Articles

Causes of Unintentional Deaths from Carbon Monoxide Poisonings in California

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The purpose of this study was to determine the annual number and incidence of unintentional deaths from carbon monoxide (CO) poisonings in California and to identify specific factors that caused or contributed to the deaths. Unintentional CO deaths in California over a ten-year period (1979 to 1988) were identified from the database of the California Master Mortality File and coroners' investigation reports. Factors associated with unintentional CO deaths were determined based on the information from the investigation reports. The annual number of unintentional CO deaths varied from 27 to 58 over the ten years examined, with an average annual death incidence of 1.7×10^{-6}. Death rates were high among males and African-Americans. Alcohol appeared to be a factor in 31% of the cases. The types of combustion sources associated with unintentional CO deaths were: heating or cooking appliances; motor vehicles; charcoal grills and hibachis; small engines; and camping equipment. Factors associated with unintentional CO deaths interact in a complex way. To reduce the rate of unintentional CO deaths effectively, joint efforts involving several prevention methods are suggested.

(Girman JR, Chang Y-L, Hayward SB, Liu K-S. Causes of unintentional deaths from carbon monoxide poisonings in California. West J Med 1998; 168:158–165)

Many papers have been written about carbon monoxide (CO) and its effects on health, which range from headache and nausea to low birth weight to death by asphyxiation.[1–3] CO is one of the few indoor air pollutants to which death can unambiguously be ascribed; it is one of the most common causes of deaths from poisonings in the United States.[4] A number of papers have provided anecdotal information about causes and factors related to unintentional CO deaths, and many states and the US Consumer Product Safety Commission have compiled summary statistics obtained from death certificates. Few studies, however, have examined in any detail and with population-based statistics the causes and factors related to unintentional deaths from CO. Two exceptions are papers examining unintentional CO deaths in West Virginia.[5–6] A fairly recent paper[7] provides a good summary of the national statistics on CO deaths from the database complied by the National Center for Health Statistics, but it lacks the detail made possible by examining actual coroners' investigation reports.

In this study, we examined individual coroners' investigation reports for information about unintentional CO deaths in California over a ten-year period. Our study had two major objectives: to determine the annual number and incidence of unintentional deaths from CO in California and to identify specific factors that caused or contributed to the deaths. These factors included the types of combustion sources, the location of the deaths, whether drugs (including alcohol) were involved, and demographic information about the decedents.

Methods

Study Design

The California Master Mortality File (CMMF), which contains information from death certificates, was obtained for the most recent ten-year period (1979 through 1988) available at the inception of the study. The CMMF included information about almost 100% of the deaths in California. More than 20 codes of the International Classification of Disease, Ninth Revision (ICD-9), which were potentially CO poisoning–related, were searched through the CMMF. Records containing ICD-9 code 986 (indicating the toxic effect of carbon monoxide) were used as the basis for checking "E" codes, which classify external causes of injury and poisoning. Records excluded were deaths from suicide

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ABBREVIATIONS USED IN TEXT
CMMF = California Master Mortality File
CO = carbon monoxide
ICD-9 = International Classification of Disease, Ninth Revision

(E951 through E959) and homicide (E960 through E969). Records included were those involving accidental poisoning by gas distributed by pipeline (code E867); accidental poisoning by other utility gas and carbon monoxide (codes E868.1–E868.9); and those not determined to be either accidentally or purposely inflicted (codes E981.0–E982.9).

Data from the selected records—name, date of birth, date of death, county of death, county of residence, and cause of death of the deceased—were extracted from the database. These data were organized by county of death and forwarded to county coroners or medical examiners along with a request for the investigation report for each listed death. When the county coroners did not respond to the first letter or when only some of the investigation reports from a county were received, a second letter was mailed referencing the first letter and again requesting a copy of the coroner's investigation reports. If inadequate responses continued, telephone solicitation was begun until either all requested reports were received, an explanation of why particular reports could not be obtained was received, or a visit was scheduled to allow our staff to copy the reports.

To assist in extracting information from the coroners' investigation reports for statistical analysis, a detailed evaluation sheet and criteria[8] for filling out the evaluation sheet were developed. The evaluation sheet listed the parameters believed necessary to assess the factors associated with unintentional death from CO and was developed in the following manner: First, a draft evaluation sheet and its criteria were created after reviewing a sample selection of coroners' investigation reports. Next, three evaluators examined approximately 20 investigation reports that had been selected to encompass a wide range of unusual circumstances related to unintentional CO deaths and that made it difficult to apply the criteria. The evaluators recorded any questions and problems that occurred in applying the criteria and then met to discuss their experiences and compare completed evaluation sheets. Based on this experience, the evaluators modified the evaluation sheet and its criteria. To finalize the evaluation sheet, this process had to be repeated several times.

