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Indoor Use of Concrete Saws and Other Gas-Powered Equipment: Analysis of Reported Carbon Monoxide Poisoning Cases in Colorado

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Abstract

Poisoning due to "non-automobile" gas-powered engines accounts for the largest proportion of occupational carbon monoxide (CO) poisonings in Colorado workers. The present analysis was undertaken to characterize the problem and develop prevention strategies. Cases of occupational CO poisoning were identified from Colorado's population-based surveillance system for unintentional CO poisonings. For cases poisoned by "non-automobile" gas-powered engines, medical records were obtained. Results showed that almost all of the poisonings from these engines occurred indoors or in an enclosed space. Concrete saws were the most frequent source of poisoning. When compared with operators of other equipment, concrete saw operators had shorter durations of exposure to CO but generally experienced more severe symptoms and signs of poisoning. These results underscore the hazard associated with the indoor use of any gas-powered equipment; however, operators of concrete saws may receive a higher dose of CO.

Carbon monoxide (CO) is a by-product of incomplete fuel combustion. Although the physical properties of CO (a colorless, odorless, non-irritating gas) result in no warning of its presence, the seriousness of exposure to high concentrations of CO has been realized since the earliest medical writings. Intentional CO poisoning was used by the Greeks and Romans as a means of executing criminals and committing suicide.[1] Airborne concentrations of CO in US automobile repair shops were characterized as early as 1928.[2] Recommendations for an occupational exposure limit were in place in the United States as early as 1946.[3] Carbon monoxide was among the first topics chosen by the National Institute for Occupational Safety and Health(NIOSH)[4] for development of criteria for an occupational standard.[1] Federal Occupational Safety and Health Administration (OSHA) regulations requiring an occupational limit for CO exposure were promulgated in 1971.[5]

Still, little is known about morbidity from non-fatal poisonings in today's workplace. Measurement of this morbidity is difficult because exposure symptoms are often ignored by employees, employers, and medical providers.

To find out more about the morbidity of occupational CO poisonings in Colorado workers, the present study was undertaken in 1994 by the Occupational Epidemiology Program of the Colorado Department of public Health and Environment (CD-PHE). Specifically, we were interested in determining the number of employees poisoned as a result of exposure to CO, the common sources of exposure, and the symptoms that caused workers to seek medical assistance. Additionally, there had been an increased number and severity of poisonings attributed to gas-powered concrete saws reported during the previous year, and we were interested in determining whether operators of concrete saws were at increased risk for more severe symptoms of CO poisoning when compared with operators of other equipment.

The program was in a unique position to evaluate these concerns because Colorado has one of the few state-based surveillance systems for both fatal and non-fatal CO poisoning within the United States. As part of this system, the Occupational Epidemiology Program reviews and investigates cases that occur on the job under funding from a NIOSH Sentinel Even Notification System for Occupational Risk (SENSOR) program interagency agreement. The purpose of the investigation is to gather data so that intervention programs can be developed to prevent future workplace poisonings and to protect the health of workers.

Methods

Cases of occupational CO poisoning due to "non-automobile" gas-powered motors were identified from Colorado's population-based surveillance system for unintentional CO poisonings. This surveillance system, described in detail elsewhere,6 is briefly described below.

Population-based surveillance for CO-related fatal and non-fatal poisoning has been conducted by the CDPHE since February 1985. Case reports for the surveillance system are obtained from clinical laboratories, hyperbaric chambers, and death certificates and are obtained for both non-occupational and occupational poisonings. Reporting by clinical laboratories is mandatory, and carboxyhemoglobin (COHb) levels greater than 12% must be reported within 30 days. Reporting by hyperbaric chamber personnel is voluntary, and they have been requested to report patients treated for CO poisoning at their units regardless of the patient's COHb level.

