Evaluation of Street-Level Carbon Monoxide Levels in the U.S.

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Abstract

Carbon monoxide (CO) levels are routinely monitored in the U.S. at agency monitoring stations; however, these stations are purposely located away from sources at an elevation above breathing zone height. There are few published data regarding street level or breathing zone concentrations in the U.S. associated with general use of automobiles and other combustion sources. We provide a review of the available published literature and agency reports that provide street level CO. In addition, we recorded real-time CO levels at busy intersections in San Francisco, California, relevant to pedestrians, cyclists, and car occupants as well as workers, such as street vendors, drivers, and other workers who may spend significant time near areas with heavy traffic. We also collected CO measurements in garage settings.

Introduction

CO is a well-known air pollutant, largely originating from incomplete combustion of fuel in motor vehicles. The Occupational Safety and Health Administration (OSHA) has established a permissible exposure limit (PEL) of 50 ppm CO in workplace air averaged over an 8-hour day. For outdoor ambient levels, the Environmental Protection Agency (EPA) has established a National Ambient Air Quality Standard of 9 ppm CO averaged over 8 hours and not to be exceeded more than once per year.

Methods

Our methods consist of the following

1. A review and summary of the published scientific literature and government agency reports via PubMed, Google, and agency websites for street-level CO concentrations. The time period of focus was 1995–2020 as CO regulations and technology improvements have resulted in reduced emissions.
2. Measurement of real-time CO levels using the ToxiRAE Pro portable gas monitor (manufactured by RAE Systems). Measurements were collected on multiple dates at various street locations, tunnels and garages in the San Francisco Bay Area at 1-second intervals during the months of January and February, 2020. The detection limit of the monitor was 1 ppm.

Photo 1. ToxiRAE Pro portable gas monitor

Literature Review

A review of the literature resulted in only four U.S. studies in the past 25 years on street-level CO concentrations. These studies reported concentrations of CO in vehicles, on bicycles, in traffic, on sidewalks, and downwind of a freeway. The mean concentrations ranged from 0.1 to 4.0 ppm, with maximum concentrations reported up to 10.6 ppm. One additional study conducted in 1995 in the Netherlands reported mean levels of up to 5.9 ppm. These studies are summarized in Table 1.

Table 1. Summary of Street Level CO concentrations reported in Literature (ppm)

Author	Year	Location	Receptor/Location	Sampling Period[a]	N	Min	Mean	Max
Chang et al.	2000	Baltimore, MD	In vehicle Outdoor near road Outdoor away from road	60 min	83 27 20	-	~2.8–4.0 ~0.8 ~0.5–0.7	-
Jarjour et al.	2013	Berkeley, CA	Bike – low traffic route Bike – high traffic route	28.7–49.5 min	8 10	0.20 0.10	0.79 0.90	4.9 10.60
Jiao & Frey	2014	Raleigh, NC	Bus commuters Car commuters Pedestrians	120 min 84 40	87	-	0.7–0.9 1.0–1.7 0.7-0.8	-
van Wijnen et al.	1995	Amsterdam, Netherlands	Bus commuters Car commuters Pedestrians	30 min	82 71 10	<0.5 <0.5 1.6	<0.5–2.3 <0.5–5.9 2.1	-
Zhu et al.	2002	Los Angeles, CA	Upwind of freeway (200m) Downwind of freeway (17m) Downwind of freeway (20m) Downwind of freeway (30m) Downwind of freeway (90m) Downwind of freeway (150m) Downwind of freeway (300m)	120 min	Various	0.0 1.9 1.5 1.1 0.2 0.1 0.1	0.1 2.3 2.0 1.7 0.5 0.4 0.2	0.2 2.6 2.4 1.9 0.7 0.5 0.3

