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ALERT

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Preventing Carbon Monoxide Poisoning from Small Gasoline-Powered Engines and Tools

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Public Health Service
Centers for Disease Control and Prevention
National Institute for Occupational Safety and Health

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PREFACE

This ALERT is the joint product of a combined effort among the following agencies:

- The National Institute for Occupational Safety and Health (NIOSH)
- The Colorado Department of Public Health and Environment (CDPHE)
- The U.S. Consumer Product Safety Commission (CPSC)
- The Occupational Safety and Health Administration (OSHA)
- The U.S. Environmental Protection Agency (EPA)

Each agency has a unique role in protecting workers, consumers, or the general public from safety and health hazards. Because of their common interest in prevention of carbon monoxide (CO) poisonings resulting from widespread use of small gasoline-powered engines and tools in enclosed or confined spaces, the agencies elected to work together to produce a joint document to address this problem and provide recommendations for prevention. Such a combined effort avoids duplication and confusion from multiple documents and promotes efficient use of government resources.

ACKNOWLEDGMENTS

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WARNING!

Do not use equipment and tools powered by gasoline engines inside buildings or other partially enclosed spaces unless the gasoline engine can be placed outdoors and away from air intakes.

Hundreds of people performing many different tasks have been poisoned because small gasoline-powered engines and tools produced hazardous concentrations of carbon monoxide (CO) even in relatively open buildings:

- In December 1992, a farm owner found his 12-year-old son unconscious near the door of a swine-farrowing building (birthing barn) in Iowa. The boy had been working alone using an 11-horsepower, gasoline-powered pressure washer for about half an hour to clean the building.

- In January 1993, a 33-year-old farm owner in Iowa died of CO poisoning while using an 11-horsepower, gasoline-powered pressure washer to clean his swine-farrowing barn. He had worked about half an hour before being overcome.

- In January 1993, a 60-year-old drywall finisher in Colorado collapsed and fell from the scaffold on which he was standing. He was using a small gasoline-powered compressor to apply a textured surface to a cathedral ceiling in a house. Although he landed on a balcony below, escaping further injury, he was confused and unable to identify an escape route from the building. He was rescued by coworkers who saw him beckoning for help at the patio door.

- In February 1993, a 30-year-old plumber in Colorado developed a severe headache and dizziness and began to demonstrate paranoid behavior that was later diagnosed as CO poisoning. He had worked for 2 to 3 hours using a gasoline-powered concrete cutter to access pipes in a basement. He and his supervisor anticipated possible problems related to the exhaust from this equipment and had set up what they considered to be adequate ventilation (they opened doors and windows and placed cooling fans near the cutter and farther down the hall).

- In June 1994, five workers in Washington, D.C., who experienced dizziness, confusion, headaches, and nervousness were treated for CO poisoning after using two 8-horsepower, gasoline-powered pressure washers for 4 hours in an empty, poorly ventilated underground parking garage. When one of the five workers collapsed at the worksite, coworkers carried him outside, remained with him for a short time, and then, unaware of the hazard, re-entered the hazardous worksite. Only after a second worker collapsed did workers recognize the hazard, evacuate the environment, and seek help.

- In October 1994, a 37-year-old municipal employee at an indoor water treatment facility in Colorado lost consciousness while trying to exit from a 59,000-cubic-foot room where he had been working with an 8-horsepower, gasoline-powered water pump for 4 hours.

- In December 1994, a previously healthy 59-year-old owner/operator of a flooring installation business in Colorado experienced headache and dizziness after working for 2½ hours in the stairwell of a building containing a gasoline-powered generator supplying power to the construction site. He left the building and rested in his car. Upon returning to the stairwell, he collapsed in a grand mal seizure related to CO poisoning.

These are examples of the many situations in which people have been poisoned because they did not recognize the danger of using small gasoline-powered engines indoors. These poisonings can occur quickly, even in the presence of what many would consider "adequate ventilation" and in areas that many would define as relatively open spaces, such as parking garages.

HEALTH EFFECTS

CO is a lethal poison that is produced when fuels such as gasoline are burned. It is one of many chemicals found in engine exhaust and can rapidly accumulate even in areas that might appear to be well ventilated. Because CO is colorless, tasteless, odorless, and nonirritating, it can overcome the exposed person without warning. It produces weakness and confusion, depriving the person of the ability to seek safety.

CO poisons primarily by tightly binding to hemoglobin in the blood (forming carboxy-hemoglobin), replacing oxygen, and reducing the oxygen-carrying capacity of the blood. CO may also poison by binding to tissues and cells of the human body and interfering with their normal function. Persons with pre-existing heart disease are at increased risk. Fetuses of pregnant women are also at increased risk—especially when mothers are exposed to high CO levels. Recognizing early warning signs of CO poisoning is sometimes difficult because early symptoms of CO exposure (headache, dizziness, and nausea) are nonspecific and may be mistaken for symptoms of other illnesses such as colds, flu, or food poisoning. Confusion and weakness can inhibit a person's ability to escape the hazardous environment.

