Journal of Occupational and Environmental Hygiene
Publication details, including instructions for authors and subscription information:
http://oeh.informaworld.com/soeh/title~content=t713657996

Occupational Carbon Monoxide Poisoning in Washington State, 2000-2005

Carolyn K. Reeb-Whitaker[a]; David K. Bonauto[a]; Stephen G. Whittaker[b]; Darrin Adams[a]
[a] WA State Department of Labor and Industries, SHARP Program, Olympia, Washington [b] Local Hazardous Waste Management Program, Public Health - Seattle & King County, Seattle, Washington

First published on: 14 July 2010

To cite this Article Reeb-Whitaker, Carolyn K. , Bonauto, David K. , Whittaker, Stephen G. and Adams, Darrin(2010) 'Occupational Carbon Monoxide Poisoning in Washington State, 2000-2005', Journal of Occupational and Environmental Hygiene, 7: 10, 547 — 556, First published on: 14 July 2010 (iFirst)

To link to this Article: DOI: 10.1080/15459624.2010.488210

URL: http://dx.doi.org/10.1080/15459624.2010.488210

Journal of Occupational and Environmental Hygiene, 7: 547–556
ISSN: 1545-9624 print / 1545-9632 online
DOI: 10.1080/15459624.2010.488210

Occupational Carbon Monoxide Poisoning in Washington State, 2000–2005

Carolyn K. Reeb-Whitaker,[1] David K. Bonauto,[1] Stephen G. Whittaker,[2] and Darrin Adams[1]

[1]WA State Department of Labor and Industries, SHARP Program, Olympia, Washington
[2]Local Hazardous Waste Management Program, Public Health - Seattle & King County, Seattle, Washington

Washington State workers' compensation data can be used to guide prevention efforts focused on occupational carbon monoxide (CO) poisoning. Between 2000 and 2005, a total of 345 individual claims comprising 221 different exposure incidents were identified for the 6-year time period. The construction industry had 43 (20%) CO incidents, followed by wholesale trade with 32 (15%), and agriculture with 27 (12%) incidents. Fuel-powered forklifts caused 29% of all incidents, while autos/trucks/buses were responsible for 26%. The number of forklift incidents in fruit packing and cold storage companies declined significantly from 1994 through 2007 (Spearman's rho = 0.6659, p < 0.01). While this study used multiple medical records from workers' compensation claims to identify CO poisoning, a surveillance system that lacks extensive medical records may rely principally on carboxyhemoglobin (COHb) tests. This study demonstrated that 71% of the identified workers' compensation claims had associated COHb tests. The recurrence and timing of CO poisoning as well as control of the CO-generating source were determined. Approximately 8% of all work sites had recurring CO poisoning incidents. Two percent experienced a recurrent incident within 16 days of the initial incident, and 6% experienced a recurrent incident between 16 days and 3 years after the initial incident. Sixty-seven percent of claimants exposed to CO were not in direct control of the CO-generating source; this has implications for CO prevention and underscores the need for all employees to be trained on CO hazards.

Keywords aviation, COHb, construction, forklifts, surveillance, warehouse

Address correspondence to: Carolyn K. Reeb-Whitaker, WA State Department of Labor and Industries, SHARP Program, PO Box 44330, Olympia, WA 98504; e-mail: whca235@Lni.wa.gov.

INTRODUCTION

Workers' compensation claims filed for carbon monoxide (CO) exposure can be used to monitor injury trends, identify the root sources that generate and cause CO poisoning, and guide prevention efforts. A workers' compensation claims review was conducted previously for claims filed between 1994 and 1999 in Washington State.[(1)] This current descriptive study describes the CO poisoning claims in successive years and characterizes them by occupation, industry, source, and workers' compensation cost. In addition, CO incidents caused by forklifts in Central Washington's vegetable and fruit packing and storage industry are described from 1994 through 2007. Washington State Department of Labor and Industries (L&I) compliance and consultation officers have focused prevention efforts in this industry since the mid 1990s. We sought to determine whether CO poisoning incidents had decreased in response to these prevention efforts.

While the Washington workers' compensation database provides detailed medical and circumstantial information about CO poisoning, we questioned whether it would be valuable to ascertain CO cases from other data sources. Data sources for CO surveillance could include mandatory notifiable condition reporting and poison control center data. At the present time, 13 states participate in mandatory reporting of acute CO poisoning.[(2)] This mandatory reporting requires physicians, laboratories, and hospitals to report carboxyhemoglobin (COHb) blood tests to their respective state departments of health and the Centers for Disease Control and Prevention. Although Washington State does not currently have mandatory CO reporting, such a system may be instituted in the future.

To evaluate the reporting accuracy of surveillance systems that may rely predominantly on COHb tests, we determined the number of workers' compensation claims with medical bills for COHb blood tests. In this claims review there is evidence of COHb testing (from medical bills) but not the test result itself. Beyond mandatory reporting, information about CO poisoning is also available through the American Association of Poison Control Centers' Toxic Exposure Surveillance System.[(3)] Poison control center data involves anonymous reporting and contains details about the location and source of CO poisoning.[(4)]

Because CO surveillance can be used to target prevention efforts, we determined the number of companies that experienced recurrences of CO poisoning at the same business location. Because the timeliness of reporting CO cases is important, we determined the length of time between repeat poisonings to inform how quickly an intervention (site visit) should be carried out after an initial poisoning. Historically at L&I, informal reporting of CO injury claims by a claim reviewer to L&I compliance inspectors has helped guide prevention efforts. Formal reporting of claims to L&I compliance and consultation officers can promote hazard abatement and reduce the risk of illness.

METHODS

Industrial insurance is mandated in Washington for employers of one or more employees. Industrial insurance can be obtained through either (a) the state's industrial insurance program (State Fund) administered by L&I or (b) through self-insurance. This analysis is limited to insurance claims filed through the State Fund, which covers approximately 99.5% of all Washington employers. Employers who self-insure (and are not included in this analysis) include the federal government and large employers with more than $25 million in assets.

