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Surveillance of carbon monoxide-related incidents — Implications for prevention of related illnesses and injuries, 2005–2014

Sutapa Mukhopadhyay[a], **Annie Hirsch**[b], **Suze Etienne**[b], **Natalia Melnikova**[c], **Jennifer Wu**[c], **Kanta Sircar**[d], **Maureen Orr**[c,*]

[a]Tennessee Department of Health, Office of Informatics & Analytics, 710 James Robertson Parkway, Nashville, TN 37243, USA

[b]North Carolina Department of Health and Human Services, Division of Public Health, Occupational and Environmental Epidemiology Branch, 101 Blair Drive, Raleigh, NC 27699, USA

[c]Agency for Toxic Substances and Disease Registry, Division of Toxicology and Human Health Sciences, Environmental Health Surveillance Branch, 4770 Buford HWY, NE, Atlanta, GA 30341, USA

[d]Centers for Disease Control and Prevention, National Center for Environmental Health, Office of Non-communicable Diseases, Injury and Environmental Health, 4770 Buford HWY, NE, Atlanta, GA 30341, USA

Abstract

Background: Carbon monoxide (CO) is an insidious gas responsible for approximately 21,000 emergency department visits, 2300 hospitalizations, and 500 deaths in the United States annually. We analyzed 10 combined years of data from two Agency for Toxic Substances and Disease Registry acute hazardous substance release surveillance programs to evaluate CO incident-related injuries.

Methods: Seventeen states participated in these programs during 2005–2014.

Results: In those 10 years, the states identified 1795 CO incidents. Our analysis focused on 897 CO incidents having injured persons. Of the 3414 CO injured people, 61.0% were classified as general public, 27.7% were employees, 7.6% were students, and 2.2% were first responders. More than 78% of CO injured people required hospital or pre-hospital treatment and 4.3% died. The location for most injured people (39.9%) were homes or apartments, followed by educational facilities (10.0%). Educational services had a high number of people injured per incident (16.3%). The three most common sources of CO were heating, ventilation, and air conditioning systems; generators; and motor vehicles. Equipment failure was the primary contributing factor for most CO incidents.

Conclusions: States have used the data to evaluate trends in CO poisoning and develop targeted public health outreach. Surveillance data are useful for setting new policies or supporting existing

*Corresponding author. Mco0@cdc.gov (M. Orr).

policy such as making CO poisoning a reportable condition at the state level and requiring CO alarms in all schools and housing. Public health needs to remain vigilant to the sources and causes of CO to help reduce this injury and death.

Keywords

NTSIP; Toxic substance surveillance; Carbon monoxide poisoning; CO

1. Introduction

Carbon monoxide (CO) is an odorless, colorless gas that can cause sudden illness and death. CO can be produced any time when a fossil fuel is burned in a furnace, vehicle, generator, grill, or elsewhere [1]. CO from these sources can build up in enclosed or semi-enclosed spaces and poison the people and animals inside, without them being aware of what is happening. CO poisoning is very common, with an estimated 21,000 unintentional non-fire–related emergency department visits, 2300 hospitalizations, and about 500 deaths in the United States annually [2,3]. Each year, about 15,000 additional people visit emergency departments and 2000 people die from intentional (suicidal) CO poisoning [4].

Many of the unintentional CO poisoning incidents occur inside the home as a result of negligence and complacency about the maintenance of the most common sources of CO, such as gas furnaces, water heaters, and clothes dryers. CO poisoning happen year-round. They peak with increased use of generators, alternate warming appliances, and power tools after storms and disasters that cause power outages [3]. The highest CO-related death rates are reported among western and mid-western states, likely because of variations in weather and certain risk behaviors [3].

During 1975–1996, after the first catalytic convertors and other automobile emission control devices were introduced in the United States, the unintentional motor vehicle-related annual rate of CO-related deaths declined 21.3%. Declines in CO-related suicides and unintentional fire-related deaths also were reported. However, the years 1999 through 2012 did not show a decreasing trend in unintentional non-fire–related CO poisoning deaths [3].

