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To cite this article: Dawn Tharr Column Editor (1995) Case Studies: Simulated Carbon Monoxide Exposure in an Enclosed Structure from a Gasoline-Powered Pressure Washer, Applied Occupational and Environmental Hygiene, 10:7, 581-584, DOI: [10.1080/1047322X.1995.10387647](https://doi.org/10.1080/1047322X.1995.10387647)

To link to this article: <https://doi.org/10.1080/1047322X.1995.10387647>



Published online: 25 Feb 2011.



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# Simulated Carbon Monoxide Exposure in an Enclosed Structure From a Gasoline-Powered Pressure Washer

*Dawn Tharr, Column Editor*

Reported by H. Venable, K. Wallingford, D. Roberts, and D. Booher

### Introduction

Exposure to carbon monoxide (CO) as a product of combustion occurs extensively in both occupational and nonoccupational environments.<sup>(1-3)</sup> It has been estimated that the population at risk for exposure to CO exceeds that of any other occupational chemical hazard and that it accounts for more human deaths annually than all other gaseous poisons combined.<sup>(4,5)</sup> In 1986, Marzella and Myers<sup>(6)</sup> reported that CO was responsible for half the total poisoning deaths that occurred annually in the United States. In nonoccupational environments, exposure to CO usually occurs as a result of malfunctioning or unvented sources of heating equipment such as furnaces, space heaters, and hot water heaters.<sup>(7)</sup> Exposure to CO in the occupational setting is more varied but is also usually related to some source of incomplete combustion.<sup>(8)</sup>

Because CO is a colorless, odorless, tasteless gas, it gives no warning signs of its presence to those exposed.<sup>(9)</sup> It combines with hemoglobin and interferes with the oxygen-carrying capacity of the blood. The onset of toxic effects is insidious since the victim is usually unaware of being poisoned. Initial signs of CO poisoning such as headache, malaise, and dizziness may be attributed to influenza.<sup>(10)</sup> As poisoning progresses, the victim may lose the ability to recognize the importance of symptoms and fail to realize the need to escape from the hazardous environment. The results of CO poisoning, usually dependent upon degree and length of exposure, range from complete recovery to postexposure neurologic sequelae to death.<sup>(1,5,11-13)</sup> The concentration of CO considered immediately dangerous to life and health (IDLH) is 1200

ppm.<sup>(14)</sup> The National Institute for Occupational Safety and Health (NIOSH) recommended exposure limit for CO is 35 ppm for an 8-hour time-weighted average (TWA) with a ceiling limit of 200 ppm, not to be exceeded any time during the workday.<sup>(15)</sup> The Occupational Safety and Health Administration permissible exposure limit for CO is 50 ppm for an 8-hour TWA.<sup>(16)</sup> The American Conference of Governmental Industrial Hygienists threshold limit value for CO is 25 ppm for an 8-hour TWA.<sup>(17)</sup>

An important consideration regarding exposure to CO is whether it occurs in an enclosed space.<sup>(18)</sup> In an enclosed space, sufficient ventilation may not exist to exhaust or dilute the CO generated by a combustion source to essentially harmless concentrations. In fact, it may be difficult to determine (or even accomplish) sufficient ventilation, particularly for casual users of gasoline-powered rental equipment.

The purpose of this case study is to report the findings from a limited simulation of potential CO exposure in an enclosed space resulting from the use of a commercially available gasoline-powered pressure washer.

### Background

In January 1993, NIOSH received a request to investigate the occurrence of CO poisoning in farm workers who were using gasoline-powered pressure washers for indoor cleaning activities. As a result of this NIOSH investigation, it was found that CO poisoning was occurring in farm workers who operated these pressure washers inside structures used for confined-livestock-raising operations.<sup>(19)</sup> Periodically, these structures and the equipment contained inside them are cleaned using a pressure washer prior to use for the next cycle in the raising of livestock. CO poisoning resulted when the pressure washer was operated inside the structure rather than

outside. In some cases, the pressure washers were reportedly used indoors to prevent lines from freezing. Interviews with these CO poisoning victims disclosed that they were not fully aware of the hazards of operating the pressure washers indoors and were surprised at the rapidity of being poisoned in their respective work environments. In some of these cases, doors and windows were left open, and exhaust fans were operating.<sup>(19)</sup> Apparently, even these efforts did not provide sufficient exhaust or dilution ventilation to prevent CO poisoning.