In addition, L&I's State Fund provides workers' compensation insurance to approximately 70% of all Washington workers. Examples of workers who do not participate in the State Fund are sole proprietors, such as residential construction contractors; some domestic workers; and workers covered under the Federal Employees' Compensation Act, Longshoremen's and Harbor Workers' Compensation Act, Jones Act, and Law Enforcement Officers and Fire Fighters Compensation Plan.[5]

Claim Coding and Case Identification for Carbon Monoxide Poisoning

A worker, his or her employer, and the worker's physician complete a Report of Industrial Injury or Occupational Disease (RIIOD) claim form to initiate a Washington State Fund workers' compensation claim. The claim form is used to assign American National Standards Institute (ANSI) Z16 codes for injury type, source, body part, and nature.[6] Medical bills submitted by the health care provider or the treatment facility (e.g., hospital or urgent care) are submitted to L&I and contain *International Classification of Diseases*, *Ninth Revision, Clinical Modification (ICD-9-CM)* codes.[7]

L&I claim adjudicators also assign ICD-9-CM codes to the claim for allowed diagnoses. Medical and hospital procedures are coded using Outpatient Services Current Procedural Terminology (CPT) codes and Healthcare Common Procedure Coding System (HCPCS) codes.[8,9] The ICD-9 codes, CPT, HCPCS codes, and ANSI Z16 codes used to identify and define workers' compensation claim cases for exposure to CO are presented in Table I. L&I claim administrators must assign specific ICD-9 codes and hospital procedural codes to individual claims to authorize and process bill payments.

In October 2007, we identified 549 State Fund workers' compensation claims with dates of injury between January

TABLE I. Data System Codes to Identify Workers' Compensation State Fund Claims for CO Poisoning

ANSI Z 16		
Injury Source Code	0954	Carbon monoxide
Associated Source Code	09540	Carbon monoxide
ICD-9 CM Codes		
Diagnosis Code	986	Toxic effects of CO
E Codes[A]	868.3	CO from incomplete combustion of other domestic fuels
	868.8	Carbon monoxide from other sources (blast furnace gas, kiln vapor, incomplete combustion of fuels in industrial use)
	868.9	Unspecified carbon monoxide
	952.1	Suicide and self-inflicted poisoning by other gases and vapors – Other carbon monoxide
	982.1	Poisoning by other gases, undetermined whether accidentally or purposefully inflicted – Other carbon monoxide
Medical or Hospital Procedure Codes		
CPT[B] Codes	82375	Carbon monoxide, (carboxyhemoglobin); quantitative
	82376	Carbon monoxide, (carboxyhemoglobin); qualitative
	99180	Hyperbaric oxygen pressurization, initial
	99182	Hyperbaric oxygen pressurization, subsequent
HCPCS[C] Level II Codes	C1300	Hyperbaric oxygen under pressure, full body

[A]External Causes of Injury and Poisoning codes.
[B]Current Procedural Terminology codes.
[C]Healthcare Common Procedure Coding System.

1, 2000, and December 31, 2005, that met the above case definitions for CO poisoning. We eliminated all claims that were not accepted by the department (n = 142). Accepted claims are those for which (a) a physician determines that work on a more probable than not basis caused the illness; (b) there are objective medical findings to support the diagnosis; and (c) the disease arises "naturally and proximately" from work. A certified industrial hygienist reviewed narrative text fields on the claim form to determine the source of CO poisoning. Claims with exposure to fire or smoke (n = 10) or claims filed for conditions other than CO poisoning (n = 52) were eliminated. The claim forms for the remaining 345 claims were further reviewed by the toxicologist for independent verification of CO exposure sources. Discrepancies in determining the CO source occurred for less than 3% of the claims and were resolved by further review of medical records.

Workers' Compensation Claim Data

Data obtained for each claim included the unique claim identification number, the claimant's date of birth, the date of injury, the ANSI Z16 injury codes, health care facility type, and the business location of the employer. The employer's North American Industrial Classification System (NAICS) code and the worker's Standard Occupational Classification (SOC) code were also obtained for each claim.[10,11]

Claims can be either "closed" with no further activity or "open" with ongoing medical care and related costs. Claim costs were obtained and represent paid-to-date costs for closed claims. Claim costs on "open" claims represent paid-to-date costs as well as an estimate of future incurred claim costs.

Claim costs were adjusted for inflation to the year 2009. All bills were adjusted using the Consumer Price Index for Urban Wage Earners and Clerical Workers for Seattle-Tacoma-Bremerton, Washington. Bills were adjusted on a simplified basis using the date of injury as the "payment" date for all bills. Incurred medical costs were adjusted using the Medical Care Series (CWUSA423SAM), while all other costs were adjusted using All Items Except Medical Care Series (CWUSA423SA0L5). Indirect costs to employers and workers (e.g., employee turnover, productivity loss, public relations issues, and poor employee morale) and the administrative costs of managing the claim are not included in the claim costs.

Compensable claims are those with L&I status codes of either "compensable," "kept-on-salary," "total permanent disability," "fatal," or "loss of earning power." A claim qualifies as compensable if it involves 4 or more days of time loss from work. Time loss payments occur over time and in some cases stretch over several years. Both compensable and medical-only (non-compensable) claims were included in the study.

A CO exposure "incident" was defined as one or more claims occurring on the same day in the same business location. Review of the claim form and medical records were necessary to establish that recurring incidents within a business location were truly independent exposure events. Medical record review of individual claims differentiated whether the claimant was the operator of the CO source or a bystander.