Public health data collected on these CO incidents have been used to help develop laws and regulations intended to protect public health. Examples include requiring CO detectors in new homes, rental properties, and other structures, engineering solutions to reduce the amount of CO emitted by appliances, and health education campaigns to promote CO detector use, regular maintenance of appliances, and proper use of power generators [5]. However, unintentional, non-fire–related CO poisoning remains the second most common cause of non-medical poisoning deaths in the United States [3].

The Agency for Toxic Substances and Disease Registry (ATSDR) acute hazardous substance release surveillance programs [5] and the Centers for Disease Control and Prevention (CDC) National Center for Environmental Health tracking program [6] are two key public health databases available to track the public health effects of CO. For this analysis, we used ATSDR data for 2005–2014 on CO incidents with injured people. We looked at categories of injured people, where they were injured, the severity of injuries, the associated CO source and causal factors of incident with injured people. We also looked at legislation and outreach in the surveillance states. Our objective was to describe the CO incident-related injuries and associated public health efforts in these states.

2. Methods

We used 10 years of combined surveillance data from the ATSDR Hazardous Substances Emergency Events Surveillance (HSEES) program (2005–2009) and its successor, the National Toxic Substance Incidents Program (NTSIP) (2010–2014). ATSDR funded 17 state health departments to collect and analyze information on morbidity and mortality associated with acute or threatened releases of hazardous substances (Fig. 1). The states were broadly distributed and their participation varied over the years. Three states participated in the surveillance programs for all 10 years; 14 states participated in the surveillance for various intervals of 1–9 years.

HSEES (2005–2009) defined an event as an uncontrolled or illegal release or threatened release of at least one hazardous substance. The amount of substance released must have required cleanup under federal, state, or local law. A threatened release must have resulted in actions to protect public health, such as evacuation. Incidents involving petroleum only were excluded; those involving petroleum and a qualifying hazardous substance were included [7].

NTSIP (2010–2014) defines an incident as any acute, uncontrolled, or illegal hazardous substance release that meets established minimum reporting quantities [1]. NTSIP includes petroleum-related incidents if they resulted in an injury or a public health action, such as evacuation or decontamination. It excludes all threatened releases, incidents in a residence that did not involve a public health action, and smokestack or flare incidents with no public health action or injury [8].

State health departments collected incident information for the HSEES and NTSIP programs from two main federal data sources: the National Response Center and the U.S. Department of Transportation. They also collected information from state agencies, county health departments, media sources, and emergency response personnel, among others. They recorded information on the time, circumstances, and place of the incident; substances released; persons affected; and public health actions taken [7,8]. Industries involved were classified by the North American Industry Classification System (NAICS).

Incidents that had multiple substances released or were only permit violations were not included in this analysis. We included intentional and unintentional CO related incidents. Reported signs or symptoms of illness or injury consistent with CO exposure were used as the basis for inclusion of injured persons. We did not have CO poisoning medical diagnosis information for injured persons.

2.1. Determination of CO release source

From 2005 through 2014, HSEES and NTSIP collected data on 49,762 chemical release incidents, from which 1962 single substance CO-related incidents were identified. We removed 167 permit violation incidents that did not involve injury because they were not consistent with the other types of incidents, leaving 1795 CO incidents for analysis. Among the 1795 incidents, 897 incidents had at least one CO-injured person.

Reports did not specifically identify chemical release sources. We relied on two free text fields, the Synopsis and Comments, which provide a description and details of the incident, to identify a source of the CO. We identified 13 potential CO release sources: 1) permit violation, 2) generator; 3) space heater; 4) heating, ventilation, and air conditioning systems (HVAC); 5) grills; 6) power machinery; 7) forklift; 8) appliance; 9) vehicle; 10) wood stove/fireplace; 11) outdoor recreation; 12) electric utility/power cable; and 13) fuel/natural gas line. We then determined key words for each source. Key words for grills, for example, included BBQ, barbeques, and charcoal grill. A macro function assigned release sources to each of the incidents, based on key words entered in reports. The incidents were then transferred to a spreadsheet for manual review of the assigned sources. Two people reviewed each release source assigned by computer from the Comments and Synopsis information and resolved differences.