The severity of symptoms of CO exposure is influenced by three main factors: (1) the concentration of CO in the environment, (2) how long the exposure lasts, and (3) workload and breathing rate. In general, assuming that users of gasoline-powered engines are engaged in at least a moderate level of activity, exposure to CO concentrations of 80 to 100 parts per million (ppm) for 1 to 2 hours can result in decreased exercise tolerance and, in persons who are at risk, may bring on chest pain and cause irregular heartbeat [EPA 1991a]. Symptoms associated with CO exposure concentrations of 100 to 200 ppm include headache, nausea, and mental impairment. More serious central nervous system effects, coma, and death are associated with CO exposure concentrations of 700 ppm or greater for an hour or more [Ilano and Raffin 1990; Forbes et al. 1945]. Symptoms of nervous system effects include staggering, confusion, changes in personality, and muscle aches. These symptoms may continue to occur for several days to several weeks after the exposure stops and the poisoned person has apparently recovered. Victims of CO poisoning should be immediately removed from the exposure site and given 100% oxygen. Hyperbaric chambers provide oxygen under pressure and are sometimes necessary in cases of serious CO poisoning.

CURRENT STANDARDS AND RECOMMENDED GUIDELINES

Organizations set standards or make recommendations for exposure to hazardous substances based on assumptions inherent to their regulatory oversight or authority. Differences in the stated values reflect variations in the place, duration, characteristics of the population, or proposed use.

Workplace/Industry

The current Occupational Safety and Health Administration (OSHA) permissible exposure limit (PEL) for CO is 50 ppm as an 8-hour time-weighted average (TWA) [29 CFR 1910.1000*]. The NIOSH recommended exposure limit (REL) for CO is 35 ppm as an 8-hour TWA and a ceiling limit (CL) of 200 ppm [NIOSH 1992]. The NIOSH recommended immediately dangerous to life and health concentration (IDLH) for CO is 1,200 ppm. The IDLH is the concentration that could result in death or irreversible health effects, or prevent escape from the contaminated environment within 30 minutes. The American Conference of Governmental Industrial Hygienists (ACGIH) has adopted a threshold limit value (TLV) for CO of 25 ppm as an 8-hour TWA [ACGIH 1992a].

Ambient Air/Residential Settings

The U.S. Environmental Protection Agency (EPA) has established an ambient (outdoor) CO air quality Federal standard of 9 ppm for an 8-hour exposure and 25 ppm for a short-term (1-hour) exposure [EPA 1991a]. The Consumer Product Safety Commission (CPSC) staff recommends that long-term exposures to CO in indoor environments be limited to less than 15 ppm as an 8-hour TWA and 25 ppm for 1 hour, but product-specific recommendations for CO may vary depending on expected usage patterns and exposure.

**Code of Federal Regulations*. See CFR in references.

DATA SUMMARIZING CO POISONINGS

Illness related to CO exposure is probably underestimated because workers with mild symptoms may go untreated or medical providers may not recognize their symptoms as CO poisoning. In addition, persons may not recognize the cause of their symptoms unless coworkers and other persons become ill at the same time.

Two surveys assessing individuals' beliefs, knowledge, and risk perceptions regarding CO suggest that many people are unaware of the hazards associated with CO. In 1993, NIOSH assessed flood victims' risk perceptions associated with CO poisoning from using equipment powered by small engines (e.g., gasoline-powered pressure washers indoors to clean up flood-related debris) [Greife et al. 1995]. Many of the 416 respondents (26%) incorrectly believed that with only a window open, the use of a gasoline-powered engine indoors would be safe. A majority of respondents (54%) and 92% of respondents between the ages of 12 and 20 incorrectly believed that it was safe to operate a gasoline-powered engine indoors with windows and doors open and an exhaust fan running. In a second survey, during follow-up investigations of nonfatal, unintentional CO poisoning in residential settings in Connecticut between November 1993 and March 1994, investigators interviewed 36 victims or their adult representatives [CDC 1995b]. Many of the victims of CO poisoning (poisoning that was related to heating systems, gas appliances, and fireplaces) still demonstrated a lack of knowledge about prevention strategies. When asked to list prevention methods, 14% were unable to list any method, 44% listed appropriate maintenance of appliances, 39% listed the use of a CO detector, and 14% listed proper ventilation.