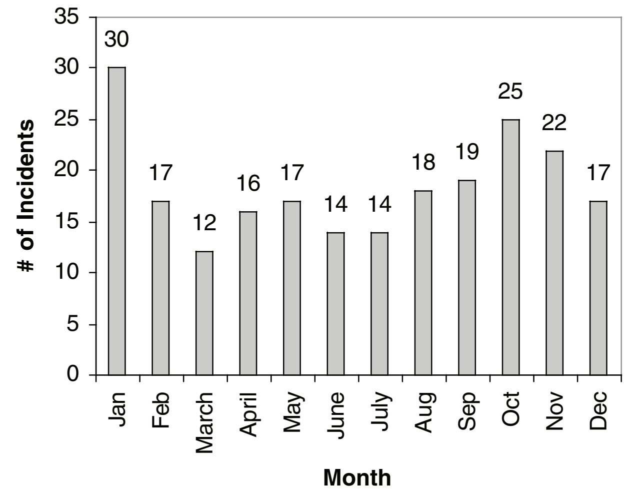

FIGURE 1. Seasonal distribution of CO incidents totaled for all years by month, 2000–2005.

RESULTS

Frequency, Source, and Costs for Carbon Monoxide Claims

For the period 2000–2005, a total of 221 incidents and 345 individual claims were identified. There were no CO fatalities during this time period in the workers' compensation claims data. The average number of claims per year was 58 (SD = 30, range 28 to 115) and the median was 51. The average number of incidents per year was 37 (SD = 9, range 23 to 50) and the median was 35. Figure 1 shows that CO incidents, totaled for all years, were seasonally distributed, with the greatest number occurring in October, November, and January. The seasonality trend holds for all years (data not shown). The majority of cold weather incidents were associated with forklifts (35%) operating in the agriculture and warehouse industries and auto/truck/buses (25%) operating in a wide variety of industry sectors.

The identifiable sources of CO poisoning primarily occurred within 10 major categories (Table II). Claims that had no obvious source were categorized as Undetermined. The Other category comprises 21 different sources ascribed to four or fewer claims each. Sources responsible for two or more claims in the Other category included: airplane exhaust, concrete power trowel, man-lift, mine blast, snowplow, tractor, and welding. Overall, the most common sources of CO incidents were forklifts (29%), auto/truck/bus (26%), heater/furnace (8%), and saw (6%). Regarding the auto/truck/bus source, a total of 31 incidents (54%) were attributed to trucks alone, five (9%) were attributed to autos alone, four (7%) to buses alone, and 17 incidents (30%) were attributed to multiple types of vehicles, such as in parking garages, and vehicle exhaust entrained into a building. Nine (69%) of the saw incidents

TABLE II. Sources and Hyperbaric Treatment for CO Incidents and Claims, 2000–2005

Source	No. of Incidents (%)	No. of Claims (%)	No. of Claims[A] Requiring Hyperbaric Treatment
Forklift	65 (29)	154 (45)	7
Auto/truck/bus	57 (26)	61 (18)	—
Heater/furnace	18 (8)	23 (6)	—
Saw	13 (6)	18 (5)	2
Pressure washer	6 (3)	8 (2)	1
Boiler	5 (2)	9 (3)	—
Generator	4 (2)	7 (2)	—
Insulation Blower	4 (2)	5 (1)	—
Food fryer	3 (1)	5 (1)	—
Oven	2 (1)	5 (1)	—
Other	30 (14)	34 (10)	3
Undetermined	14 (6)	16 (5)	—
Sum Total	221	345	13

[A]There were a total of five *incidents* (10 out of the 13 claims) that required hyperbaric treatment.

were ascribed specifically to concrete cutting saws as opposed to other types of fuel-powered saws.

The cumulative workers' compensation incurred costs for CO claims over the 6-year period were $2.6 million. These claim costs were compared with the costs from all State Fund accepted claims in the same 6-year period (Table III). Medical-only claims had a median cost of $504 (range $30 to $16,093), while compensable claims had a median cost of $5295 (range $67 to $823,765). The median number of time loss days from CO claims was 23 (range from 1 to 1685 days). While the median costs for CO medical-only claims are higher than all State Fund medical-only claims, the median costs of compensable CO claims are lower than all State Fund compensable claims.

TABLE III. Costs of Carbon Monoxide State Fund (SF) Claims Compared with All SF Claims, 2000–2005

	CO SF Claims	All SF Claims
Accepted claims	n = 345	n = 769,335
Average cost per claim	$7704	$10,528
Median cost	$552	$548
Medical-only claims	n = 314	n = 577,742
Average cost per claim	$924	$923
Median cost	$504	$398
Compensable claims[A]	n = 28	n = 191,593
Average cost compensable claims	$83,747	$39,492
Median cost	$5295	$7696
Time loss claims	n = 28	n = 191,593
Average time loss days per claim	379	196
Median time loss days	23	27

Note: Costs adjusted for inflation to 2009 using the Consumer Price Index.
[A]Compensable claims includes claims with payment for time lost from work, injured workers kept on salary, or an injured worker receiving a disability award, or a fatality.

The most expensive CO claims (n = 11) totaled approximately $2.3 million (87% of all costs). Much of this cost comes from approximately 10,000 paid-time lost work days (98% of all lost work days). These 11 claims were caused by forklifts (n = 5), auto/truck/bus (n = 2), and one claim each caused by a floor buffer, welding, marine engine, and gas-powered saw. The medical-only cost, compensable cost, and time loss days were compared between forklift claims (n = 154) and all other claims (n = 191) combined; there was no significant difference between claim costs or time loss (data not shown). Only 1 of these 11 claims involved treatment in a hyperbaric chamber. It is not definitively understood what makes these claims so costly, but pre-existing co-morbidity, incident severity, medical treatment, and return-to-work are contributing factors.