2.2. Analysis

Descriptive analysis of the CO incidents and public health consequences among those exposed to CO was performed using SAS 9.4 software (Cary, NC). With the frequency procedure, we produced one-way to n-way contingency tables, listed number of cases and percentage for incidents type, state, release source, type of injured people, type of injury, type of property/industry, and also year, season, day of a week, and time when incident happened.

3. Results

3.1. Distribution

The 1795 CO incidents reported by 17 states made up 3.6% of all ATSDR surveillance incidents for 2005–2014. A total of 3414 people were injured in 897 (50.0%) of these CO incidents. Each state had a different array of incident notification sources available to them. Table 1 shows the varied distribution of CO incident notification sources by state. New York, for example, mainly used the state environmental department or division, the media, and the on-scene commander/incident commander or staff reports to identify CO incidents. In contrast, Michigan used mainly medical facility or poison control center reports and the media.

CO contributed to the largest percent of all incidents in Michigan (12.8%), New York (12.0%), and Washington (7.1%). CO also contributed the largest percentages of injured people in these states: 48.7% in Michigan, 39.5% in Washington, and 34.5% in New York (Fig. 1).

Out of 1795 CO incidents reported by 17 states from 2005 to 2014, the highest number (555) occurred between midnight and 5:59 a.m., but the highest number of injuries (1241) occurred between 6:00 a.m. and noon. The numbers of CO incidents, CO incidents with injuries, and number of people injured in these incidents increased during fall (September–November) and winter (December–February) (Fig. 2).

3.2. Injured people

Among 3414 persons injured by CO in participating states from 2005 to 2014, 2082 (61.0%) were categorized as general public, followed by 946 (27.7%) employees, 261 (7.6%) students, and 76 (2.2%) first responders (firefighters, police officers, and emergency medical services) (Table 2). The severity of injuries of 115 (3.4%) persons was unknown. Most injured persons (2671; 78.2%) required hospital or pre-hospital treatment without admission. However, 480 (14.1%) persons injured by CO required hospital admission, and 148 (4.3%) died (Table 2).

Of the 2694 CO-injured people whose age was known, 743 (27.6%) were children younger than 18 years, and 211 of those were at their school when injured by CO.

3.3. Source of CO for injured people

Among the 17 states who report CO incidents, we were not able to identify a CO source for 179 incidents, corresponding to 557 injured persons. HVAC systems, by far, accounted for the most injuries (35.0%), followed by 15.5% for generators. Motor vehicles, forklifts, and other power machinery made up another 6.8% each. These were also the main sources for each of the categories of people injured, in different orders. For employees, the main sources of CO injury were HVAC, forklifts, and power machinery. For the general public, the main sources were HVAC, generators, and motor vehicles. For responders, the main sources were generators, HVAC, and forklifts. For students, HVAC and power machinery were the main sources of CO injury (Table 3).

3.4. Causal factor of incident with injured people

Human error (a mistake made by a person resulting in a release of a hazardous substance) and equipment failure (a failure of process vessels, storage vessels, valves, pipes, pumps, or other equipment that allows the release of hazardous substances) were the primary contributing factors for most of the CO incidents with injury (53.9% and 39.9% accordingly). Intentional or illegal act (1.8%), bad weather conditions or natural disasters (1.0%), and other (0.8%) were the primary contributing factors for the rest of the CO incidents with injury, including 2.6% of CO incidents where information on the primary contributing factor was missing.

Although only 1% of all CO-associated incidents with injured people had a primary contributing factor of disaster or bad weather condition, about 24% of incidents involving generators and almost 15% of people injured in these incidents had a secondary contributing factor of disasters or indicated a bad weather condition. Of the 29% of CO-associated incidents that involved space heaters, almost 18% of injuries in those incidents happened when there was snow, ice, sleet, or hail. More than 50% of incidents related to generators and space heaters were not associated with any disaster or bad weather condition that we could identify.