As the coroners' investigation reports were received, an evaluator read each and recorded relevant information on the evaluation sheets. Evaluations included an assessment of the accuracy of the classification—such as whether the death was an accident related to CO poisoning. With investigation reports that contained any ambiguous information, a second evaluator was designated to read the report and attempt to resolve the ambiguity. In the few instances in which the two evaluators could not agree, a third evaluator read the report and a majority decision was reached.

The evaluation sheets were then examined for completeness and accuracy by a reviewer, who also read the coroners' investigation reports. (The reviewer of each sheet was not one of its evaluators.) When data on evaluation sheets were incomplete or incorrect, the reviewer contacted the original evaluator to resolve the problem.

Data from completed evaluation sheets were entered into a database and analyzed using the Statistical Analysis System. Analyses included the generation of one- and two-way frequency tables to distribute variables of interest. Several Chi-square tests of homogeneity were performed to make sure the sample distribution was consistent with the California population distribution. A regression analysis was used to see if any trends existed for the number of unintentional CO deaths over the ten-year period.

Study Population

From the CMMF database and based on ICD-9 E-codes, 549 deaths were identified as having occurred from unintentional CO poisoning during the ten-year study period. Of these, seven are believed to have occurred in a state other than California. We thus requested 542 reports from 46 county coroners. Twenty-one reports were unavailable for evaluation. Twelve California counties recorded no unintentional CO deaths during the study period.

We received and evaluated 522 investigation reports from county coroners. This included one report of a CO death that was not listed in the CMMF but found by reading the investigation report of a co-decedent. Of the 522 reports evaluated, 444 (85%) were judged by the evaluators to be authentic cases of unintentional death from CO poisoning. The remaining 78 reports were judged to be misclassified cases, which included homicide, suicide, gas poisoning (such as natural gas or gasoline), fatal burns, and so on. Some misclassifications were obvious coding errors, such as a stabbing homicide (which has a numerical code in the CMMF that is almost identical to that for unintentional CO poisoning, except for the transposition of two digits). Other cases, whose causes of death were less obvious, were judged by the evaluators to be misclassified based on extensive study of the investigation reports. Doing so involved, to a certain degree, subjective judgment in determining whether a case was a suicide or an accident and what was the most likely source of CO poisoning. All reports were reviewed by at least two evaluators. Ambiguous cases were discussed among all three evaluators before a final decision was made.

Results

Demographic Characteristics

Table 1 shows the gender, ethnic, and age group distributions of the 444 unintentional CO decedents. The characteristics of the CO decedents differed significantly by Chi-square tests ($P < 0.001$) from that of the state population for all three variables: the number of male

TABLE 1.—*Demographic Information on Unintentional CO Decedents in California from 1979 to 1988*

Parameter Census(%)	Number CO Decedents	Percent CO Decedents	State
Sex:			
Male	322	72.5	49.3[1]
Female	122	27.5	50.7
Ethnic Group:			
Caucasian	282	63.5	67.0[2]
Hispanic	67	15.1	19.0
African-American	67	15.1	7.5
Asian	14	3.2	3.5
Filipino	7	1.6	0.7
Native American	4	0.9	0.8
Other	3	0.7	0.8
Age:			
< 10	27	6.1	15.6[1]
10–19	26	5.9	14.1
20–29	103	23.3	18.0
30–39	86	19.4	17.0
40–49	48	10.8	11.0
50–59	51	11.5	9.2
60–69	51	11.5	8.1
70–79	37	8.4	4.9
≥ 80	14	3.2	2.2

* State of California, Department of Finance, population projections for California counties 1980 to 2020 with age/sex detail to 2020; DOF Baseline 86, 1985 state population, December 1986
** US Department of Commerce, Bureau of the Census, 1980 Census of Population, chapter 8, part 6, July 1982

decedents (322, or 72.5%) was about 2.5 times the number of female decedents (122, or 27.5%); the proportion of African-Americans among the total unintentional CO deaths was twice the proportion of African-Americans among the California population; and Caucasians and Hispanics appeared to be less likely unintentional CO decedents than would be expected based on California demographics. Unintentional CO deaths were more likely to occur among the age groups 20 to 39 years and older than 50 years.