Reports from a number of sources show that CO poisoning from the use of gasoline-powered tools indoors happens frequently:

- **Occupational Health Nurses in Agricultural Communities (OHNAC):** The NIOSH-sponsored OHNAC Surveillance Program identified 18 cases of CO poisoning related to the use of small engines; 17 cases occurred in less than 3 years [CDC 1993; Ehlers 1994]. Although only one case resulted in a fatality, at least three cases could have been fatal had the victims not been found by coworkers or family members, removed from the hazardous environment, and taken for medical care. At least four were overcome in about half an hour. Persons working in open environments (e.g., doors and windows open and exhaust fans operating) began developing symptoms in as little as 1 hour of constant work or as many as 7 hours of intermittent exposure. All interviewed persons reported being unaware that they could be poisoned in a short time and that CO can attain hazardous levels inside buildings with windows and doors open. Several victims, although appearing obviously confused and ill to family members at the worksite, were unaware of their impaired conditions and sought medical help only at the insistence of family members. Seven of the 18 incidents occurred among Iowa farmers using pressure washers to clean animal housing between January 1992 and March 1994. Of the other 11 cases, 7 occurred while using pressure washers to clean animal housing elsewhere or in other years, and 4 occurred while using gasoline-powered pressure washers or concrete saws to clean up after floods.

- **Colorado Department of Public Health and Environment (CDPHE):** In Colorado, 40% (135) of all work-related CO poisonings reported to CDPHE since 1985 have been related to the use of gasoline-powered equipment [CDPHE 1996]. Other sources of exposure associated with reported occupational poisonings in Colorado include automobile exhaust (25% of poisonings) and furnaces (12%). Seventeen of the 135 workers poisoned by gasoline-powered equipment lost consciousness during their exposures to emissions, and 2 workers died. The 135 poisonings were primarily caused by concrete-cutting saws (28 workers), power trowels (15 workers), high-pressure washers (14 workers), compressors (10 workers), welding equipment (9 workers), and floor buffers (9 workers). Other equipment causing poisonings included jackhammers, pumps, carpet cleaners, and paint sprayers. Information about where the 135 poisoned workers were using gasoline-powered equipment was available in 115 cases; 110 (96%) of these 115 poisonings occurred indoors.

- **George Washington University (GWU):** Seven worker poisonings related to the emissions from gasoline-powered tools used indoors have also been identified by the GWU Emergency Department Surveillance Project. Five of these poisonings occurred in June 1994 and were discussed above (workers using a pressure washer in an empty underground parking garage) [CDC 1995a]. Two additional workers were poisoned while using gasoline-powered saws.

- **California:** A study of all death certificates in the State of California during the 10-year period from 1979 to 1988 showed 444 deaths due to unintentional carbon monoxide poisoning [CDHS 1993]. Of these deaths, 23 (5%) were caused by small engine exhaust.

- **National Estimates:** There is no complete U.S. database for this problem. According to the U.S. Bureau of Labor Statistics (BLS), there were nearly 900 work-related CO poisonings resulting in death or illness in private industry in the United States in 1992 (32 deaths and 867 nonfatal poisonings) [BLS 1992a,b]. CPSC estimates that in 1992 (the latest year for which mortality data are available), there were 212 deaths from CO associated with the use of household fuel-burning appliances; 13 of these deaths were reported to have involved the use of gasoline-powered appliances [NCHS/CPSC 1992]. In 1994 (the latest year for which injury data are available), CPSC estimates that 3,900 CO injury incidents occurred in which an average of two to three persons per incident were treated in hospital emergency rooms. Of these 3,900 incidents, approximately 400 incidents were associated with the use of gasoline-powered appliances [CPSC 1994].

Three of the above groups measured CO concentrations after the CO poisoning incidents in the same or similar exposure situations to estimate how quickly dangerous CO concentrations developed. A fourth group modeled the time to reach dangerous CO concentrations.

- **OHNAC:** NIOSH measured the generation of CO by a gasoline-powered pressure washer using a 5.5-horsepower engine under environmental conditions comparable with those experienced by the farmers using pressure washers described in this report [Venable et al. 1995]. A 5.5-horsepower, gasoline-powered pressure washer was operated inside an 8,360-cubic-foot, double-car garage using two ventilation scenarios. In the first or "worst-case" scenario, all doors, windows, and vents were closed. Breathing-zone concentrations of CO reached 200 ppm within 5 minutes, 1,200 ppm (IDLH value) within 15 minutes, and 1,500 ppm within 19 minutes; they continued to increase thereafter. In the second or "best-case" scenario, the two double-car garage doors and one window were left open and the vent was unsealed; breathing-zone concentrations of CO reached 200 ppm within 3 minutes and peaked at 658 ppm within 12 minutes. The results from the simulations indicate that acutely toxic concentrations of CO greater than 200 ppm (NIOSH ceiling) can be quickly generated within 3 to 5 minutes near a pressure washer operated indoors (even when passive ventilation is provided), and IDLH concentrations of 1,200 ppm can be generated rapidly in enclosed spaces.

