than half of the designed load); class 2, maximum increase between 0.05 and 0.5 ppm; these were mostly 1970 through 1974 models and some newer cars carrying heavy loads (100 percent or more of the designed load); class 3, maximum increase between 0.5 and 5 ppm; this class includes largely older cars but also some heavily loaded newer vehicles such as motor homes and pickup trucks; class 4, maximum increase between 5 and 30 ppm; these were all heavily loaded vehicles, most of them older than 1970; and class 5, maximum increase greater than 30 ppm; there were two vehicles in this class: one was a pickup truck pulling a four-horse trailer; the other (CO concentration, 45 ppm) was a no-brand fuel oil delivery truck.

The peak measured increase in CO concentrations for all the vehicles in each class were added, and the percentage contribution of each class to the total concentration was computed. The results are shown in Fig. 2a. If the vehicles falling in class 1 and class 2 are grouped together, they represent 76 percent of all the vehicles observed and contribute 12 percent of the total CO; class 4 and class 5 combined represent 3.3 percent of the total vehicles and contribute 45 percent of the total CO. The finding that 30 percent of the vehicles monitored appeared to be equipped with catalytic converters is in agreement with a recent study done in California (*4*).

In order to develop some feeling for the variability of the data, I divided the total data set into three nearly equal parts. The first third contained the data collected from New Orleans to Brookshire, Texas; the second third from Brookshire, Texas, to Wilcox, Arizona; and the last third from Wilcox, Arizona, to San Diego, California. The percentage of vehicles in each class was determined for each third of the total sample (Fig. 2b). In the second third of the sample, there was a smaller percentage of the vehicles in class 2 and a greater percentage in class 3 than for the sample as a whole. The reason is probably due to more uphill grades in this section of the route as well as differences in wind speed and wind direction. However, the overall pattern is much the same for all three sections of the route, which reaffirms the character of the total distribution.

As a result of the experiments conducted in the urban areas, I conclude that most drivers are not exposed to toxic doses of CO but that under certain circumstances the potential exists to exceed the FAAQS. The major observations resulting from the data are that the CO automobile emissions can vary by three orders of magnitude depending on a number of factors and that more attention should be directed toward that small minority of vehicles which are the major polluters.

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References and Notes

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5. Supported by Environmental Protection Agency grant R-803399.

6 October 1977; revised 5 December 1977