A case of CO poisoning was defined as a person (1) with a COHb level greater than 12% reported by a clinical laboratory; or (2) who was treated in a hyperbaric chamber for CO poisoning regardless of COHb level; or (3) who had a CO poisoning reported as the underlying or contributing cause on the death certificate. In addition, prior to 1989, any worker who received compensation for CO poisoning through workers' compensation was also considered a case. Cases were included in the surveillance system if the exposure occurred in Colorado, and intentionally inflicted poisonings were excluded. For this study, a case of occupational CO poisoning was defined as an individual who (1) met the above criteria and (2) had an occupationally related CO poisoning due to exposure to emissions from any gas- or propane-powered motor other than an automobile. Poisonings reported to the surveillance system from February 1985 through the end of September 1994 were included in the analysis. Medical records were requested for review on all cases treated as an outpatient or inpatient at a hospital. Records were not requested for individuals treated at a practitioner's office. A medical epidemiologist and an industrial hygienist reviewed all of the medical records received. For cases in which the type of equipment causing the poisoning was uncertain, the employers were contacted by telephone for clarification. Statistical analysis was performed using SAS.7 Chi-square, Fisher exact test, and student's*t* tests were used to assess statistical significance of observed differences.

To determine how well hospitalizations for all CO poisonings were reported, the surveillance data collected from 1990-1992 were compared with the Colorado Hospital Association's (CHA) discharge data from the same time period. The discharge data are collected from all non-federal acute care hospitals in Colorado. The database includes medical record number; hospital code; patient age, sex, and zip code of residence; dates of admission and discharge; disposition; and, prior to 1993, up to five diagnostic and five procedure codes for each hospitalization. For the analysis, we included records with any discharge diagnosis of accidental CO poisoning (ICD-9CM codes 986.0, E868.0, E868.1, E868.2, E868.3, E868.8, E868.9) or CO poisoning of undetermined cause (E982.0, E982.1). Records that had any diagnosis of suicide attempt (E952.0, E952.1, E951.8, E951.1 E951.0) or assault (E962.2) were excluded. The discharge data and surveillance data were matched using birthdate, zip code of residence, and sex (variables found in both data sets), and date of exposure in the surveillance data and date of admission from the hospital discharge data set. Records were judged a suitable match if they agreed on all of the variables listed; admission date to the hospital must have occurred within one day of the exposure date in the surveillance report record.

We also examined how well the surveillance system captured patients treated with hyperbaric oxygen. Once the patients hospitalized for unintentional CO poisoning had been identified from the CHA dataset, the procedure codes for those records were used to identify those patients who received hyperbaric oxygen (ICD-9-CM procedure code 93.95). The records in the CHA dataset were compared with those in the surveillance system, and records were judged a suitable match using the same criteria as above.

Results

From 1985 through September 1994, 2,343 unintentional CO poisonings were reported to the surveillance system. Three hundred forty-nine (14.9%) of these were work-related. Twenty-four persons died from CO poisoning that occurred on the job; 14 of these persons were firefighters who died in a forest fire. Figure 1 illustrates the number of occupational cases poisoned by each source. Gas-powered engines accounted for the largest number of cases (139/349 or 40%), automobiles the second (92/349 or 26%), and furnaces the third (43/349 or 12%). In contrast, gas-powered motors accounted for only 2% (41/1994) of cases of non-occupational CO poisoning.