Distribution of CO Incidents Among Occupation, Industry, and Regionally in Washington State

CO Incidents and Occupation

The 221 incidents described here were associated with 82 different occupation (SOC) codes. However, nearly half of all CO incidents were concentrated in four occupational groups: (1) Material Moving Workers (SOC 537), (2) Construction Trades Workers (SOC 472), (3) Motor Vehicle Operators (SOC 533), and (4) Agricultural Workers (SOC 452). Three-digit occupation codes with eight or more incidents are listed in Table IV. At the six-digit level (data not shown), Material Moving Workers included "Laborers and Freight, Stock and Material Movers, Hand" (SOC 537062) and "Industrial Truck and Tractor Operators" (SOC 537051). These Material Moving Workers were exposed to CO primarily from forklifts. Construction Trades Workers included "Construction

TABLE IV. Distribution of CO Incidents (2000–2005) for Standard Occupation Codes (SOC) Having Eight or More Incidents

SOC	SOC Description	No. of Incidents
537	Material Moving Workers	39
472	Construction Trades Workers	28
533	Motor Vehicle Operators	23
452	Agricultural Workers	13
119	Other Management Operations	8
493	Vehicle and Mobile Equipment Mechanics, Installers, and Repairers	8
999	Nonclassifiable	30

TABLE V. Distribution of CO Incidents by Industry Sector for the Four Most Frequently Occurring Sources, 2000–2005

NAICs Code	NAICs Description	Total No. Incidents	Forklift	Auto/Truck/ Bus	Heater	Saw	All Remaining Sources	Undetermined
23	Construction	43	3	6	3	9	16[A]	6
42	Wholesale Trade	32	25	4	0	0	3	0
11	Agriculture, Forestry, Fishing and Hunting	27	17	4	1	0	4	1
48–49	Transportation and Warehousing	18	2	10	1	1	3	1
56	Administrative and Support and Waste Management and Remediation Services	17	2	4	1	1	8	1
92	Public Administration	17	5	6	2	1	3	0
81	Other Services (except Public Administration)	12	0	9	2	0	1	0
31–33	Manufacturing	12	7	2	1	0	2	0
44–45	Retail Trade	11	3	4	4	0	0	0
72	Accommodation and Food Services	9	0	1	0	1	6	1
61	Educational Services	8	0	4	1	0	3	0
62	Health Care and Social Assistance	6	0	0	2	0	1	3
54	Professional, Scientific, and Technical Services	3	1	0	0	0	1	1
21	Mining	2	0	1	0	0	1	0
52	Finance and Insurance	1	0	1	0	0	0	0
53	Real Estate and Rental Leasing	1	0	1	0	0	0	0
71	Arts, Entertainment	2	0	0	0	0	2	0
	Total	221	65	57	18	13	54	14

[A]Remaining sources for construction included insulation blower, machinery, manlift, crane, power trowel, jackhammer, welding, and excavator.

Laborers" (SOC 472061) and "Carpenters" (SOC 472031). Construction workers were exposed to CO primarily from powered saws and heaters. Motor Vehicle Operators included "School Bus Drivers" (SOC 533032) exposed to exhaust fumes. Agricultural Workers included "Graders and Sorters, Agricultural Products" (SOC 452041) and "Farm Workers and Laborers, Crop, Nursery, and Greenhouse" (SOC 452092) exposed primarily to forklifts.

CO Incidents and Industry

Incidents occurred over 17 different industry sectors. A total of 154 incidents (70%) occurred in six sectors: (1) Construction (NAICS 23); (2) Wholesale Trade (NAICS 42); (3) Agriculture, Forestry, Fishing and Hunting (NAICS 11); (4) Transportation and Warehousing (NAICS 48 and 49); (5) Administrative, Support, Waste Management and Remediation Services (NAICS 56); and (6) Public Administration (NAICS 92). Public Administration is a growing industry with diverse occupations; the CO incidents associated with this occupation predominantly involved agricultural inspectors working in fruit warehouses, followed by indoor air quality incidents (office workers and emergency personnel) and maintenance workers exposed to vehicle exhaust. Although a relatively high rate of CO poisoning would be expected in the mining industry, there is very little underground mining in Washington State. Only two CO poisoning incidents were reported from this industry sector.

Four sources (forklift, auto/truck/bus, heater, and saw) occurred the most frequently; each source was associated with five or more workplace incidents. The industry sectors in which these top four CO sources occurred are shown in Table V. Forklifts were the source in 29% of all incidents; these were found in nine different industries, predominantly in Wholesale Trade and Agriculture, Forestry, Fishing and Hunting. Auto/truck/bus incidents were widely dispersed across 14 different industries, predominantly in Transportation and Warehousing and Other Services. Heater/furnace incidents occurred across 10 different industries. Saw incidents occurred across five different industries, although predominantly in Construction. Construction workers were exposed to the greatest variety of CO sources. Incidents with the greatest number of claims occurred in Agriculture. The largest incident (45 workers) occurred from forklifts in a fruit-packing warehouse, and three incidents (six to nine workers each) occurred from

TABLE VI. Geographical Distribution of CO Incidents in Washington State, 2000–2005

Washington Region	No. of Incidents	No. of NAICS Sectors Represented	Predominant NAICS (no. of incidents)
1. NW Washington	28	12	23 Construction (7)
2. Seattle and Vicinity	59	11	23 Construction (14)
			48–49 Transportation and Warehousing (9)
			42 Wholesale Trade (7)
3. Tacoma and Olympic Peninsula	21	12	23 Construction (4)
			48–49 Transportation and Warehousing (4)
4. SW Washington	30	1	92 Public Administration (10)
			23 Construction (7)
5. Central Washington	61	11	11 Ag, Forestry, Fishing and Hunting (23)
			42 Wholesale Trade (18)
6. E Washington (Spokane)	22	8	23 Construction (8)

forklifts in agriculture and wholesale trade. The remaining incidents involved four or fewer injured workers.

At the *four-digit* NAICS level (data not shown) forklift incidents occurred most frequently in Grocery & Related Product Merchant Wholesalers (NAICS 4244, n = 19), Support Activities for Crop Production (NAICS 1151, n = 8), and Fruit and Tree Nut Farming (NAICS 1113, n = 7). Auto/truck/bus incidents occurred primarily in Auto Repair and Maintenance (NAICS 8111, n = 5) and in General Freight Trucking (NAICS 4841, n = 4). Two sources occurred exclusively in just one industry: food fryer in Accommodation & Food Services and insulation blower in Construction.