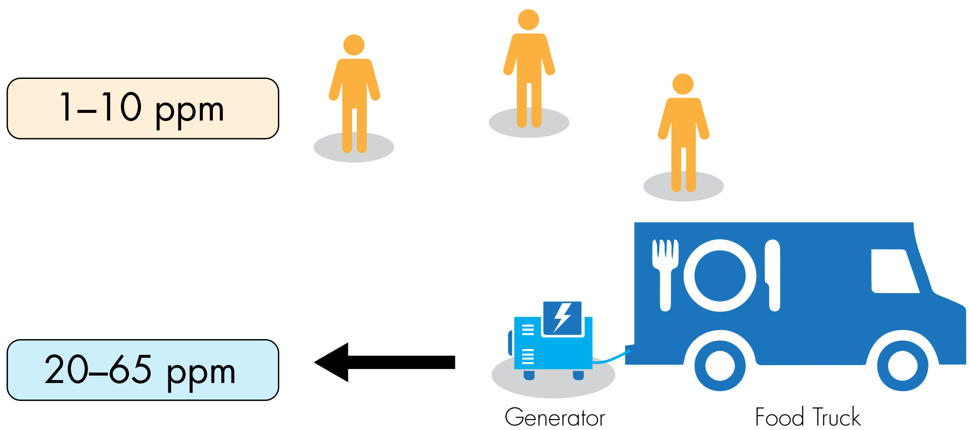
[a] The concentrations are not necessarily time-weighted averages during the sampling periods. Studies varied in sample averaging time and instrument methods.

Current Study

Street-level CO was measured at two main locations: downtown San Francisco and inside Bay Area traffic tunnels. Measurements in downtown San Francisco took place along a major street for several blocks with heavy traffic as well as inside a nearby bus terminal. Various locations were monitored, such as at a crosswalk adjacent to heavy traffic, adjacent to large commercial trucks, in a partially covered hotel taxi stand, at bus stops, and at locations of various street vendors. The majority of buses in San Francisco are fully electric, with others being electric-hybrid buses with tailpipes located at the top of the bus, rather than the bottom near the breathing area of a person on the street. The concentrations measured in the newly built bus terminal were all non-detect despite multiple buses in an almost-indoor environment; the terminal also had numerous large exhaust fans. These locations were all under the detection limit of 1.0 ppm and read as 0 ppm.

Concentrations were measured adjacent to a food stand that used a small gasoline-powered generator. High levels (20–65 ppm) were detected in the area in the line of the exhaust of the generator from 4 to 20 feet away. Levels of 1 to 10 ppm were detected in adjacent areas where a person may stand in line to order food. These locations and results are summarized in Figure 1.

Figure 1.
Diagram of sampling at food truck stand.



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To evaluate CO levels inside traffic tunnels, we drove through two Bay Area tunnels two times each with the monitor mounted on the driver's side door to represent driver exposures. The tunnels were built over 50 years ago and have two lanes of traffic, with each approximately 0.6 miles in length. The concentrations on each trip during the evening commute (4:00–6:00 p.m.) with speeds ranging 15 to 45 mph fluctuated from 0 to 2 ppm CO for the one- to two-minute ride.

Photo 2. Monitor placement on car door.

To further evaluate the concentrations adjacent to vehicle tail pipes, we evaluated several scenarios in a large open parking garage with a vehicle idling. We monitored the concentration approximately 10 feet directly behind the tail pipe of a 2015 model year sedan with a gasoline-based conventional engine. As shown in Figure 3, the concentration after engine start quickly peaked at 12 ppm over a 10-second period and then slowly tapered to between 0 and 1 ppm. Additional measurements collected adjacent to the vehicle after revving the engine also hovered between 0 and 1 ppm and reflect the well-diluted open air garage conditions.