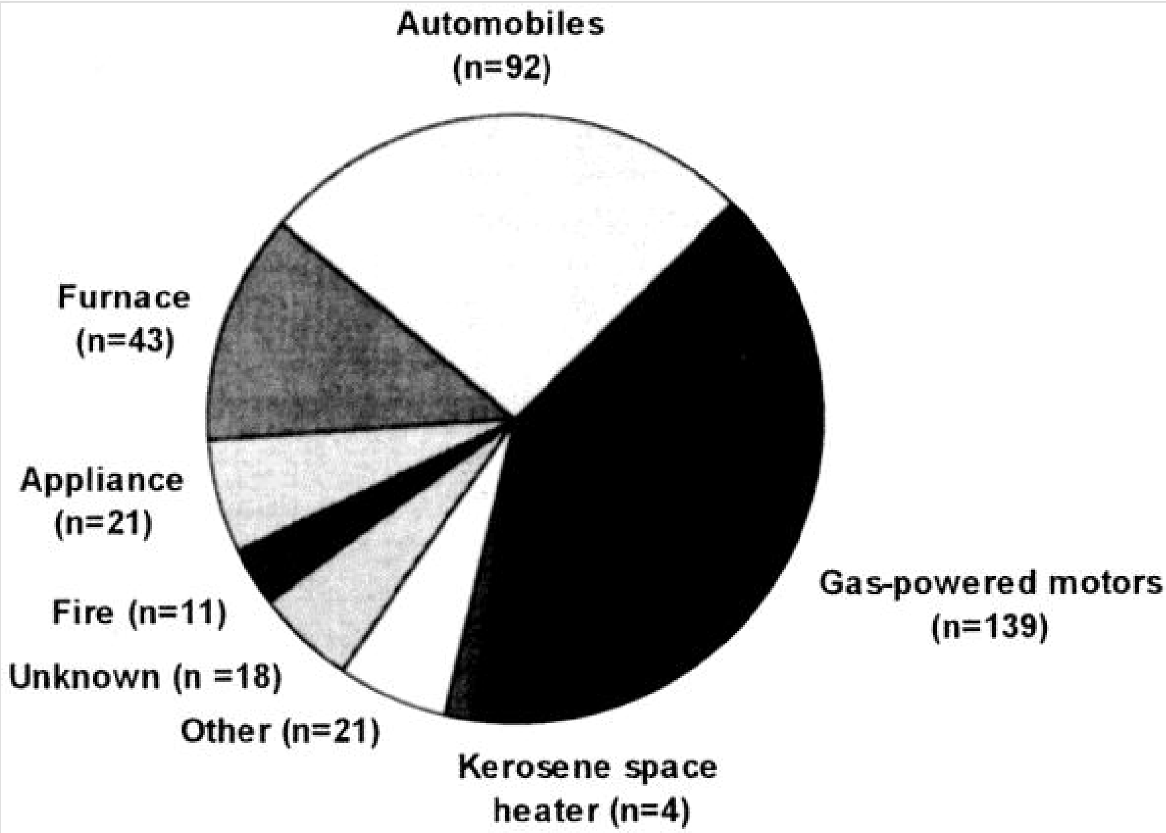

Fig. 1. Sources of occupational carbon monoxide poisoning: Colorado, 1985-September 1994 (*n* = 349).

The gas-powered engines category includes smaller engines such as those found in forklifts, construction equipment, and cleaning equipment. One hundred thirty-nine persons in 89 separate incidents were poisoned by a gas-powered motor; two persons died. In addition, there were two incidents of mass poisoning due to power trowels. Both of these incidents occurred to workers in the same company.

The poisonings from these motors were fairly evenly distributed throughout the seasons. Approximately 56% of the poisonings occurred from November through March.

Of the gas-powered engines, concrete saws were the most frequent source of poisoning (n = 29), as shown in Figure 2. Ninety-six percent of all poisonings from gas-powered engines occurred indoors or in an enclosed space. Sixty-nine of the poisonings occurred in the construction industry. Besides the sources named in Figure 2, other sources that contributed to at least one poisoning included the following: drywall texturizer, sandblaster, carpet cleaner, pump, boiler, boat motor, jackhammer, insulation blower, boiler, power saw, floor stripper, and paint sprayer.