A literature search of NIOSHTIC and other databases resulted in no reports regarding the exhaust volume or the peak concentration of CO generated by gasoline-powered pressure washers when operated in enclosed structures. In subsequent discussions with appropriate experts, it was reported that such data are difficult to produce or even estimate because of the variability in type and condition of single-cylinder internal combustion engines, the conditions of their operation, and quality and type of the fuel they consume.

Because of this gap identified in the scientific literature and as part of the ongoing investigation, NIOSH researchers conducted a limited study to simulate CO exposure during the use of a gasoline-powered pressure washer. To simulate the conditions of the CO poisonings observed in the field, a typical pressure washer was operated in a similar enclosed structure to determine the peak CO concentrations and the time required to reach those peaks in both best- and worst-case conditions of available passive ventilation.

### Methods

Based on both the observations and technical data gathered in the previous NIOSH investigation of CO poisoning cases in farm workers, conditions of enclosure were simulated using a garage and



FIGURE 1. Pressure washer used in the simulation.

a rented gasoline-powered pressure washer. The garage was a detached, two-car, one-story brick, rectangular structure (25.5 × 28.5 ft) with a floor area of 727 ft<sup>2</sup>. The garage was open overhead (8.5 ft to the soffits and 14.5 ft to the peak of the roof) with a total volume of 8360 ft<sup>3</sup>. The front of the garage had a double-wide garage door (7 × 18 ft) and a separate entry door (31 × 79 inches); and the left wall of the garage had one window (28 × 37 inches). The dimensions of this garage are somewhat similar to the enclosed structures involved in the CO poisoning cases we investigated (mean floor area of 654 ft<sup>2</sup> and mean total volume of 4740 ft<sup>3</sup>).<sup>(19)</sup>

Passive ventilation of the garage was provided by a 12-inch diameter turbine vent located near the peak of the roof, four individual 4-inch diameter vents arranged in a diamond pattern located in the center of each gable, and a 2-inch wide soffit vent running the full length of the eaves on the front and back of the garage.

A pressure washer (manufactured by Simpson, Inc.) powered by a 5.5 horsepower single cylinder (163 cm<sup>3</sup> displacement) Honda GX-160 four-cycle gasoline engine rated at 3400 rpm was leased from a local equipment rental company for use in this simulation (Figure 1). This pressure washer generated a maximum water pressure of 1500 lbs/in<sup>2</sup>. According to the equipment rental company, this pressure washer was purchased new and placed in service on July 21, 1992 (about 14 months prior to its lease for this research). Total hours of operation of the pressure washer prior to the time of this research was estimated to be 890 hours. Routine maintenance, including oil changes, had been performed every 150 hours of operation by the equipment rental company. This pressure washer

performed without problem for both of our simulations.

To perform both of the CO exposure simulations, the pressure washer was placed at the interior center of the garage and a remote-control off switch was connected. During the simulations, CO was measured in the center of the garage using a precalibrated Biosystems Model 1600 PhD gas detector operating in the datalogging mode. This instrument was placed 3 ft from the pressure washer at a height of 6 ft to approximate the breathing zone. Around the perimeter of the garage, CO was measured by four precalibrated National Draeger Model 190 Datalogger gas detectors operating in the datalogging mode. One of these instruments was placed in each corner of the garage, three feet from the walls at a height of 6 ft to approximate the breathing zone. The Biosystems PhD gas meter has a nominal range of measurement from 0 to 1500 ppm for CO. The National Draeger Datalogger gas detectors have a nominal range of measurement from 0 to 1000 ppm for CO. Recorded data from each instrument was transferred to a personal computer for analysis after each simulation.

The first CO exposure simulation was considered a "worst case" scenario and was created by sealing all of the passive vents with plastic and closing both doors and the window of the garage. For this simulation, the CO monitoring instruments were turned on and the pressure washer was started cold (not previously allowed to reach operating temperature) and operated for 30 minutes. After 30 minutes, the pressure washer was stopped using the remote-control off switch and the garage door was opened with an electronic garage door opener. The other door and window of the garage were also opened to allow the CO to dissipate prior to retrieving the monitoring instruments.