Geographic and Seasonal Variations

The average annual death rates by county ranged from 0 to 3×10^{-4}. The highest death rate, that of Alpine County, most likely resulted from the small county population (1,182) and the fact that two episodes with a total of three deaths were recorded during the study period. Because of the small number of CO deaths for most counties, the differences in death rates due to climatic and geographic differences could not be distinguished from random variation. In California, there were 358 episodes with 444 deaths for the years 1979 to 1988. During the ten-year period of the study, the annual average incidence of unintentional CO deaths in California was 1.7×10^{-6}.

Figure 1 shows the percentages of unintentional CO deaths by month averaged over the ten-year period. In this figure, a winter peak is evident, with December having the highest number of deaths and July having the lowest number of deaths. The ten-year total percentage of CO deaths in the winter months (December, January, and February) was approximately 50%, and the highest numbers of CO deaths were observed in every winter of the ten years. To determine the types of CO sources that contributed to this seasonal peak, the percentages of unintentional CO deaths by month averaged over the ten-year period were calculated for three categories of CO sources: heating and cooking appliances, vehicles, and charcoal grills or hibachis. The winter peak for heating appliances and vehicles is, perhaps, expected. There is also a winter peak, although not as pronounced, for the charcoal grill or hibachi category. This suggests that even for this source, colder weather is an important factor: a review of coroners' investigation reports has revealed that in many incidents the charcoal grill or hibachi was used as a heater and not necessarily as a cooking device.

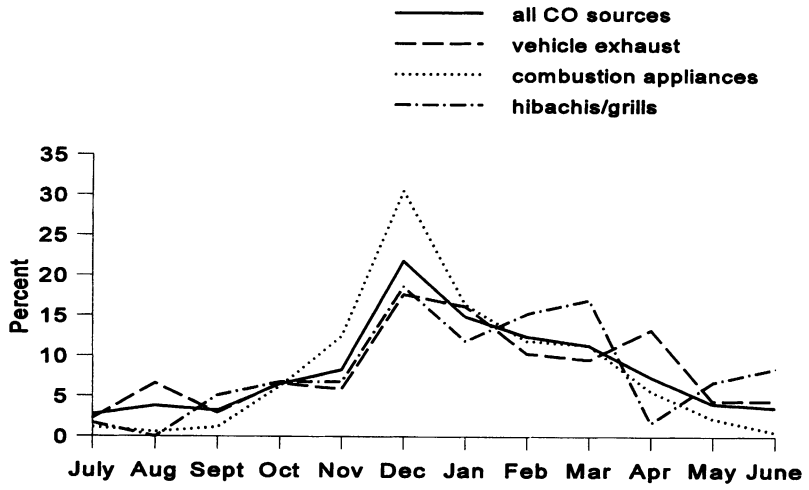

Figure 1.—The diagram shows the causes of unintentional CO deaths are shown by month over a 10-year period in California

TABLE 2.—*Number and Percentage of Unintentional CO Deaths and Episodes in California from 1979 to 1988 by CO Source*

Deaths per Episode	Vehicle		Heating & Cooking Appliance		Charcoal Grill/ Hibachi		Small Engine		Camping Equipment		Other		Total
	No.	(%)	No.	(%)	No.	(%)	No.	(%)	No.	(%)	No.	(%)	No. (%)
1	121	(33.8)	86	(24.0)	37	(10.3)	8	(2.2)	6	(1.7)	27	(7.5)	285(79.6)
2	8	(2.2)	28	(7.8)	9	(2.5)	7	(2.0)	2	(0.6)	5	(1.4)	59 (16.5)
3	0		5	(1.4)	1	(0.3)	1	(0.3)	0		1	(0.3)	8 (2.2)
4	0		4	(1.1)	0		0		0		0		4 (1.1)
5	0		2	(0.6)	0		0		0		0		2 (0.6)
Total Episodes	129	(36.0)	125	(34.9)	47	(13.1)	16	(4.5)	8	(2.2)	33	(9.2)	358(100)
Total Deaths*	136	(30.6)	178	(40.1)	58	(13.1)	24	(5.4)	10	(2.3)	38	(8.6)	444(100)

*Total Deaths only include cases with coroner's reports.