- **CDPHE:** CDPHE measured or recreated exposures in four poisonings related to the use of gasoline-powered tools indoors [CDPHE 1996].

  First, CDPHE attempted to estimate the CO exposure of the drywall texturizer discussed earlier by sampling the air at another construction site where he was doing similar work. On the day of the air sampling, the gasoline-powered compressor was placed just outside the garage door. Because of the way the equipment was designed and oriented, exhaust from the engine on the compressor went directly into the house when the garage door was open. As is usual for this operation, all windows and external doors in the home had been closed and sealed with tape and paper to protect the surfaces from the texturing material and to maintain the proper conditions for drying. The concentration of CO at the tailpipe of the compressor engine was substantially greater than 1,000 ppm (this was the upper limit of the testing equipment). Within the first 20 minutes of the operation, CO concentrations as high as 410 ppm were measured in the basement of the home, and concentrations as high as 322 ppm were measured where the worker was standing. CDPHE asked the worker to open the windows and external doors on the upper floor of the duplex because of concerns about this concentration of exposure. CO concentrations within the house dropped to approximately 30 ppm when that was done, but this is not the way the process is usually carried out.

In response to the second incident (another CO poisoning related to the use of an 8-horsepower pressure washer in a 30,000-cubic-foot room of a municipal construction project), CDPHE asked to run the same pressure washer in the same room a few days later. There was no mechanical ventilation in this room because the facility was not yet operational. The pressure washer was placed approximately 15 feet from one corner of the room (the same place the worker had placed it on the day of the poisoning). The power unit was an integral part of the washer. Again, the CO concentration at the engine exhaust pipe was greater than 1,000 ppm, the highest concentration CDPHE could measure at the time. CDPHE measured CO concentrations as high as 450 ppm at several locations in the room within 20 minutes of activation of the washer engine, and concentrations as high as 546 ppm approximately 50 minutes after the washer engine was activated. The test was then terminated.

In a third incident, CDPHE asked the managers of the enclosed municipal water treatment plant to recreate the exposure situation encountered by the worker mentioned before who was using the 8-horsepower pump in the 59,000-cubic-foot room (48 x 88 x 14 feet). This room was only partially enclosed so that employees could observe operations in the room from the level above. Outside air was introduced into the area through a forced-air heating system that was running on the day of the poisoning and on the day of air sampling. External doors to the treatment plant were opened on both days as well. Ten minutes after the pump engine was started, CO concentrations as high as 395 ppm were measured within 7 feet of the pump, near the location where the employee was standing for much of the time on the day of the poisoning. CO concentrations 25 feet from the water pump rose as high as 193 ppm during the 20-minute test. CDPHE returned to the room 1 hour after the water pump was stopped and measured 40 ppm of CO.

Finally, in January 1996, two Colorado workers were poisoned as a result of operating a gasoline-powered, 5-horsepower, walk-behind concrete saw during a remodeling project. The machine was 3 years old and was used two to three times per year. The workers operated the saw for about an hour and a half inside what had previously been two bathrooms (the dividing wall had been removed and the volume of the room was 2,332 cubic feet). The workers were cutting a hole in the floor to allow access to pipes below the floor. The two doors to the room were open and the bathroom ventilation system was operating when these poisonings occurred. The day after the poisonings occurred, the work in this bathroom was continued with two differences: A cooling fan was used this time in an effort to better move CO from the room, and the saw was operated for shorter periods (the periods of operation were not clearly defined but were thought to be 15 to 30 minutes). CDPHE recreated the second day's operating conditions to measure CO concentrations in the room. The NIOSH ceiling limit of 200 ppm was exceeded within the first minute of operation. Within 5 minutes of operation, the CO concentration within the room reached 842 ppm, at which point the demonstration was discontinued (see Figure 1).

- **GWU:** In the poisoning incident in which five workers were using pressure washers in an underground garage, the fire department measured 648 ppm CO 1 hour after the washers had been turned off (washers had been running for 3 hours).