Figure 2. CO Concentration 10 feet from tailpipe in open air parking garage

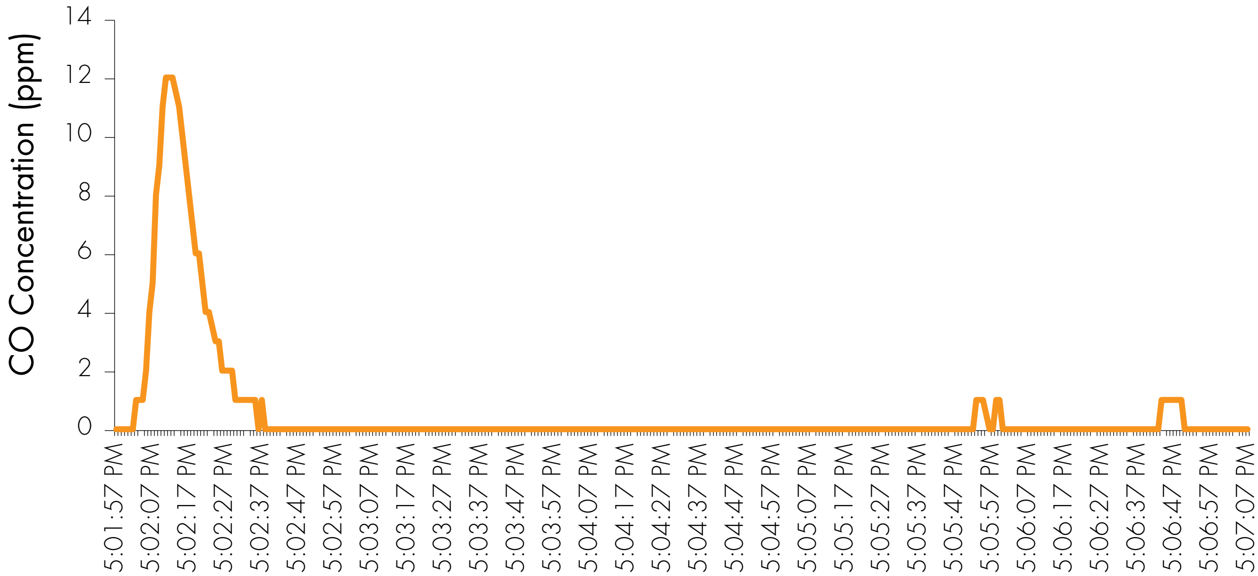