The second CO exposure simulation was considered a "best case" scenario and was accomplished by unsealing all of the passive vents and leaving both doors and the window of the garage fully open. For this simulation, the pressure washer was started and allowed to reach operating temperature outside of the garage. Once operating temperature was achieved, the pressure washer was stopped and moved to the interior center of the garage. The CO monitoring instruments were then

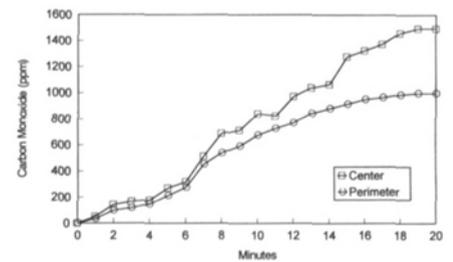


FIGURE 2. Worst case CO exposure simulation.

turned on and the pressure washer was restarted hot (at operating temperature) and operated for 30 minutes as before. Also, during this simulation, the wind direction and wind speed were measured using an Alnor Model 6000-P Velometer. As previously described, the pressure washer was stopped after 30 minutes and the monitoring instruments retrieved after the CO had dissipated.

### Results and Discussion

The results from the "worst case" CO exposure simulation are shown in Figure 2. The concentration of CO in the center of the garage increased to more than 200 ppm (NIOSH ceiling limit) within 5 minutes and continued to increase to more than 1200 ppm (IDLH level) within 15 minutes. The CO concentration in the center of the garage reached 1500 ppm (upper range limit of the monitoring instrument) within 19 minutes. At the perimeter of the garage, the CO concentration also increased to more than 200 ppm within 5 minutes and reached 1000 ppm (upper range limit of the monitoring instruments) within 19 minutes. (The perimeter CO concentrations shown in Figure 2 are the means calculated from the CO concentrations measured by the monitoring instruments placed in each corner of the garage.)

The results from the "best case" CO exposure simulation are shown in Figure 3. The concentration of CO in the center of the garage increased to more than 200 ppm (NIOSH ceiling limit) within 3 minutes and reached a peak concentration of 658 ppm within 12 minutes. After the initial 6 minutes, the CO concentration in the center of the garage fluctuated between 300 and 650 ppm for the remainder of the 30-minute simulation period. At the perimeter of the garage, the CO concentration in-

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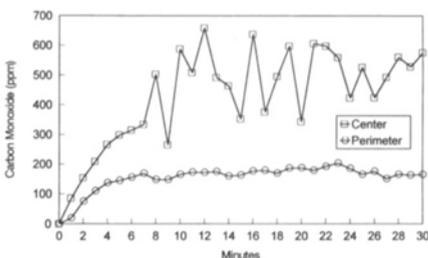


FIGURE 3. Best case CO exposure simulation.

creased to more than 100 ppm within 3 minutes and reached a peak concentration of 203 ppm within 23 minutes. After the initial 3 minutes, the CO concentration at the perimeter of the garage fluctuated between 140 and 200 ppm for the remainder of the 30-minute simulation period. (The perimeter CO concentrations shown in Figure 3 are the means calculated from the CO concentrations measured by the monitoring instruments placed in each corner of the garage.) The

fluctuations in CO concentrations measured during this simulation are most likely due to turbulence and dilution resulting from variations in wind speed. During this simulation, the prevailing wind direction with respect to the front of the garage was from left to right and the wind speed usually varied from less than 20 to 50 ft/min with periodic wind gusts up to 90 ft/min.

The results from these two exposure simulations indicate that acutely toxic concentrations of CO greater than 200 ppm (NIOSH ceiling limit) can be quickly generated within 3 to 5 minutes nearby a pressure washer operated indoors, even when passive ventilation is provided. Additionally, concentrations of CO around the interior perimeter of a passive ventilated structure can be near or above 200 ppm so that the operator of a pressure washer could still be quickly poisoned even when somewhat distant from the CO source.

These two simulations were intended to determine the operator's potential CO exposures during best and worst conditions of passive ventilation when a pressure washer was used indoors. As observed during the NIOSH investigation of CO poisonings, the practical use of these pressure washers is usually somewhere in between the conditions of these two simulations. The results from these two simulations support the observation made earlier by NIOSH investigators that adequate ventilation cannot be achieved just by leaving doors and windows of an enclosed structure open when a pressure washer is operated inside. These results are also consistent with the survivor reports of the rapid onset of CO poisoning from the use of a pressure washer indoors.<sup>(19)</sup>