Geographic Distribution of CO Incidents

L&I has offices in six major regions of the state; the location of CO incidents and their predominant industries are summarized by these six regions in Table VI. Two regions, Seattle (and vicinity) and central Washington, had 59 and 61 incidents, respectively, representing two to three times the number of incidents seen in other regions. The Seattle area is the most populous region, and the CO incidents predominantly occurred in the Construction industry. In contrast to all other regions, central Washington had no CO incidents reported from the construction industry. Central Washington is dominated by the agriculture industry with numerous tree fruit, vegetable packing, and produce storage enterprises; most incidents here were caused by forklifts operating indoors during the post-harvest work. These post-harvest forklift incidents have been a focus area for L&I's enforcement and consultation officers in central Washington. Because of this focus, we looked closely at the claim history for CO forklift incidents in Agriculture, Warehousing, and Wholesale Trade (NAICS 11, 49, 42) in central Washington for the period 1994 through 2007. The number of CO incidents decreased significantly over this time period (Spearman's rho $= -0.6659$, $p < 0.01$, Figure 2). For the time period 1994–1998 there were 12 or more CO incidents in most years; from 1998–2007 there were nine or fewer incidents per year.

Carbon Monoxide Surveillance and Poisoning Prevention

CO Surveillance

Of the 345 claims in this study, 244 (71%) had medical bills for COHb tests. Whether a claim was billed for COHb testing was determined using the procedure billing codes for carboxyhemoglobin quantitative (CPT 82375) and carboxyhemoglobin qualitative (CPT 82376). Place of service codes identify the location where COHb tests are administered. The code is given on the medical bills received by L&I's workers' compensation insurance department. Of the 244 claims having COHb CPT codes, 223 (91%) were coded as outpatient hospital services. Other place of service codes included independent lab (n = 12) and office (n = 5); a few claims did not have the place of service provided (n = 4).

CO Poisoning Prevention

To understand whether companies have recurring CO poisoning, we counted the number of companies that had

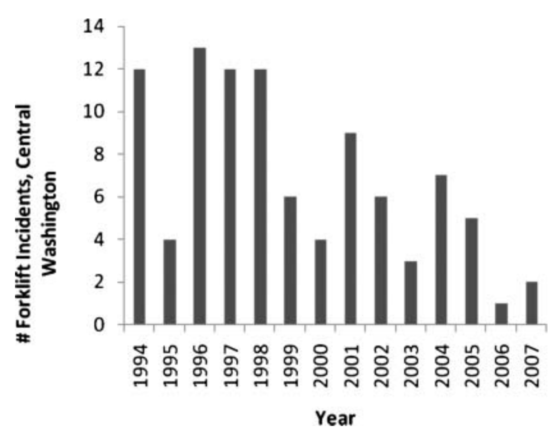

FIGURE 2. CO incidents caused by forklifts in Central Washington for Wholesale Trade, Warehousing, and Agricultural industry sectors, 1994–2007.

TABLE VII. Source and Industry Classification for Companies Incurring More than One CO Incident, 2000–2005

No. of Companies Having Multiple CO Incidents	Source	NAICS (n)
7	Forklift	42 (4) Wholesale Trade
		11 (2) Agriculture, Forestry, Fishing and Hunting
		92 (1) Public Administration
3	Auto/Truck/Bus	42 (1) Wholesale Trade
		56 (1) Administrative and Support and Waste Management and Remediation Services
		92 (1) Public Administration
1	Fryer	72 (1) Accommodation and Food Services
1	Heater/Furnace	92 (1) Public Administration
1	Other (manlift)	23 (1) Construction
1	Undetermined	11 (1) Agriculture, Forestry, Fishing and Hunting
1	Saw	23 (1) Construction

more than one CO incident. "Multiple incidents" are those that occur at the same business location but on a different day and possibly from a different source than the initial incident. The injury date filed on the claim form was used to define the date on which incidents occurred.

Out of 201 companies that had incidents, 15 (7.5%) companies experienced multiple incidents: During the 6-year period described here, 10 companies experienced two incidents each, four companies had three incidents each, and one company had five incidents. At most companies (12 of 15), the same source was involved in the initial and subsequent incidents. The source and NAICS classifications for repeat incidents are shown in Table VII. Most repeat incidents occurred with forklifts operating in the wholesale trade industry (n = 7).

To understand how quickly an intervention might need to be undertaken, the time interval between recurring incidents (n = 21) was determined. The minimum number of working days (weekends and holidays excluded) between incidents was 3 days, and the maximum was 1060 days. The average number of days between incidents was 244 (SD = 313, n = 21), and the median was 101 days. Seventeen out of 21 incidents (81%) had 16 or more working days elapse between incidents. Further review of the four incidents with elapsed times of less than 16 days revealed that they were discrete events and not a function of delayed reporting: two involved different sources between initial incident and subsequent poisonings, and one case involved forklift drivers seeking emergency medical attention on different days as a result of working in controlled atmosphere rooms. The final case involved exposure to a leaking gas-powered fryer at a fast food restaurant; the initial leak was not repaired correctly, resulting in a subsequent incident.

Individuals were poisoned from CO from actively operating a CO-generating source (operator) or as a consequence of being a bystander to the source. Claim narrative text was reviewed for all claims, and the classification of operator vs. bystander was determined for 205 claims; the injured worker was a bystander in 137 instances (67%). Because some CO sources such as boilers and heaters do not have an active driver or operator, the frequency of operator vs. bystander was also calculated for workers exposed to actively operated sources only, which in this dataset, included: forklift, auto/truck/bus, insulation blower, pressure washer, saw, and a subset of "other" claims. Injured workers exposed to actively operated sources were bystanders in 85 out of 153 cases (56%), or the majority.