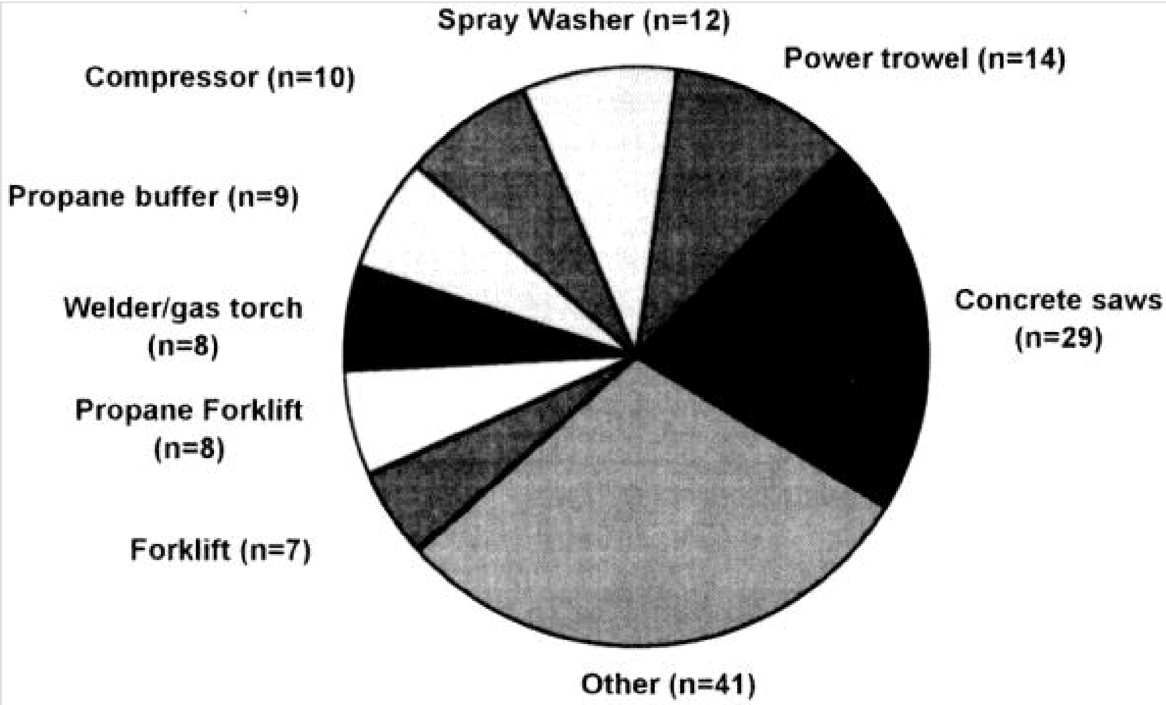

Fig. 2. Gas-powered equipment most frequently involved in unintentional work-related carbon monoxide poisoning: Colorado, 1985-September 1994 (n = 139).

We were interested in examining the possible reasons for the recent increase in concrete saw poisonings and in determining whether the concrete saw operators had characteristics that increased their risk for CO poisoning and, specifically, whether using a concrete saw led to an increased risk.

Medical records were received for 97 cases (69% of all cases associated with use of a gas-powered motor that were examined in an emergency department or admitted to a hospital). When the operators of concrete saws were compared with operators of other equipment, there were no significant differences between the two populations regarding the age distribution of cases, percentage of males, percentage of individuals with pre-existing heart or lung disease, or the percentage who smoked.

Headache, nausea, and dizziness (or lightheadedness) were the most commonly reported symptoms for the operators of concrete saws and other gas-powered machinery. Weakness, which included incoordination, and confusion were reported more frequently by operators of concrete saws ($[\chi]^2$= 4.0, P = 0.05 for weakness; $[\chi]^2$ = 4.7, P = 0.03 for confusion). The cases who operated other gas-powered machinery reported more frequent syncopal episodes or loss of consciousness. Only one person did not report any symptoms.

Table 1 summarizes the clinical findings. The concrete saw cases had higher COHb levels, and the mean COHb level of 27% in the non-smoking concrete saw cases was statistically significantly higher(student's *t* test, $P < 0.01$) than the level of 19% in the non-smoking operators of other gas-powered machinery. Consistent with the physical examination and COHb results was the finding that 91% (20/22) of the concrete saw cases were treated with hyperbaric oxygen, compared with 48%(35/73) of the cases who operated other machinery ($[chi]^2 = 12.8$; $P < 0.01$). This particular finding could not be completely explained by the hospitals where the cases were initially treated. Approximately 40% of the concrete saw cases and 26% of the other machine operators treated with hyperbaric oxygen were initially evaluated at a hospital with a hyperbaric chamber; the remainder were transferred from another facility.