Longitudinal Trend

The number of unintentional CO deaths for each year varied from 27 to 58. The annual incidence of death ranged from 1.0×10^{-6} to 2.2×10^{-6}. A linear regression model for the annual CO death rate was adopted to examine the longitudinal trend ($R^2 = 0.17$). Although the slope shows a decreasing trend over the ten years, it is not significantly different from zero; the 95% confidence interval of the slope is -0.045 ± 0.076 deaths per million per year.

Sources of CO Poisonings

Table 2 shows the number and percentages of episodes and deaths by various sources. Among different source categories, deaths caused by CO emitted from heating and cooking appliances constituted the largest category. The largest numbers of unintentional CO deaths were caused by heating or cooking appliances. Exhaust from motor vehicles—causing 36% of the episodes and 31% of the deaths—was the second largest cause of CO deaths. Charcoal grills or hibachis was the third largest category with 13% of the episodes and 13% of the deaths. Small engine exhaust and emissions from camping equipment (such as stoves or lanterns) caused smaller proportions of the deaths. Other sources of CO contributed to 9% of the deaths.

Combustion Appliances and Fuel Type

Table 3 shows the number and percentage of episodes and deaths by type of heating and cooking appliance. Among the various types of heating and cooking appliances, deaths due to wall heaters and free-standing heaters accounted for the highest and second-highest number of CO episodes. Stoves ranked as the third most common CO source among heating and cooking appliance–related deaths. The remaining episodes came from water heaters, furnaces, floor heaters, and other miscellaneous sources.

TABLE 3.—*Number and Percentage of Unintentional CO Deaths and Episodes in California from 1979 to 1988 by Heating and Cooking Appliance Type*

Deaths per Episode	Stove		Free Standing Heater		Water Heater		Furnace		Wall Heater		Floor Heater		Misc.		Total
	No.	(%)	No.	(%)	No.	(%)	No.	(%)	No.	(%)	No.	(%)	No.	(%)	No. (%)
1	14	(11.2)	18	(14.4)	8	(6.4)	10	(8.0)	28	(22.4)	4	(3.2)	4	(3.2)	86 (68.8)
2	5	(4.0)	4	(3.2)	2	(1.6)	2	(1.6)	12	(9.6)	3	(2.4)	0		28 (22.4)
3	1	(0.8)	1	(0.8)	0		0		2	(1.6)	1	(0.8)	0		5 (4.0)
4	1	(0.8)	0		1	(0.8)	1	(0.8)	1	(0.8)	0		0		4 (3.2)
5	0		1	(0.8)	0		0		1	(0.8)	0		0		2 (1.6)
Total Episodes	21	(16.8)	24	(19.2)	11	(8.8)	13	(10.4)	44	(35.2)	8	(6.4)	4	(3.2)	125 (100)
Total Deaths*	30	(16.9)	33	(18.5)	16	(9.0)	15	(8.4)	67	(37.6)	13	(7.3)	4	(2.2)	178 (100)

*Total Deaths only include cases with coroner's reports.

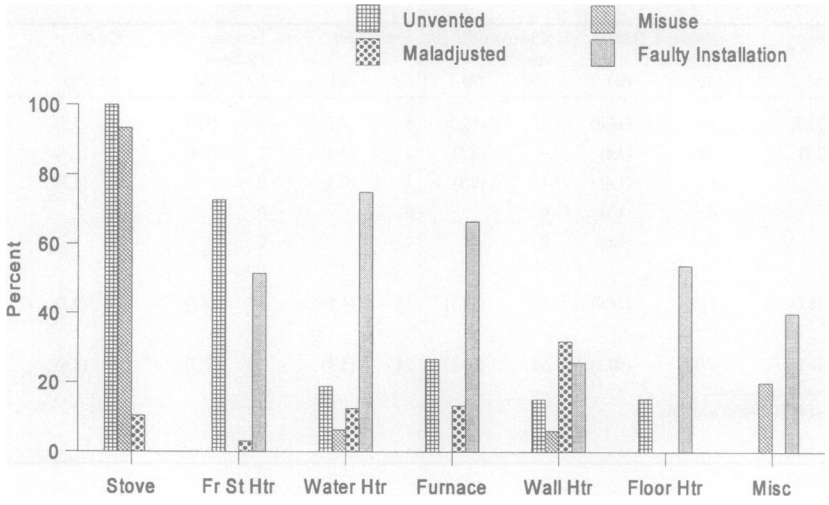

Figure 2.—This figure shows the percentages of possible causes of combustion appliance malfunctions related to unintentional CO deaths in California from 1979 to 1988.