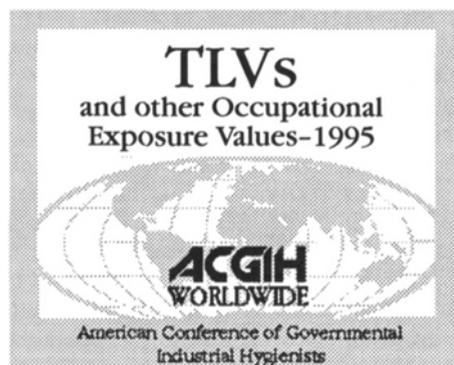
### Conclusions

Although limited, the results from these two exposure simulations support previ-

ous case reports and indicate that CO poisoning is likely to occur in anyone operating a pressure washer indoors, even when passive ventilation is provided. For this reason, these pressure washers should not be used indoors. Although not using a pressure washer indoors seems to border on "common sense," CO poisonings from their use continue to occur, as seen in the ongoing NIOSH investigation.<sup>(19)</sup> Therefore, industrial hygienists must continue efforts to educate the public regarding the hazard of CO poisoning when operating these pressure washers (or any other equipment powered by gasoline engines) indoors.

### References

1. Anonymous: Disease Caused by Asphyxiants: Carbon Monoxide, Hydrogen Cyanide and Its Toxic Derivatives, and Hydrogen Sulfide. Early Detection of Occupational Diseases, World Health Organization, Geneva, pp. 154-164 (1986).
2. Kindwall, E.P.: Carbon Monoxide. In: Occupational Medicine: Principles and Practical Applications, Second Edition, pp. 503-508. C. Zenz, Ed. Year Book Medical Publishers, Chicago, IL (1988).
3. Seger, D.L.; Welch, L.: Hazardous Materials Toxicology. In: Clinical Principles of Environmental Health, pp. 1160-1164. J.B. Sullivan, Jr., and G.R. Krieger, Ed. Williams and Wilkins, Baltimore, MD (1992).
4. Anger, W.K.; Johnson, B.L.: Chemicals Affecting Behavior. In: Neurotoxicity of Industrial and Commercial Chemicals, Vol. 1, pp. 51-148. J.L. O'Donoghue, Ed. RC Press, Boca Raton, FL (1985).
5. Barret, H.M.: Carbon Monoxide Poisoning. Can. Pub. Health J. 25(9):430-438 (1934).
6. Marzella, L.; Myers, R.A.M.: Carbon Monoxide Poisoning. Am. Family Phys. 34(5):186-194 (1986).
7. Anonymous: Carbon Monoxide. Hazard Evaluation System and Information Service, State of California. p. 2. Berkely, CA (1983).
8. Nelson, N.: Target Health Hazards: Carbon Monoxide. Safety Standards 21(4): 21-25 (1972).
9. Stewart, R.D.: The Effect of Carbon Monoxide on Man. Combustion Toxicology 1:167-176 (1974).
10. Nightingale, T.E.: Biological Effects of Short, High-Level Exposure to Gases: Carbon Monoxide. Environmental Protection Research Division, U.S. Army Medical Bioengineering Research and Development Laboratory, Fort Detrick. Contract No. DAMD17-79-C-9086, p. 120. Frederick, MD (1980).
11. Ali-Cherif, A.; Royere, M.L.; Gosset, A.; et al.: Behavioral and Mental Activity Disorders After Carbon Monoxide Poisoning. Revue Neurologique (Paris) 140(6-7):401-405 (1984).
12. Ikemura, Y.: Consideration About Residual States After Acute Carbon Monoxide Poisoning. Brain and Nerve 35(4): 331-336 (1983).
13. Krants, T.; Thisted, B.; Strom, J.; Sorensen, M.B.: Acute Carbon Monoxide Poisoning. Acta Anaesthesiologica Scandinavica 32(4):278-282 (1988).
14. National Institute for Occupational Safety and Health: Pocket Guide to Chemical Hazards, pp. 54-55. DHHS (NIOSH) Pub. No. 94-116. NIOSH, Cincinnati, OH (1994).
15. Centers for Disease Control: NIOSH Recommendations for Occupational Safety and Health Standards. Morbidity and Mortality Weekly Reports 37(Suppl. S-7) (1988).
16. Code of Federal Regulations, 29 CFR 1910.1000. Federal Register. Government Printing Office, Washington, DC (1989).
17. American Conference of Governmental Industrial Hygienists: Threshold Limit Values and Biological Exposure Indices for 1993-1995. ACGIH, Cincinnati, OH (1994).
18. Sahli, B.P.; Armstrong, C.W.: Confined Space Fatalities in Virginia. J. Occup. Med. 34(9):910-917 (1992).
19. Unintentional Carbon Monoxide Poisoning from Indoor Use of Pressure Washers—Iowa, January 1992–January 1993. Morbidity and Mortality Weekly Report, Epidemiologic Notes and Reports 42(40):777-779 (October 15, 1993).



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