Finding	Concrete Saw Operators ($n = 23$)	Operators of Other Gas-Powered Machinery ($n = 74$)	*P* Value
% with an abnormal neurologic finding on physical examination (includes physical or psychiatric abnormality)*	42.9 (9/21)	36.1 (22/61)	NS
Mean carboxyhemoglobin levels (%)			
nonsmokers ($n = 48$)	26.8 (11)	19.5 (37)	<0.01**
smokers ($n = 34$)	27.5 (6)	22.1 (28)	NS
Distribution of carboxyhemoglobin levels (%)			
≤20%	13.6 (3)	59.4 (41)	
21–29%	59.1 (13)	31.4 (22)	
30–39%	27.3 (6)	7.3 (5)	
≥40%	0 (0)	1.5 (1)	<0.01§
% treated with hyperbaric oxygen	90.0	48.0	<0.01¶
% who had recurrence or worsening of CO poisoning symptoms within 24 hours of initial treatment for CO poisoning without further exposure	17.4	5.0	NS
% with sequelae	4.4	2.7	NS

* Included any focal motor, sensory, reflex, or cerebellar deficit on physical exam or an abnormality on mental status or psychometric testing. NS, not statistically significant, $P > 0.05$.

** Student's *t* test; $P < 0.01$.

§ χ^2 for linear trend = 9.6; $P < 0.01$.

¶ $\chi^2 = 12.8$; $P < 0.01$.

TABLE 1 Physical and Laboratory Findings in Cases for Whom Medical Records Were Obtained

When the COHb level was plotted against the duration of exposure (Figure 3), the concrete saw cases had higher COHb levels with shorter durations of exposure than did the operators of the other gas-powered equipment. The effect was the same regardless of smoking status.

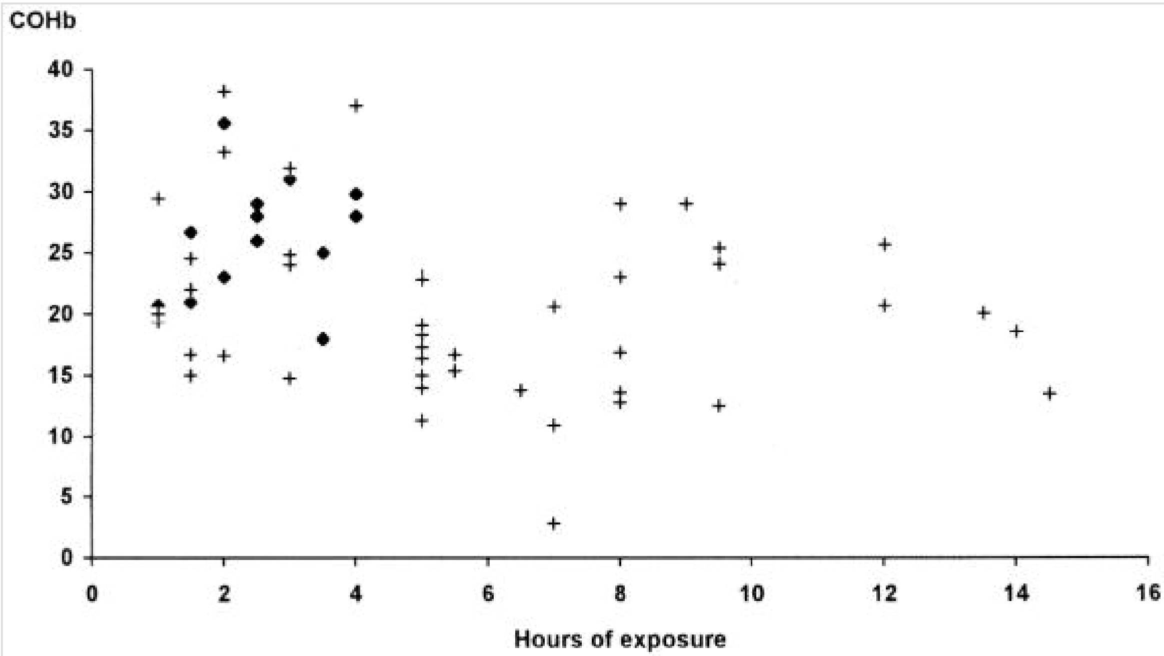

Fig. 3. Carboxyhemoglobin (COHb) concentration versus hours of exposure in operators of selected gas-powered equipment (the most frequent sources that contributed to a Co poisoning; see Figure 2): Colorado, 1985-September 1994. [black diamond] = concrete cutters; + = other gas-powered machinery.