Among different kinds of fuels used with heating or cooking appliances, natural gas caused 78% (139 cases) of the 178 unintentional CO deaths. This number is high, because when the appliance fuel was not specified in a coroner's investigation report, natural gas was listed by default. Propane/butane caused 21% (37 cases) of the unintentional CO deaths from combustion appliances. It is notable, given the probable low market penetration of propane stoves, that propane stoves caused 8% of the total unintentional CO deaths. Several coroners' investigation reports illustrated that failure to convert stoves properly from natural gas to propane can be a significant factor in CO poisoning. Use of kerosene was associated with less than 1% of the deaths, perhaps due to its low market penetration in California.

Possible Causes Associated with Non-Vehicular Sources

Figure 2 lists the possible causes of unintentional CO deaths due to heating and cooking appliances and the percentage of appliances with a particular malfunction. In many cases, the cause was clear and explicitly described in the coroner's investigation report; in some cases, considerable judgment was necessary on the part of the evaluators. In still other cases, the cause could not be determined. The causes of malfunctions for a given type of combustion appliance do not add up to 100% because they were not mutually exclusive—in other words, there were often multiple causes.

It was estimated that over 90% of the deaths from stove-use involved misuse, typically in the form of using the stove for space heating. (While not explicitly stated in coroners' investigation reports, it was assumed that 100% of the stoves were unvented, which is usually true.) In the cases of free-standing space heaters, unvented heaters were involved in over 70% of the deaths; faulty installation (most often of a space heater that is designed to be vented, but has no or inadequate venting) was involved in over 50% of the deaths. With both water heaters and furnaces, faulty installation (typically in the form of improper venting) was the leading cause of death (over 70% from water heaters; over 65% from furnaces). No specific cause appeared to predominate with wall heaters, but with floor heaters, over 50% of the deaths were caused by faulty installation.

Although a majority of nonvehicular CO deaths occurred in single-family homes, none of the 23 cases caused by small engines occurred in a single-family home. All 23 deaths occurred in poorly vented or small, enclosed spaces—mines (5); RVs (5); apartments/converted garages (3); shacks/cabins (5); boats (2); a garage (1); a truck (1); and underwater (diving) (1). Of the 23 deaths, 15 were caused by generators. Other deaths were caused by water pumps (3); dredges (2); an air pump (1); and an air compressor (1); and a heater (1). Of the 10 cases involving camping equipment, 7 were caused by CO from lanterns or lamps and 3 by stoves.

Number of Deaths and Survivors per Episode

Most vehicular CO episodes (121 of 129, or 94%) resulted in a single death and none resulted in more than two deaths. Multiple deaths were more common for heating and cooking appliances—86 of 125 (67%) of the episodes involved a single death, and two episodes (2% of the total episodes) each resulted in five deaths. The distributions of the number of deaths per episode from heating and cooking appliances appeared to be similar for natural gas and propane.

Deaths Related to Alcohol and Other Drugs

Because the use of alcohol and other drugs can impair judgment and affect a person's chances of averting a life-

TABLE 4.—*Number and Percentage of Alcohol-Related Unintentional CO Deaths by CO Source*

	Vehicle		Heating & Cooking Appliance		Charcoal Grill/ Hibachi		Small Engine		Camping Equipment		Other		Total
	No.	(%)	No.	(%)	No.	(%)	No.	(%)	No.	(%)	No.	(%)	No. (%)
Alcohol-Related Deaths	59	(43.4)	33	(18.5)	22	(37.9)	8	(33.3)	1	(10)	14	(36.8)	137(30.9)
Total CO Deaths	136	(100)	178	(100)	58	(100)	24	(100)	10	(100)	38	(100)	444(100)

threatening exposure to CO, the incidence of the presence of alcohol and other drugs in decedents was examined. Based on the review of the coroners' reports and clear evidence of alcohol involvement, at least 137 (31%) of the 444 unintentional CO deaths involved alcohol consumption. An attempt to determine the frequency distribution of blood alcohol levels in decedents was abandoned because blood-alcohol analysis had not always been reported, even when clear evidence of alcohol consumption was present. (For similar reasons, the attempt to determine the frequency distribution of carboxyhemoglobin levels was abandoned because carboxyhemoglobin analysis had not always been reported.) Table 4 shows the number and percentage of known alcohol-related deaths by CO source. As this table illustrates, there was a strong association of the use of alcohol and CO poisoning from motor vehicles. Typical cases involved drivers who, under the influence of alcohol, parked their cars in their garages and fell asleep without stopping the engine. Surprisingly, there were also cases involving decedents who experienced CO poisoning while drinking and listening to cassette tapes with the motor running, despite having parked their vehicles in the open.