3.5. Location of incident for injured persons

Among the 3414 persons injured in CO incidents, 1362 received injuries at home: 807 in private households and 555 in real estate and rental and leasing (apartments). Many people also were injured by CO in educational services (schools), accommodation and food industry (restaurants and hotels/motels), other private non-industry (private property), manufacturing, retail/wholesale trade, and transportation and warehousing. Schools in particular, had a high number of people injured per incident with injury (16.3) (Table 4). A location or industry was not identified for 38 CO incidents with injury.

In HSEES/NTSIP, people are classified by what they were doing at the time they were injured, so students were in school, employees were at work, and responders were involved in rescue or emergency operations. The general public includes everyone else and activities not otherwise classified. The locations, therefore, were fairly consistent with their classification. The general public were mainly injured in private households (37.5%) and real estate rental and leasing properties, which are mainly apartments (33.7%), followed by those in the “not an industry” location category (13.6%). Employees were mostly injured in manufacturing (23.5%), retail/wholesale trade (17.4%), and transportation/warehousing (11.6%) settings. First responders were mostly injured in places where they had gone to give aid, such as private households (31.6%) or not an industry (17.1%). Students were mostly injured in educational services (94.6%) (Table 5).

4. Discussion

Unintentional CO poisoning is a leading cause of poisoning death and injury in the United States, despite the availability of simple, effective preventive measures. A 2015 cost-benefit analysis of CO poisoning in the United States estimated that CO poisoning cost at least $1.3 billion in direct hospital costs and lost earnings. It showed a positive cost-benefit ratio for consistent use of residential CO alarms [9]. The strength of this analysis is that we have a detailed account of the incident that caused the CO release and others who were injured in the same incident. CO-related poisoning is an environmental public health issue worthy of surveillance. State-based toxic substance incident and case surveillance can be used to identify emerging risk factors for CO exposure so that prevention programs can quickly address them. Some HSEES/NTSIP CO surveillance and outreach activities are detailed below.

4.1. Improved case detection and risk assessment

Using Tennessee NTSIP data from 2010 to 2012, the NTSIP coordinator noted a lack of comprehensive and centralized data describing acute CO poisoning, leaving a gap in the understanding of the burden of the associated morbidity and mortality. Because of this, state officials accepted a proposal outlining the need for surveillance of CO poisoning and a comprehensive plan for centralized CO-related morbidity and mortality reporting. In 2013, CO poisoning became the second environmental condition to be made reportable by hospitals and medical professionals to the Tennessee Department of Health [10].

With the help of the Surveillance System and Informatics Program at the Tennessee Department of Health, the NTSIP program integrated environmental disease surveillance into data systems traditionally used for foodborne illness and other infectious diseases. CO poisoning surveillance was developed with a focus on process and impact evaluation to provide data for action, intervention, and policy change. For example, indoor generator use during emergencies and inclement weather was a frequent cause of CO poisoning. NTSIP staff helped initiate a Community Assessment for Public Health Emergency Response (CASPER) that included questions about CO awareness and preparedness. The 2012 CASPER survey conducted in rural Cheatham County in Tennessee revealed a divergence between residents' perceived risk for CO poisoning and their likely risk. NTSIP developed an expanded question set to measure general public knowledge of CO risk behaviors, which is now available statewide for inclusion in future CASPERs. A proxy measure for estimated risk was calculated based on number of gas-burning appliances per number of CO detectors in residences. These data supported continued inclusion of CO-related questions in other CASPERs conducted statewide so that outreach can be targeted appropriately [11].

4.2. Outreach to residents

Our analysis found that CO-related injuries most often occur in a home or an apartment. In 2009, a focus group study of homeowners in Chicago, Illinois, tried to identify the knowledge, attitudes, and beliefs that might lead consumers to have their furnaces inspected annually and to install CO alarm, the two main protective measures to prevent CO in homes. Although many participants were aware of CO poisoning and supported the idea of regular furnace inspections, few actually did them because of fear of related costs and unscrupulous contractors. They often owned CO alarms, but did not locate them properly or maintain them [12]. Another focus group study gathered information on storm-related CO knowledge, attitudes, and beliefs. It found that most generator owners were aware of CO poisoning, but were unsure what constituted a safe location for generator placement. Many thought that attached garages, sheds, and covered porches were safe places to operate generators. Convenience and access to appliances was more likely to dictate placement. Participants were receptive to installing CO alarms, but were unsure where to place them [13]. Based on these findings, the focus group researchers concluded that the simple installation and maintenance of inexpensive CO alarms might be the most important strategy for ultimately protecting homes from storm and other CO-related exposures [12,13].