Evaluation of the Surveillance System

From 1990-1992, a total of 657 unintentional CO poisonings were reported to the surveillance system. During this same time period, the hospital discharge data included 336 persons with at least one discharge diagnostic code for CO poisoning; 91 of these poisonings were suicide attempts or assault and were excluded from the analysis. Seventy-three matches were found when the two datasets were compared. Thus approximately 30% of the patients who were hospitalized for CO poisoning were also reported to the surveillance system.

Of the 245 persons hospitalized for unintentional CO poisoning found in the hospital discharge data-set, 84 had a treatment code indicating hyperbaric oxygen therapy. When these records were compared with those in the surveillance data, 55 matches were found; 65% of the patients who received hyperbaric treatment were captured by the surveillance system.

Discussion

Previous reports have documented occupational CO poisonings due to gas-powered concrete saws,[8] high-pressure washers,[9,10] propane-powered forklifts,[11,12] and floor burnishers.[13] Our data demonstrate that many different types of gas-powered equipment can cause CO poisoning when used in an enclosed space. In contrast to non-occupational poisonings, the distribution of occupational poisonings was fairly evenly distributed throughout the seasons since the equipment was used throughout the year.

The number of poisonings reported is most likely an underestimate of the true number of poisonings because (a) some of the poisonings were not treated at a medical facility, or (b) the poisonings were treated but not reported to the surveillance system. Evaluation of the surveillance system showed that 30% of all persons hospitalized for CO poisoning were also reported to the surveillance system, suggesting minimal overlap between the two datasets. At least three reasons could contribute to this finding. First, hospitals are not required to report. Second, it is possible that some of the poisonings in hospitalized patients were intentional but were not recorded as such on the discharge summary, thus resulting in an underestimate of agreement. Third, it was assumed that all individuals hospitalized for CO poisoning met the case definition, and that may not be true.

The fact that the surveillance system captured 65% of the patients treated with hyperbaric oxygen is an important finding. Hyperbaric chamber personnel have been requested to report cases treated at their facility; however, they are not required by regulation to report. Although this finding indicates that these facilities are a reliable source of reports, the surveillance system might be enhanced if the regulations were changed to mandate reporting by these personnel. Similarly, requiring reporting by hospitals may also increase the number of cases captured.

A limitation of this analysis is that the data were obtained retrospectively, and complete data were not available for all of the cases. The proportion of individuals for whom we were able to obtain medical records was similar for both the operators of concrete saws and of other machinery. Another limitation to this study is that industrial hygiene data were not available, and it was not possible to characterize the work environment(ventilation, size of area, ambient CO concentration).

Concrete saws were the most frequent source of poisoning from gas-powered engines, for which there could be multiple reasons: concrete saw operators were more susceptible to CO poisoning, concrete saws were used more frequently than other equipment, or there was something different about the job of sawing concrete or the concrete saw itself that led to a higher exposure. No significant demographic differences were noted between the cases who operated concrete saws and the cases who operated other gas-powered equipment. The number of users of each type of equipment was unknown, and therefore a rate for each type of machinery could not be calculated. The higher COHb levels with shorter duration of exposure in cases who operated concrete saws, compared with other operators of gas-powered equipment, suggest that operators of concrete saws may receive a higher dose of CO.

The reason for the higher exposure to CO in users of concrete saws is unclear. It is possible that concrete saws were used in smaller spaces than other equipment, thus increasing the concentration of CO in the area. The output of CO in the exhaust of concrete saws, or the load on the saw engine, may also have played a role in the higher exposure.