The statistics for drugs other than alcohol are less certain. The clear use of illegal drugs, determined by blood or urine analysis, physical evidence at the scene, or testimony of witnesses, was evident in 9.0% of CO decedents. Prescription drugs were clearly associated with 6.8% of the cases.

CO Deaths Among Minorities

Although 7.5% of the California population is African-American, the percentage of African-Americans among all unintentional CO decedents was 15.1% (Table 1). Further analysis of the place of death and the CO source involved revealed that unintentional CO poisonings of African-Americans were more likely to occur in motels and what appeared to be older apartments, with a wall heater as the source of CO. These conditions suggest that low socioeconomic status might have been a factor in these deaths.

Discussion

While the method of research employed in this study (examining the actual coroners' investigation reports rather than summary statistics) was time-consuming, it provided a wealth of detail about unintentional deaths from CO in California that was not otherwise available. Most coroners' reports were more complete than anticipated and provided ample detail for the needs of this study. Our study method allowed incorrectly coded deaths to be eliminated from consideration and provided for greater accuracy than would have been possible through a simple examination of the CMMF.

Not unexpectedly, the death rate of 1.7×10^{-6} in our study is lower than that of 2.5×10^{-6} for California reported by Cobb and Etzel[7] over the same study period. Seventy-eight misclassified cases that we found in our study were excluded from further analysis. It would not be possible to identify such cases from the information provided by death certificates, as was the method used by Cobb and Etzel. In addition, some types of cases included in Cobb and Etzel's work, such as CO-related deaths from motor vehicle accidents (records E811 through E813, E815, E816, E818, and E819) and during air transport (records E841 and E844), were not included in our study. We have adopted, from the West Virginia study, the case-inclusion criteria that CO poisoning must clearly be the primary cause of death, which tends to be conservative. The reason to exclude cases of CO deaths from traffic collisions is similar to the one for victims of fire—the traffic accident (or fire) may be the primary cause of death and CO poisoning the consequence of the accident (or fire). CO poisonings in airplanes are not included in most studies (or ours) for similar reasons. We did include records E981.0–E982.9 (undetermined whether accidentally or purposely inflicted) for review, although they were not included in any of the other studies. Only the cases that can be determined unambiguously as accidental CO poisonings, however, were included for our analysis.

Despite the differences in the case definition and a lower estimate for our study, the national rank of California does not change: the unintentional CO death rate of California is still the second lowest, ahead of only Hawaii, among all 50 states. California in general follows the national pattern with more deaths in the winter months and higher rates among males, African-Americans, and older persons. There is, however, a significant difference in the proportions of deaths due to vehicular and nonvehicular sources. Contrasting with the national data that attributes 57% of MO-related deaths to motor vehicle exhaust, California exhibited

only 31%. The difference was highly significant by Chi-square test ($P < 0.001$).

The low rate of CO deaths in California can probably be attributed to two factors—the mild climate and stringent vehicle pollution controls. The national data regarding the rates and ranks of unintentional CO death[7] clearly demonstrate the correlation between the CO death rate and the length of the heating period necessary during winter months. Most areas of California experience no snowfall, even during the winter season, so the state's heating periods are much shorter than those of other states. Hawaii, with no heating period, has the lowest unintentional CO death rate (0.5×10^{-6}) and Alaska, with the longest heating period of the states, has the highest rate (27.2×10^{-6}). California has also adopted the strictest regulations regarding the control of motor vehicle emissions and the prohibition of selling unvented heaters, both of which have most likely contributed to its low unintentional CO death rate.