- **NIOSH:** NIOSH engineers modeled the time required for a gasoline-powered, 5-horsepower, 4-cycle engine to reach the 200-ppm ceiling and 1,200-ppm IDLH CO concentration for room sizes of 1,000 to 100,000 cubic feet and general ventilation rates of 1 to 20 air changes per hour [ACGIH 1992b]. The CO generation rate used in the model was 670 grams/horsepower-hour based on data from a 1991 EPA study [EPA 1991b]. Ideal mixing was assumed. Under actual conditions, if mixing were poor, hazardous concentrations could develop more quickly. In the small 1,000-cubic-foot room, the ceiling concentration of 200 ppm was reached in approximately 0.1 minute, and the IDLH was reached in less than 1 minute at all air-flow rates. In the medium 10,000-cubic-foot room, the IDLH was reached in approximately 7 minutes for 1 air change per hour and approximately 10 minutes for 5 air changes per hour. These models demonstrate that for rooms up to 10,000 cubic feet, the NIOSH ceiling limit of 200 ppm was exceeded in less than 2 minutes—even with general ventilation rates as high as 20 air changes per hour. In no case would it be possible to operate an engine for 8 hours without exceeding the NIOSH REL of 35 ppm (see Figures 2 through 4).

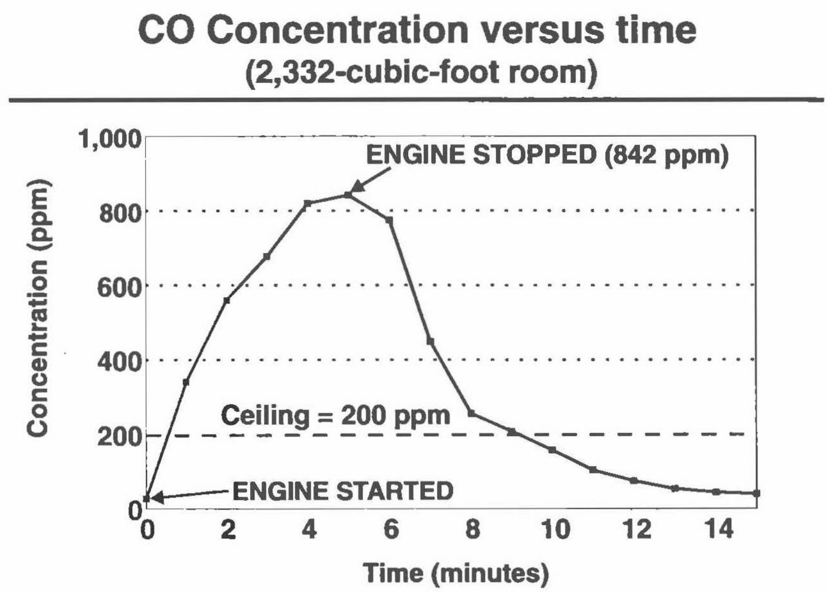

Figure 1. Actual CO concentrations measured inside a 2,332-cubic-foot bathroom with a gasoline-powered, 5-horsepower concrete saw operating (doors open, cooling fan and ventilation running).