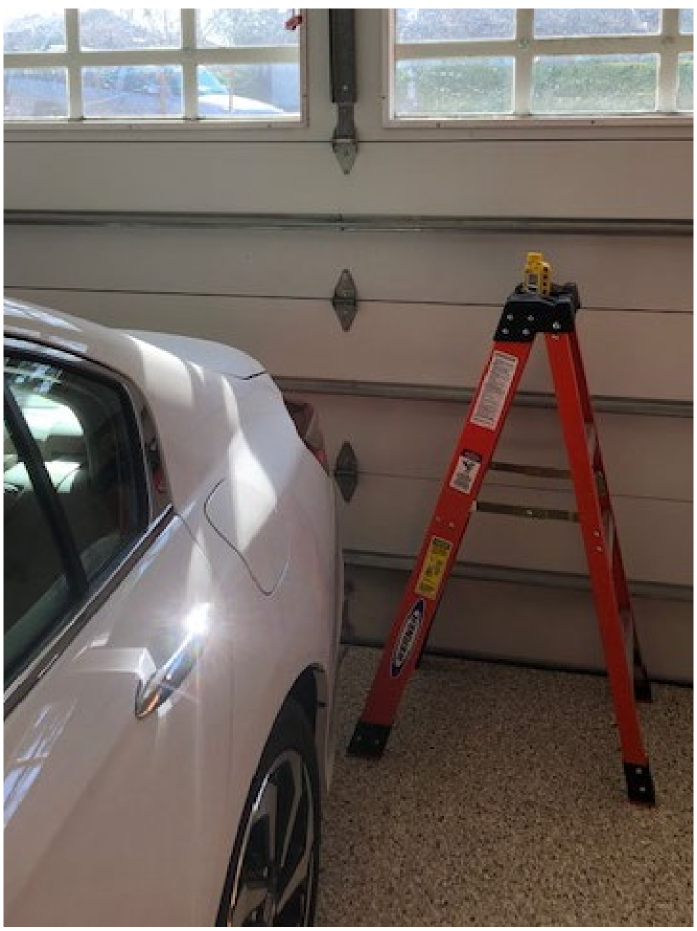
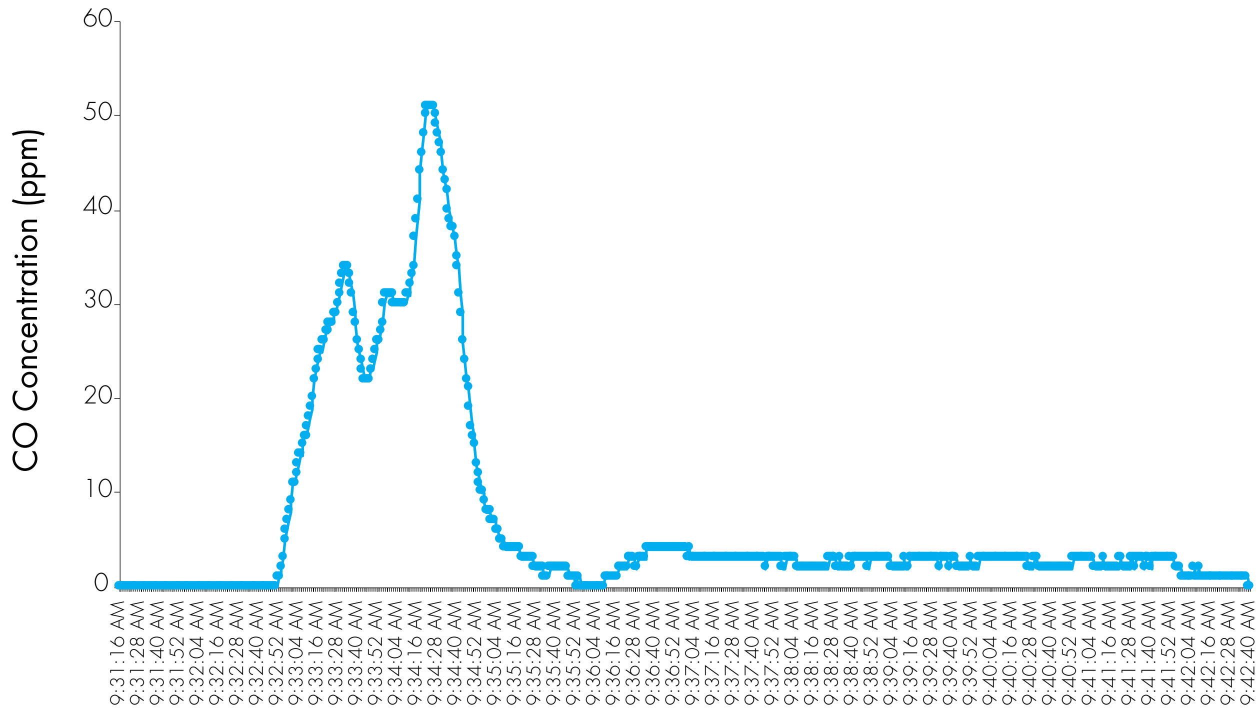