Data extracted solely from death certificates can provide only crude statistics on major causes of unintentional CO deaths. Reviewing coroners' reports allowed us to examine the factors associated with CO-related deaths more closely. As this study illustrates, many sources are capable of causing unintentional death from CO poisoning. In addition, many factors can lead to high CO exposures—cold weather, faulty vehicle exhaust systems, improper adjustments of the air shutter of combustion appliances, or faulty installations of gas water heaters. Other factors associated with individual decedents, such as gender and age, are also potential influences. Still other conditions involving activities under the direct control of individual decedents (such as the use of a gas stove for space heating, running a vehicle in a closed garage, or drinking alcoholic beverages) are potential influences. Thus, the causes of an unintentional death from CO poisoning can interact in a complex way. It is clear from reading coroners' investigation reports that, in many cases, removing even one of these factors could have averted an unintentional death from CO. Effectively implementing a prevention strategy would thus need to involve many different methods.

The causes of CO poisonings from heating and cooking appliances were one or more of the following: unvented or poorly vented conditions, faulty installation, misuse, and maladjustment. Free-standing heaters or stoves used for heating were generally unvented. Some of the wall and floor heaters were also unvented or poorly vented. There were cases in which the vents of furnaces were blocked by birds' nests or rusting materials. Currently, information on safety issues of heating and cooking appliances are generally made available to customers by gas companies before the heating season. If service personnel from gas companies were to provide annual inspections of heating and cooking gas appliances and old furnaces while checking gas meters or refilling propane tanks, some of the faultily installed, maladjusted, and malfunctioning appliances would be corrected. Some incidents of CO poisonings could therefore be avoided.

Most deaths from charcoal grills and hibachis occurred in the winter season, between the months of December and March. We were surprised to have found 58 deaths from the misuse of grills and hibachis because these devices are designed for outdoor use only and should only be used for cooking. Among these deaths, 29 were found to have occurred in motor vehicles, a place where charcoal grills and hibachis should not be used at all. Although there is a warning on the charcoal bags sold in California, it is not a multilingual label and is not very obvious. Some of the boxes of new grills and hibachis include a warning against indoor use, but no permanent warning can be found on the devices themselves. Some lives could be saved if a permanent, multilingual label is put on the charcoal grills and hibachis to warn customers about using them indoors or in an enclosed space (including in motor vehicles).

The public is well informed that one of the most important causes of traffic accidents is drinking and driving. It is not well known, however, that drinking even without driving (for instance, simply parking a car and allowing the engine to run) can also be dangerous. Alcohol was involved in 43% (59 cases) of the 136 vehicular deaths. Not only was parking a car in a garage without stopping the engine highly risky, CO deaths also occurred in cars parked and running in the open. A multimedia, multilingual educational program might be helpful in reducing the number of CO deaths from automobile emissions, but the amount of resources and efforts required for this task would not be small. It might be more cost-effective to add educational reading material into the motor vehicle driver's manual and test drivers during their driver's tests.

Among all prevention methods for CO poisoning, the required installation of residential CO alarms is currently receiving the most attention. A CO alarm may offer some protection, but consumers should not neglect the importance of the proper use[9] and maintenance of potential CO sources. A better strategy is multiple approaches that rely on not only CO alarms but also consumer education, coupled with inspections of combustion appliances and their flues.

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REFERENCES

1. Bartlett D. Pathophysiology or exposure to low concentrations of carbon monoxide. Arch Environ Health 1968; 16:719–727

2. Dolan MC. Carbon monoxide poisoning. Can Med Assoc J 1985; 133:392–398

3. Kirkpatrick JN. Occult carbon monoxide poisoning. West J Med 1987; 146:52–56

4. Baker SP, O'Neill B, Karpf RS. The Injury Fact Book. Lexington, KY: Lexington Books, 1984

5. Baron RC, Bacher RC, Sopher IM. Unintended deaths from carbon monoxide in motor vehicle exhaust: West Virginia. Am J Public Health 1989; 79:328–331

6. Baron RC, Backer RC, Sopher IM. Fatal unintended carbon monoxide poisoning in West Virginia from nonvehicular sources. Am J Public Health 1989; 79:1656–1658

7. Cobb N, Etzel RA. Unintentional carbon monoxide–related deaths in the United States, 1979 through 1988. JAMA 1991; 266:659–669

8. Girman J, Chang Y-L, Hayward SB, Liu K-S. Final Report: Causes of Unintentional Deaths from Carbon Monoxide Poisonings in California. Berkeley, CA, California Department of Heath Services, Air and Industrial Hygeine; Laboratory Report No. CA/DOH/AIHL/CO-1; 1993

9.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: Alert: Preventing Carbon Monoxide Poisoning from Gasoline-Powered Engines and Tools. National Institute for Occupational Safety and Health Publication No.96-118, Cincinnati, 1996