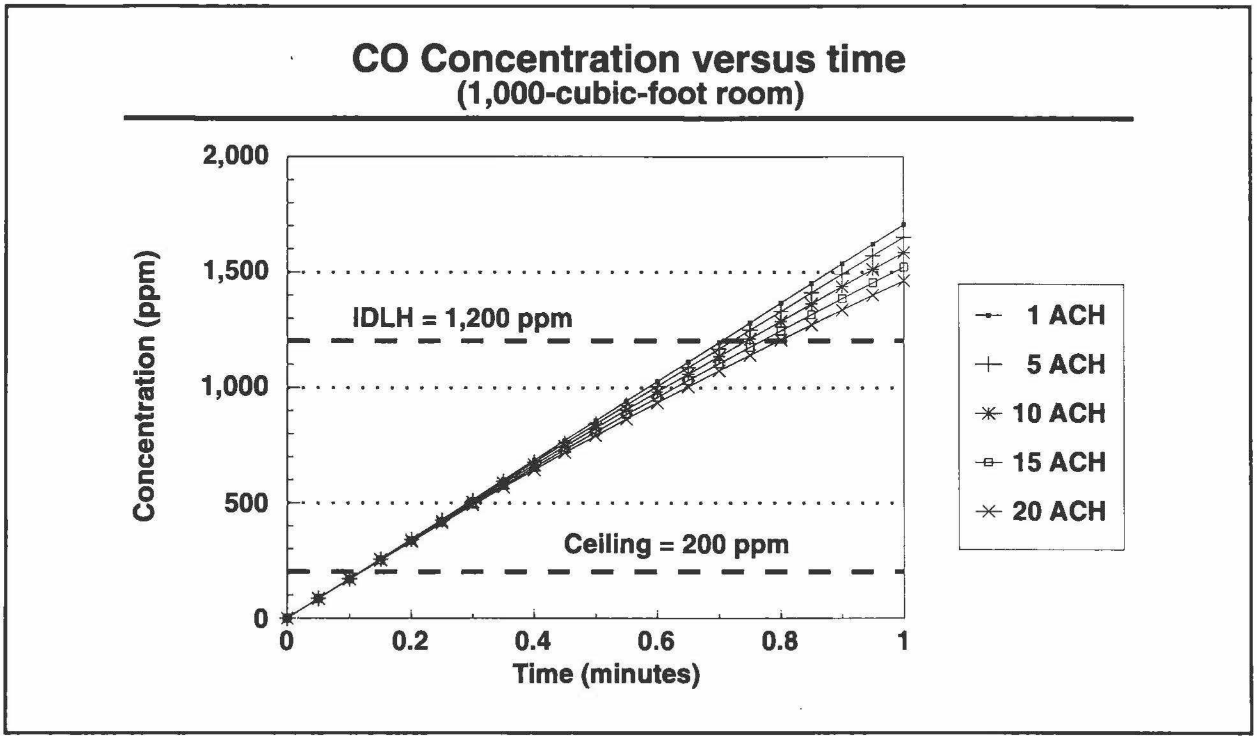

Figure 2. Calculated CO concentrations generated by a 5-horsepower, 4-cycle gasoline-powered engine in a 1,000-cubic-foot room with various air changes per hour.

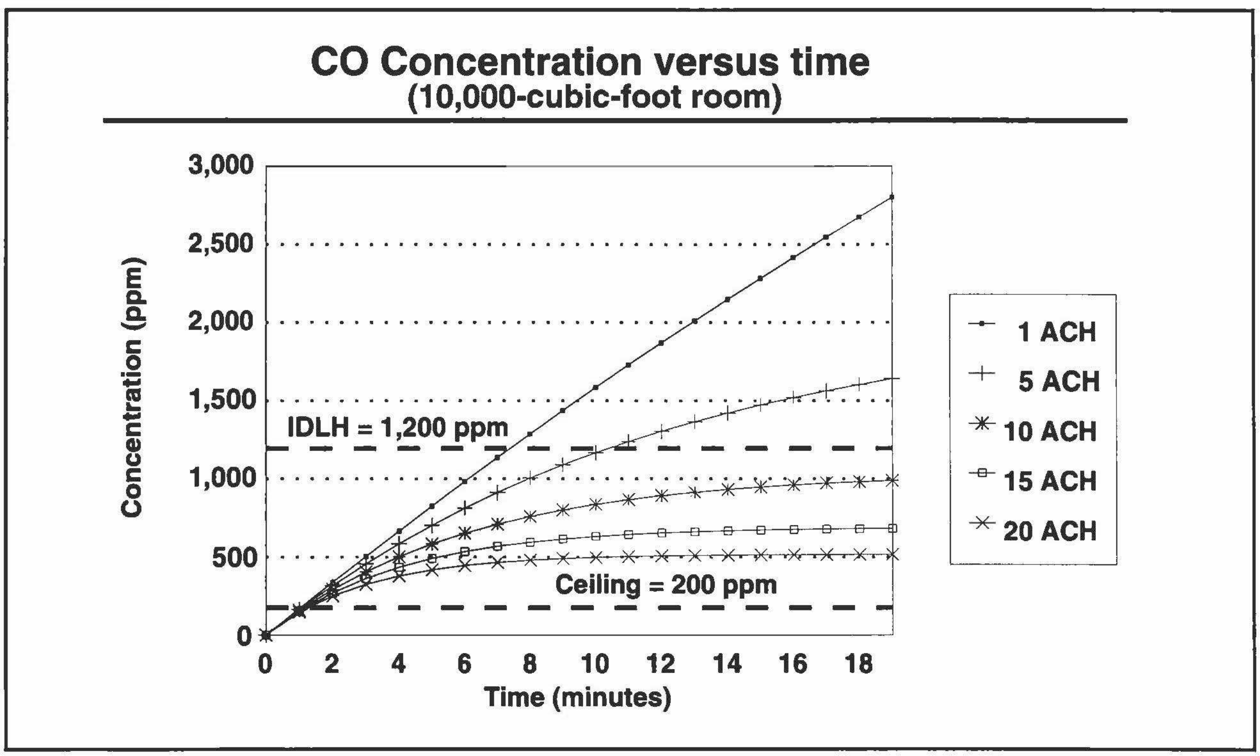

Figure 3. Calculated CO concentrations generated by a 5-horsepower, 4-cycle gasoline-powered engine in a 10,000-cubic-foot room with various air changes per hour.