The finding that approximately 30% of the cases did not immediately remove themselves from the environment or seek treatment once they developed symptoms of CO poisoning underscores the need to educate workers on the symptoms of CO poisoning. CO poisoning not only has acute effects (the most severe of which are coma and death) but can also result in neurologic sequele.[14,15] In addition, with continued exposure to CO, a worker may become confused, which will limit his/her ability to make judgments about his/her environment or to seek help. One of the workers in this study, a drywall texturizer, was unable to identify an escape route from the building because of confusion.

It is also important to note that propane-powered equipment caused CO poisoning. Although propane has generally been regarded as a "safe" substitute for gas- because it burns cleaner and has less CO as a by-product, the machinery must be properly maintained and tuned to reduce CO production and emission.

In conclusion, the use of any gas-powered equipment indoors or in an enclosed space is hazardous and should be avoided except in emergency situations, and then only if the equipment operators and assisting personnel wear CO monitoring devices. The CDPHE recently joined with several federal agencies to disseminate this message. In addition, data gathered through the Colorado CO poisoning surveillance system indicate that users of concrete saws experience more severe symptoms within a shorter period of time than users of other gas-powered equipment and tools, even though both groups used the tools indoors. These data point to the need for further work to characterize chronic CO exposures of users of concrete saws in different environments, to determine the effects of these exposures on users and coworkers, and to determine what factors about concrete saw use contribute to the problems. The focus of such work should be to determine what engineering controls or changes in tool design are needed to reduce the risk. Furthermore, the data presented here indicate the need to educate users of gas-powered equipment and tools, particularly concrete saw users, about the hazards of indoor use of the tools. Such education could be channeled through equipment rental companies, tool manufacturers, and trade and labor organizations, as well as employers.

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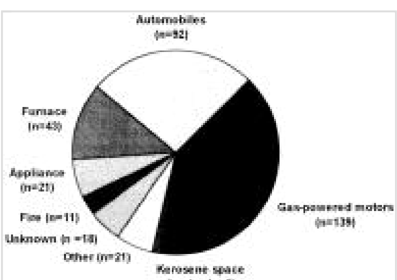

Fig. 1

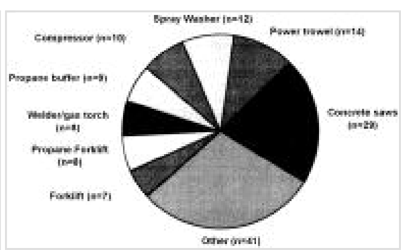

Fig. 2

Finding	Concrete Saw Operators (n = 23)	Operators of Other Gas-Powered Machinery (n = 74)	P Value
% with an abnormal neurologic finding on physical examination (includes physical or psychiatric abnormality)*	42.9 (9/21)	36.1 (22/61)	NS
Mean carboxyhemoglobin levels (%)			
nonsmokers (n = 48)	26.8 (11)	19.5 (37)	<0.01**
smokers (n = 34)	27.5 (6)	22.1 (28)	NS
Distribution of carboxyhemoglobin levels (%)			
<20%	13.6 (3)	59.4 (41)	
21–29%	59.1 (13)	31.4 (22)	
30–39%	27.3 (6)	7.3 (5)	
≥40%	0 (0)	1.5 (1)	<0.01†
% treated with hyperbaric oxygen	90.0	45.0	<0.01‡
% who had recurrence or worsening of CO poisoning symptoms within 24 hours of initial treatment for CO poisoning without further exposure	17.4	5.0	NS
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* Included any focal motor, sensory, reflex, or cerebellar deficit on physical exam or an abnormality on mental status or psychometric testing. NS, not statistically significant, $P >$ 0.05.
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Table 1

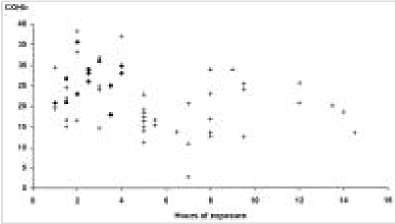

Fig. 3

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