Photo 3. Monitor Placement in Residential Garage



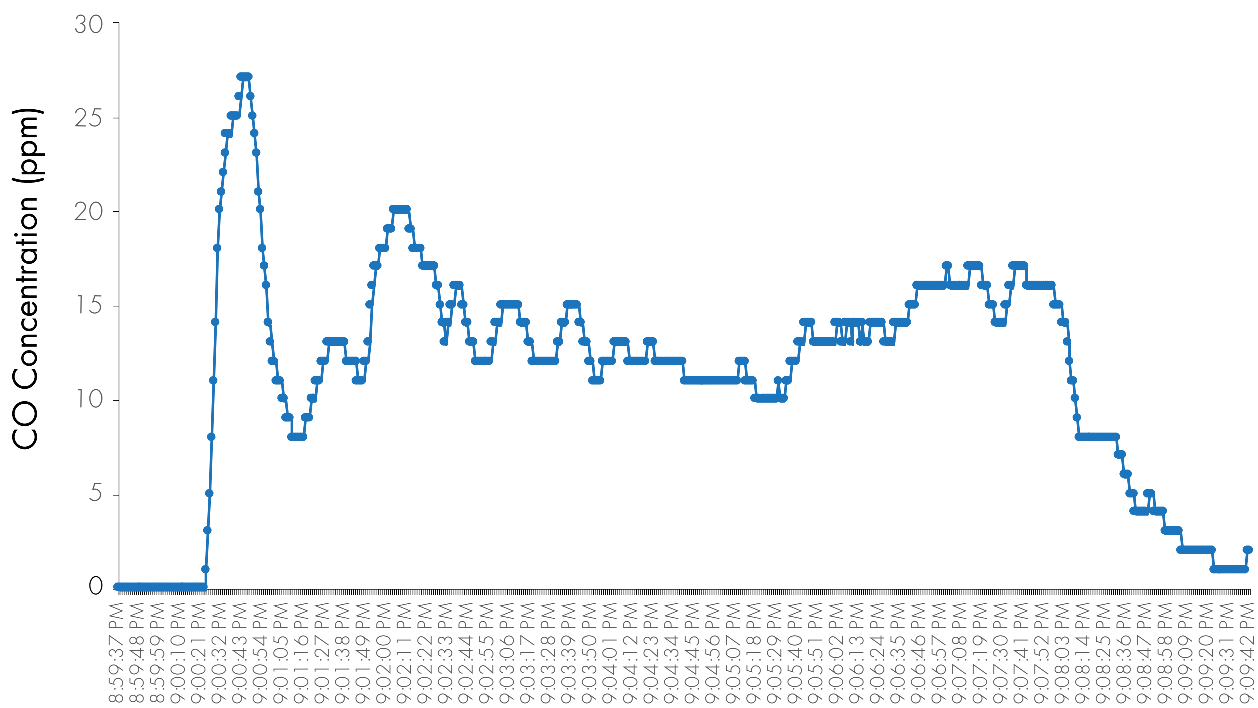
Finally, we measured CO concentrations inside a residential garage with a 2015 model year sedan idling while the garage door was closed and then opened. In Test 1, the monitor was placed at the rear of the car. For Test 2, breathing zone concentrations were obtained while a person simulated unloading and loading of the car trunk.

Figure 3. Test 1: CO Concentration near trunk of car in residential garage



As shown in Test 1, CO levels reached concentrations up to 50 ppm in the immediate vicinity of the car trunk with the garage door closed. The CO quickly dropped to 0 ppm when the garage door was opened.

Figure 4. Test 2: Breathing zone CO concentrations when simulating loading/unloading items from trunk of car



As shown in Test 2, CO levels reached concentrations of 28 ppm in the immediate vicinity of the car trunk with the garage door closed. The monitor was removed from the stationary location (shown in Figure 3) and placed on the lapel of the volunteer who proceeded to simulate loading and unloading the trunk as CO concentrations stabilized around 12 ppm for 6-7 minutes. The CO concentration dropped to 0 ppm within 1 minute after the garage door was opened.

Conclusions

In general, CO concentrations are diluted very quickly; even if there is a significant source, CO is diluted very quickly when mixed with ambient air. Few studies have evaluated ambient levels of CO in the urban environment. In urban environments, motor vehicle exhaust accounts for up to 95% of CO emissions (U.S. EPA, 2018). Overall anthropogenic CO emissions have decreased by approximately 68% from 1990 to 2014. This reduction is attributed to the improved efficiency of motor vehicles and the increase in electric vehicles; approximately 10% of vehicles in San Francisco are electric and/or hybrid vehicles (CA DMV, 2019), and buses are electric or hybrid.

In the 1990s and earlier, certain occupations, such as toll booth workers, had significant exposures to CO in outdoor air (NIOSH, 1991). While current average daily exposures to ambient CO are low, we identified several instances of detectable short-term exposures.

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