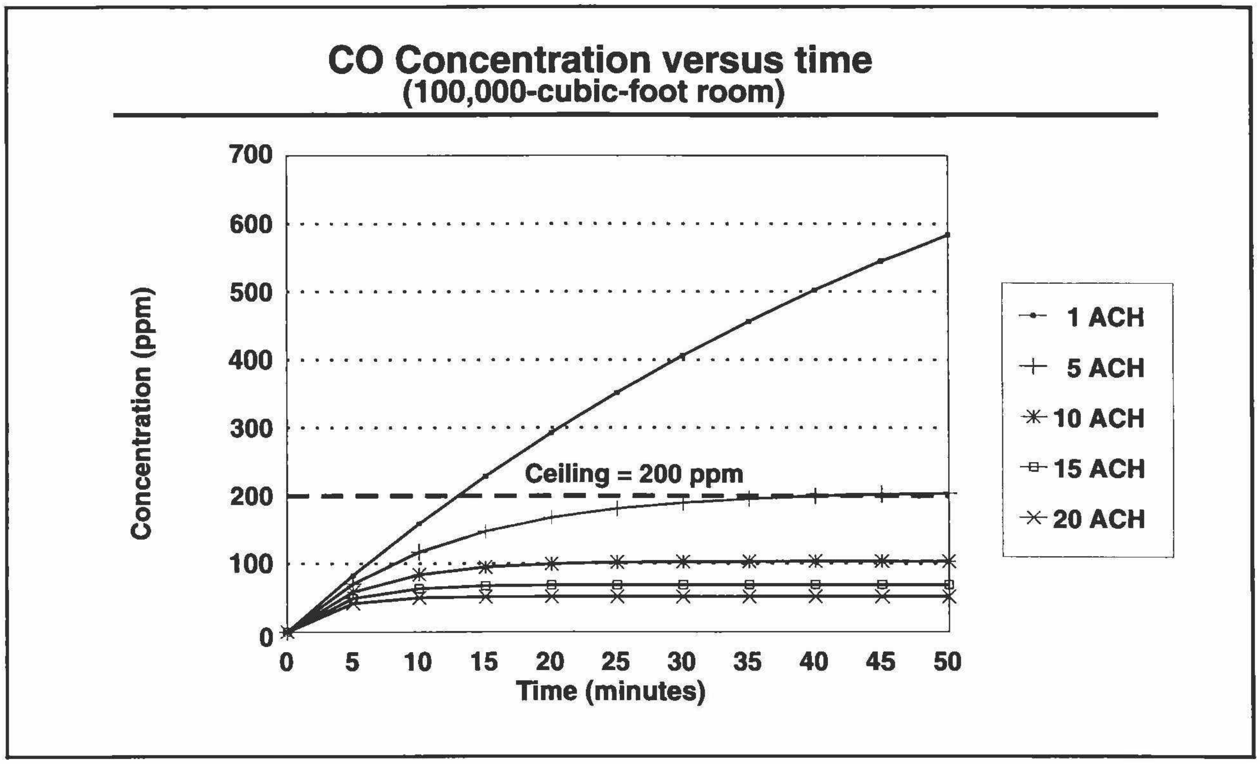

Figure 4. Calculated CO concentrations generated by a 5-horsepower, 4-cycle gasoline-powered engine in a 100,000-cubic-foot room with various air changes per hour.

RECOMMENDATIONS

It is not widely known that small gasoline-powered engines and tools present a serious health hazard. They produce high concentrations of CO, a poisonous gas that can cause illness, permanent neurological damage, and death. Because it is colorless, odorless, and nonirritating, CO can overcome exposed persons without warning. Often there is little time before they experience symptoms that inhibit their ability to seek safety. Prior use of equipment without incident has sometimes given users a false sense of safety; such users have been poisoned on subsequent occasions. Recommendations for preventing CO poisoning are provided below for employers, equipment users, tool rental agencies, and tool manufacturers.

All Employers and Equipment Users Should:

- NOT allow the use or operation of gasoline-powered engines or tools inside buildings or in partially enclosed areas unless gasoline engines can be located outside and away from air intakes. Use of gasoline-powered tools indoors where CO from the engine can accumulate can be fatal.

  An exception to this rule might be an emergency rescue situation in which other options are not available; such an exception should be made only when equipment operators, assisting personnel, and the victim are provided with supplied-air respirators.

- Learn to recognize the signs and symptoms of CO overexposure: headache, nausea, weakness, dizziness, visual disturbances, changes in personality, and loss of consciousness. Any of these signs and symptoms can occur within minutes after the equipment is turned on.

- Always place the pump and power unit of high-pressure washers outdoors and away from air intakes so that engine exhaust is not drawn indoors where the work is being done. Run only the high-pressure wash line inside.

- Consider the use of tools powered by electricity or compressed air if they are available and can be used safely. For example, electric-powered tools present an electrocution hazard and require specific precautions for safety.