DISCUSSION

Carbon Monoxide Claim Trends and Prevention Needs

Occupational CO poisonings in Washington State have been described previously for a 6-year period spanning 1994–1999.[1] This present review describes CO poisoning for the successive 6 years (2000 to 2005) using the same workers' compensation database and similar methods. The seasonal pattern of incidents, the industries affected, and the primary sources of CO exposure follow the same trends as those previously described.[1] However, there were 69 fewer incidents (24% reduction) reported for the years 2000–2005 compared with 1994–1999. The number of incidents decreased in Manufacturing (12 incidents, compared with 30), Retail Trade (11 incidents, compared with 19), Wholesale Trade (32 incidents, compared with 56), and Agriculture (27 incidents, compared with 38). Notably, the number of incidents in the construction industry was the same for both time periods.

CO poisoning from propane-powered forklifts is well documented.[12–15] The proportion of forklift incidents in Washington decreased to 29% in 2000–2005 compared with 42% in 1994–1999.[1] By industry, fewer forklift incidents were reported in Agriculture (17 incidents compared with 28), Wholesale Trade (25 incidents compared with 36), and Manufacturing (7 incidents compared with 19). While the number of incidents caused by forklifts decreased, incidents caused by auto/truck/bus and heaters slightly increased from the previous reporting period. It is not possible to make meaningful comparisons of other CO sources because there were very few incidents, and they were widely dispersed across industries.

To further explore the trend of declining forklift incidents, we summarized forklift CO incidents over a 14-year period specific to Agriculture, Wholesale Trade, and Warehousing in Central Washington. This additional analysis was performed because L&I's inspection and consultation officers in Central Washington (Region 5) have focused resources in fruit and vegetable packing and cold storage companies since the mid 1990s. While the decline in CO forklift incidents cannot be definitively attributed to L&I's prevention efforts, progress has clearly been made. Prevention efforts included (a) enforcement intervention visits in response to CO claims, (b) enforcement targeting of cold storage companies, (c) solicitation to cold storage companies by L&I consultation officers, (d) educational materials, and (e) industry partnerships.

Starting in 1997 L&I claim adjudicators began reporting CO cases to L&I enforcement officers. The relationship between the claim adjudicators and enforcement officers promoted timely hazard intervention and abatement. The trend for CO poisoning from forklifts continued, however, and L&I began formal targeting of establishments in fruit/vegetable packing and cold storage. L&I consultation officers also solicited cold storage companies and offered safety and health services.

Bilingual (English/Spanish) educational materials were developed for employers and employees in 2005.[16–18] Communication, including presentations and trade journal articles, among L&I, the local farm bureau, and industry trade organizations promoted hazard awareness and best safety practices. Successful outcomes from these agency efforts in the past 10 years include the adoption of electric forklifts; implementation of company CO hazard control programs (including area CO monitoring, CO spot checks, employee training, and employee education); and routine emission testing for fuel-powered fleets.

Although L&I regulates CO in *ambient* air, enforcement and consultation officers introduced the concept of exhaust emission testing as a primary prevention step. In response, companies requested emission testing from their fleet service providers, and in turn, at least one fleet service provider now offers the service to all their warehouse customers. Other companies purchased their own emission analyzers and now conduct routine in-house emission testing.

Affordable, real-time, hand-held emission analyzers are commercially available. Emission analyzers potentially save money on fuel costs because they can be used to tune a propane engine to its optimal, clean burning air-to-fuel (A/F) ratio of 15.2 lbs of air burned for every 1 lb of fuel. Engines that run "rich" (i.e., A/F of approximately 10:1) burn more fuel than necessary and generate CO as waste gas. Emissions should be tested with the engine at idle, cruise speed, and under load simulation. Average CO emissions of 1% or greater reflect rich running engines that require tuning to a more optimal A/F ratio.[18] Catalytic converters can also be used to reduce CO emissions. However, rich burning engines can potentially overwhelm the capacity of the catalytic converter, and the device should not be regarded as a primary prevention tool. In addition to engine maintenance, catalytic converter performance will depend on the A/F ratio controller, the state of the fuel system, and the type of catalyst used.[18] Electric forklifts are an alternative tool for use in enclosed spaces, and wider adoption of their use may ultimately be required to eliminate this hazard.

Advancements in engine technology should help reduce the risk of CO poisoning from fuel-powered forklifts in the future. Older forklifts are often associated with high concentrations (8 to 10%) of CO in exhaust emissions; the replacement of older LPG forklifts with newer, cleaner burning LPG forklifts may result in reduced CO poisoning risk and could explain some of the claims reduction described here. Forklifts manufactured before 2004 were not typically sold with catalytic converters. Forklift engines manufactured from 2004 to 2006 were required to meet the Environmental Protection Agency's (EPA) Tier 1 emission standards for large, spark-ignited non-road engines.[19] The Tier 1 standard for CO emissions was 50 g/kW-hr. Starting in 2007, a Tier 2 CO standard of 4.4 g/kW-hr applied for large, non-road spark-ignited engines. To meet the Tier 2 standard of 4.4 g/kW-hr, manufacturers must make efforts to meet regulatory requirements related to the effectiveness and durability of emission controls. For example, engines meeting Tier 2 standards must have a dashboard light that indicates when the engine's emission controls are malfunctioning. Forklifts manufactured in 2007 or later, if properly maintained, should generate much lower concentrations of CO than older forklifts.