As of January 2017, 31 states, and the DC, have enacted statutes regarding carbon monoxide (CO) detectors, and another 11 have promulgated regulations on CO detectors [14]. Iowa and Missouri are the only two states in this analysis that have no CO detector statutes or regulations in homes and other dwellings. The comprehensiveness of these regulations varies between states, with some only applying to new building construction and others to rental properties. Some states comprehensively cover single family dwellings, multifamily dwellings, and rentals. Many states have adopted or amended their state building code to include the International Residential Code (IRC) [15]. The IRC is a set of minimum regulations for single and two family dwellings. It covers everything from plumbing to electrical set up for a house. It requires CO detectors be installed in buildings that contain fuel-burning appliances or have an attached garage.

During storms that could knock out power, homes that lose electrical service are more likely to turn to alternative power and heating sources, such as generators, grills, and space heaters that might increase the risk for CO incidents. One county in particular, Mecklenburg County, North Carolina, experienced this first hand and amended their CO detector law to require alarms with battery back-up in all residences, and not just in homes with gas appliances or heating [16].

Many CO incidents with injuries involved generator use (9.6%). The U.S. Consumer Product Safety Commission recently developed a regulation requiring newly manufactured generators to have warning labels (16 CFR 1407.3) [17]. The commission has also published an advance notice of proposed rulemaking (ANPR) to limit CO emissions from operating portable generators [18], which would have great potential for saving lives.

A literature review of disaster-related CO-related deaths found that most occurred in a home among persons aged 18 years or older. Males accounted for a large percent of deaths, as did Hispanics and non-whites [19]. Authors of the review suggest that CO-related information needs to be incorporated as part of disaster preparedness, response, and prevention and that surveillance of CO poisoning is essential to this. Pre-disaster risk communication also needs to be tailored to racial, ethnic, and linguistic minorities [19].

People generally use fossil fuels and stay indoors or in enclosed spaces more in winter, resulting in an increase in CO poisoning. The Utah Department of Health's NTSIP, in conjunction with four other of their state agencies, sends out a press release just before winter every year, targeting the general public. It reminds the public to have their gas-, oil-, wood- or coal-burning appliances serviced by a qualified technician every year and to install an Underwriters Laboratory-approved CO monitor on each level of their home, among other recommendations. The press release also explains how to recognize symptoms of CO poisoning and seek care [20].

4.3. Outreach to schools

Children are particularly vulnerable to CO exposures, and far too many are being harmed by CO from faulty HVAC systems at their schools. Schools were the third most frequent incident location and had the highest number of people injured per incident with injury (15.3). These incidents could be avoided by improved HVAC maintenance and use of CO detectors. California is the only state in this analysis that required CO detectors in school buildings. It is only one of four states to have CO regulations for schools [14]. The public is not aware that this is the case in most states. Public outrage after one of these incidents often results in passage of CO regulations, but sometimes only for that locality.

In January 2013, about 40 elementary school students in Tennessee spent the night in the hospital after exposure to CO from a heater that malfunctioned. To learn more about the policies and procedures in place to protect students, faculty, and staff from CO poisoning, the Tennessee Department of Health administered a CO policies and procedures detection survey in 2015, as part of Healthy Schools Day activities. They also created an educational fact sheet for school staff [21].