- If compressed air is used, place the gasoline-powered compressor outdoors and away from air intakes so that engine exhaust is not drawn indoors where the work is being done.

- Use personal CO monitors where potential sources of CO exist. These monitors should be equipped with audible alarms to warn workers when CO concentrations are too high. More information on CO monitors is contained in the appendix.

Employers Should Also:

- Conduct a workplace survey to identify all potential sources of CO exposure.

- Educate workers about the sources and conditions that may result in CO poisoning as well as the symptoms and control of CO exposure.

- Always substitute less hazardous equipment if possible. Use equipment that allows for the placement of gasoline-powered engines outdoors at a safe distance from air entering the building.

- Monitor employee CO exposure to determine the extent of the hazard.

Equipment Users Should Also:

- Substitute less hazardous equipment whenever possible. Use electric tools or tools with engines that are separate from the tool and can be located outside and away from air intakes.

- Learn to recognize the warning symptoms of CO poisoning.

- If you have any symptoms, immediately turn off equipment and go outdoors or to a place with uncontaminated air.

- Call 911 or another local emergency number for medical attention or assistance if symptoms occur. Do NOT drive a motor vehicle—get someone else to drive you to a health care facility.

- Stay away from the work area until the tool has been deactivated and measured CO concentrations are below accepted guidelines and standards.

- Watch coworkers for the signs of CO toxicity.

Tool Rental Agencies Should:

- Place warning labels on gasoline-powered tools. For example:

  WARNING—CARBON MONOXIDE PRODUCED DURING USE CAN KILL—DO NOT USE INDOORS OR IN OTHER SHELTERED AREAS.

- Tell renters that the tool should NOT be used indoors and explain why.

- Recommend safer tools for the intended use if available.

- Have portable, audible CO monitors for rent and encourage their use.

- Provide renters with educational materials like this information sheet.

Tool Manufacturers Should:

- Design tools that can be used safely indoors.

- Provide warning labels for existing and new gasoline-powered equipment. For example:

  WARNING—CARBON MONOXIDE PRODUCED DURING USE CAN KILL—DO NOT USE INDOORS OR IN OTHER SHELTERED AREAS.

- Provide recommendations for equipment maintenance to reduce CO emissions.

- Recommend the use of portable, audible CO monitors with small gasoline-powered engines.

DISTRIBUTION

NIOSH, CDPHE, CPSC, OSHA, and EPA request that the information in this ALERT be brought to the attention of (1) all employers and workers who use small gasoline-powered engines and tools in their jobs and trades (e.g., building, construction, agriculture, and maintenance and cleaning operations), (2) tool rental agencies and equipment sellers and users, (3) tool manufacturers, and (4) editors of appropriate trade journals.

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APPENDIX

Carbon Monoxide Monitors and Detectors

Detectors for carbon monoxide (CO) are manufactured and marketed for use in either the home or occupational industrial settings. The detectors for home use are devices that will sound an alarm before CO concentrations in the home become hazardous. There is an Underwriters Laboratories, Inc., performance standard (UL 2034) for residential CO detectors. Detectors currently available on the market are battery-powered, plug-in, or hard-wired. Some models incorporate a visual display of the parts-per-million (ppm) concentration of CO present in the home. For more information on CO detectors for home use, call the Consumer Product Safety Commission Hotline at 1–800–638–2772.

CO detectors for use in residential settings are not designed for use in typical workplace settings. Monitoring requirements in an occupational setting are different from monitoring requirements in the home. In the workplace, it is frequently necessary to monitor a worker's exposure to CO over an entire work shift and determine the time-weighted average (TWA) concentration of the exposure. It may also be necessary to have CO monitors with alarm capabilities in the workplace. CO in the workplace can be detected using detector tubes, direct-reading passive badges, dosimeter tubes, and direct-reading instruments. These badges, tubes, and instruments operate on a variety of principles, including colorimetric reaction, potentiometry, coulometry, infrared spectrometry, fluorescence, thermal conductivity, and heat of combustion. The direct-reading instruments are frequently equipped with audio and/or visual alarms and may be used for area and/or personal exposure monitoring. Some have microprocessors and memory for storing CO concentration readings taken during the day. It is significant to note that some of the devices mentioned for workplace CO monitoring are not capable of monitoring TWAs, and not all are equipped with alarms. The appropriate monitor must be chosen on an application-by-application basis. For more information on the availability of workplace CO monitors or their application, call the National Institute for Occupational Safety and Health at 1–800–35–NIOSH (1–800–356–4674).

National Institute for Occupational Safety and Health

Colorado Department of Public Health and Environment

U.S. Consumer Product Safety Commission

Occupational Safety and Health Administration

U.S. Environmental Protection Agency

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