The construction industry had both the highest number of CO incidents and the highest number of different CO sources, including both small and large engines. Construction is a challenging sector for CO prevention because multiple trades perform diverse activities in proximity. Construction uses a wide variety of tools powered by propane, gasoline, or diesel engines. Saw (e.g. floor, cutoff, concrete) was the most frequent CO source in Construction, and incidents occurred with laborers and mason trades either indoors or in partially enclosed spaces, such as parking garages and construction tents. Auto/truck/bus was the second most frequent source and primarily involved exposure by insulation workers, carpenters, and laborers while driving, working indoors with equipment, or in underground parking garages. Insulation blowers were the third most frequent source and involved trades such as tapers, drivers, and carpenters working in proximity to insulation application. Additional sources in construction included crane, concrete power trowel, drywall texturizer, excavator, jackhammer, man lift, pressure washer, sandblaster, and water pump.[20–23]

Haflidson et al.[21] noted that risk assessment for CO in construction should incorporate ceiling limits, short-term exposure limits (STELS), and excursion limits because exclusive use of full-shift monitoring may fail to identify all of the health risks in these types of exposures. While substitution of gas- or propane-powered engines can be achieved with electric or diesel power, these substitutions pose additional risk from electrocution and exposure to hazardous particulate matter. Adequate ventilation can help reduce CO poisoning risk but is often difficult to achieve in the dynamic construction industry. Cleaner burning engines may help to reduce CO poisoning risk in the future. Considerable prevention work is needed with industry, trade schools, labor, and equipment manufacturers to reduce CO poisoning risk in construction.

Two different incidents were identified in this review in the "other" category for exposure to airplane exhaust. Claim narrative for all claims indicated the poisoning occurred inside the aircraft, and one incident indicated the poisoning occurred during flight. It is not known if exposures occurred inside the cockpit or other areas of the planes. The four-digit NAICS code assigned to the employer in one incident was Couriers (4921) and Scheduled Air Transport (4811) was given for the other employer. Zelnick et al.[24] report that CO poisonings in aviation are rare, and that exposure is most common in single-engine, piston-driven aircraft where air is passed over the exhaust manifold to serve as cabin heat. Aviation-related CO poisonings are of concern due to the confined space of the cockpit, which allows for rapid gas build up, the effects that CO can have on the cognitive state of the pilot, and its implications for public safety.[24]

The median cost of all accepted CO claims reported here is greater than costs reported in West Virginia and similar to costs previously reported in Washington.[1,25] Erdogan et al.[25] reported on occupational workers' compensation CO claims in West Virginia for the 6-year period 1995 to 2000.[25] We report a median claim cost of $552 here, greater than the median cost of $444 reported by West Virginia and nearly equal to the median $565 reported in Washington for 1996–1999.[1,25] West Virginia reported 18% fewer CO incidents than reported here, with only 10 claims having time loss.[25] The median time loss days reported here was 23 days, which lies between West Virginia's report of 45 time loss days and Washington's previous report of 15 time loss days. The *average* claim cost reported here is nearly four times greater than that reported by West Virginia and twice that previously reported in Washington. The average costs in this study are driven primarily by two claims of approximately $415,000 and $824,000, with each claim comprising more than 1300 paid time loss days (approximately 5 years at 260 workdays/year).

CO Surveillance

Mandatory notifiable condition reporting of CO injuries would be valuable if reporting participation was sufficiently high and if cases can be identified as work related. During a 5-year period, Maine's state-based CO surveillance system identified 20% of all cases as being occupational.[26] Notifiable condition reporting in Washington might identify occupational poisonings for which a workers' compensation claim is not filed or from employers who do not participate in the L&I State Fund insurance system.

If reporting is poor, however, then a notifiable reporting system might yield fewer cases than those identified through our workers' compensation system. Approximately 71% of the claims described here had associated COHb bills; theoretically, laboratory reporting should be able to identify these claims. Our report of 71% of claims having COHb bills is in contrast with the West Virginia study in which only 12% of claims had documentation for COHb tests.[25] The best approach for CO surveillance in Washington may include both notifiable reporting from physicians and laboratories as well as regular review of CO claims from the workers' compensation database. Since 91% of all COHb tests are conducted in outpatient hospital services, successful notifiable condition reporting will require educating individuals involved at this place of service.

Surveillance data can be used to direct prevention efforts. Historically, at L&I, informal reporting of CO injury claim clusters has occurred between a claims reviewer and L&I compliance enforcement inspectors. This informal reporting was concerned primarily with exposure to CO from forklifts in the fruit packing and storage industry and initiated site visits where CO hazards were subsequently abated. This review demonstrated that for business locations in which CO incidents recur, 2% experience the recurrence within 16 days of the initial incident, and 6% experienced the recurrence between 16 days and 3 years. A more formal CO surveillance and reporting system would likely help to reduce CO poisoning risk; Washington's informal experience with CO incident reporting suggests that such an activity can lead to valuable targeting and prevention activities.

The injured worker was a bystander in most poisoning instances. Workplaces should educate not just machine operators and maintenance staff on the hazards of CO but also production and office employees. Education regarding CO sources, symptom recognition, and how to respond to a CO poisoning is appropriate for both work and home environments.

Limitations

First, it is likely that there is significant under-recognition of CO poisoning by health care providers and workers because CO poisoning symptoms are relatively non-specific. Such under-reporting of work-related injuries and illnesses to the workers' compensation systems is well documented. The second limitation of this study is that the analysis was limited to workers enrolled in Washington's State Fund industrial insurance system. Consequently, self-employed individuals such as small, independent construction contractors would not be included in this analysis. Third, changes in the scheme used to code industry necessitated the use of simple counts to describe injuries rather than rates. The transition from the Standard Industrial Classification (SIC) system to the current NAICS system made straightforward selection of denominators for rate calculations problematic.

CONCLUSION

This study indicates that continued prevention efforts are needed for CO poisoning caused by fuel-powered forklifts. Prevention efforts are also needed to address CO poisoning in the construction sector, where the highest number of claims occurred. Construction workers are exposed to CO from a wide range of sources, and they are at risk as bystanders as well as when actively operating the CO generating source. Construction is a challenging industry for prevention, and success will require collaboration from contractors and labors as well as equipment designers, manufacturers, and vendors.

Most of the workers' compensation claims reviewed had COHb hospital billing codes associated with them. A surveillance system that identifies potential CO cases through COHb tests would therefore identify most of the cases described by this workers' compensation data. CO poisoning does recur at workplaces, and surveillance is valuable for directing intervention activities. This study demonstrates that occupational health surveillance can play a vital role in preventing injury and illness in the workplace.

ACKNOWLEDGMENTS

Thanks to Alan Stout of the EPA and Steven Griffin of Intertek for their input concerning engine technology. We acknowledge L&I's Vicki Skeers for her reporting of CO clusters, and the L&I compliance and consultation officers who have dedicated time and energy to preventing carbon monoxide illness. Those who have contributed significantly in this area include Chuck Durham, Don Lofgren, Wil Lohman, Terry Walley, and Marty Weis.

REFERENCES

1. **Lofgren, D.J.:** Occupational carbon monoxide poisoning in the State of Washington, 1994–1999. *Appl. Occup. Environ. Hyg. 17*:286–295 (2002).
2. **King, M., and C. Bailey:** Carbon monoxide related deaths - United States, 1999–2004. *MMWR 56(50)*:1309–1312 (2007).
3. **Litovitz, T., G. Oderda, J.D. White, et al.:** Occupational and environmental exposures reported to poison centers. *Am. J. Publ. Health 83(5)*:739–743 (1993).
4. **Bekkedal, M., K. Sipsma, E.S. Stremski, et al.:** Evaluation of five data sources for inclusion in a statewide tracking system for accidental carbon monoxide poisonings. *Wis. Med. J. 105(2)*:36–40 (2006).
5. "Industrial Insurance, Employment and Occupations Covered." [Online] Available at http://apps.leg.wa.gov/rcw (Accessed March 2010).
6. **American National Standards Institute (ANSI):** *Methods of Recording Basic Facts Relating to the Nature and Occurrence of Work Injuries* (ANSI Z16.2-1962). [Standard] New York: ANSI, 1969.
7. **Buck, C.J.:** *Saunders 2008 ICD-9-CM*. St. Louis, Mo.: Saunders Elsevier, 2008.
8. **American Medical Association (AMA):** *Current Procedural Terminology*. Chicago: AMA, 2007.
9. **Ingenix:** *2007 HCPCS Level II*. Eden Prairie, Minn.: Ingenix, 2006.
10. **Office of Management and Budget (OMB):** *North American Industry Classification System, United States: Executive Office of the President*. Lanham, Md.: National Technical Information Service and Bernan Associates, 2002.
11. **Office of Management and Budget (OMB):** *Standard Occupational Classification Manual, Executive Office of the President*. Lanham, Md.: National Technical Information Service and Bernan Associates, 2000.
12. **Fawcett, T.A., R.E. Moon, P.J. Fracica, et al.:** Warehouse workers' headache: Carbon monoxide poisoning from propane-fueled forklifts. *J. Occup. Med. 34*:12–15 (1992).
13. **Roberge, B.:** Evaluation and control of carbon monoxide exposure from propane-fueled forklifts. *Appl. Occup. Environ. Hyg. 13*:183–191 (1998).
14. **McCammon, J.B., L.E. McKenzie, and M. Heinzman:** Carbon monoxide poisoning related to the indoor use of propane-fueled forklifts in Colorado workplaces. *Appl. Occup. Environ. Hyg. 11*:192–198 (1996).
15. **Comstock, R.D., R.W. Currier, K.V. Markiewicz, et al.:** Carbon monoxide poisoning associated with use of LPG-powered (propane) forklifts in industrial settings—Iowa, 1998. *MMWR 48*:1121–1124 (1999).
16. "Carbon Monoxide and Forklifts: Warning Poster for Employees." [Online] Available at http://www.lni.wa.gov/Safety/Research/Pubs/default.asp#General (Accessed March 2010).
17. "Carbon Monoxide and Forklifts: Educational Pamphlet for Workers." [Online] Available at http://www.lni.wa.gov/Safety/Research/Pubs/default.asp#General (Accessed March 2010).
18. "Prevent Carbon Monoxide Poisoning from Forklifts: Successful Strategies for Electric and Fuel-Driven Forklift Fleets." [Online] Available at http://www.lni.wa.gov/Safety/Research/Files/HazardousChem/PreventCarbonMonoxidePoisoningFromForklifts.pdf (Accessed March 2010).
19. "Control of Emissions from New, Large Non-Road Spark Ignited Engines." [Online] Available at http://www.gpoaccess.gov/cfr (Accessed March 2010.)
20. **Centers for Disease Control and Prevention:** Carbon monoxide poisoning from use of gasoline fueled power washers in an underground parking garage—District of Columbia, 1994. *MMWR 44(18)*:363–364 (1995).
21. **Haflidson, W.O., and C.S. Figueira:** Carbon monoxide exposure of concrete finishers. *Appl. Occup. Environ. Hyg. 12*:126–131 (1997).
22. **Hawkes, A.P., J.B. McCammon, and R.E. Hoffman:** Indoor use of concrete saws and other gas-powered equipment: Analysis of reported carbon monoxide poisoning cases in Colorado. *J. Occup. Environ. Med. 40(1)*:49–54 (1998).
23. **Venable, H., and K. Wallingford:** Simulated carbon monoxide exposure in an enclosed structure from a gasoline-powered pressure washer. *Appl. Occup. Environ. Hyg. 10*:581–584 (1995).
24. **Zelnick, S.D., M.W. Lischak, D.G. Young III, et al.:** Prevention of carbon monoxide exposure in general and recreational aviation. *Aviat. Space Environ. Med. 73(8)*:812–816 (2002).
25. **Erdogan, M.S., S.S. Islam, A. Chaudhari, et al.:** Occupational carbon monoxide poisoning among West Virginia workers' compensation claims: Diagnosis, treatment duration, and utilization. *J. Occup. Environ. Med. 46(6)*:577–583 (2004).
26. **Graber, J.M., and A.E. Smith:** Results from a state-based surveillance system for carbon monoxide poisoning. *Publ. Health Rep. 122(2)*:145–154 (2007).