4.4. Outreach to accommodation and food service

Accommodation and food service locations had the fourth highest number of CO incidents. These locations have limited outreach to prevent CO poisoning. California, Louisiana, Michigan, New Jersey, Tennessee, and Wisconsin all require installation of CO detectors in hotels. In two of those states (New Jersey and Wisconsin) administrative regulations are complementary [14]. However, in 2017, one child died and more than a dozen other people, including first responders, were injured by a CO leak from the indoor pool heater of a hotel in Michigan. Michigan law requires newly built hotels to have CO detectors, but this hotel was built before passage of that legislation [14,22]. An analysis of news reports found that CO poisonings at hotels led to the death of eight people and sickened more than 170 people between 2010 and 2012 [23]. In 2013, a couple died at a hotel in North Carolina, and 6 weeks later, a boy died in the same room. The cause of death was a CO leak in the heating system for the swimming pool, just below the room where the deaths occurred [23]. Ideally, all hotels would have CO alarms, not just newly built lodgings or ones using fossil fuels, because actions of guests or workers could put sleeping guests at risk for CO poisoning.

4.5. Outreach to industries/workers

According to OSHA statistics, employees working in industries that use combustion-powered equipment or power tools indoors or in confined spaces are at high risk for CO poisoning [24]. This is similar to what we found: for employees, the main sources of CO exposure were HVAC, forklifts, and power machinery. We found that 2.2% of injured persons were responders. To reduce the risk for work-related CO poisoning, surveillance states have used their data to determine which industries are the most affected and design targeted outreach materials. New York, for example, analyzing incidents collected by the NY NTSIP program, discovered that its aging underground utility cables were being corroded by salt used for deicing the roads. This led to cables burning out and producing CO that migrated into buildings [25]. Staff with the North Carolina Division of Public Health used their NTSIP data to determine that the manufacturing industry had the greatest number of CO incidents in the state. Because of that, they created CO poisoning prevention materials specifically for workers and business owners in the manufacturing industry, and worked with a statewide manufacturing alliance to distribute the information.

In August 2013, in North Carolina two employees were overcome by CO and lost consciousness while using a propane-powered forklift to load produce into a refrigerated trailer backed up to a warehouse [26]. One employee died, the other was admitted to the hospital and received hyperbaric oxygen treatment. A family member who discovered the employees, two bystanders who stopped to offer assistance, and 13 first responders who assisted in the emergency response were exposed to CO and treated at the hospital. In response to this incident, personnel in the Occupational and Environmental Epidemiology Branch of the North Carolina Division of Public Health initiated a statewide CO poisoning surveillance program using emergency department and poison center data. They also began sending monthly surveillance reports to local health directors, first responder organizations, and others.

First responders, including firefighters, police officers, emergency medical services personnel, and company emergency response team (CERT) members play a critical role in protecting people and property in the event of CO incidents and might face significant risk for injury or death. CO injuries to responders more often occurred in private households (31.6%) than in industry locations (17.1%), often with outdoor recreation and electric utility/power cable as the source of the CO release. A previous ATSDR study found that CO was among the three top chemicals responsible for the highest rate of first responder injuries [27]. It also found that most responders did not receive at least basic awareness-level hazardous material training to address the health risks emergency responders face during CO incidents and the way to recognize and avoid exposure. Another study showed that personal protective equipment use during the response was not common among responders other than firefighters [27]. Using their NTSIP data, the North Carolina Division of Public Health created a carbon monoxide safety bulletins for firefighters [28] and for EMS personnel [29] and sent copies to the targeted professionals.

4.6. Future directions

Despite extensive outreach efforts, unintentional CO incidents continue to occur, resulting in hundreds of deaths and thousands of hospital admissions and emergency department visits each year. CO incidents can theoretically be prevented, but there is little data on the effectiveness of prevention measures such as carbon monoxide detectors in preventing morbidity or mortality. Our data suggests that CO detector placement should include homes, apartments, hotels, schools, and businesses, regardless of year built, ownership, or use of fuel-burning appliances. How this is achieved is the difficult part. Options might include improved compliance with current regulations, increased regulation, education, promotions, etc. A CO detector does not work if not placed properly or maintained. Primary prevention is also needed, including improved performance of fuel burning appliances and education of users on safe use of those appliances. Additionally, responders, including emergency healthcare workers, need training to quickly recognize CO poisoning victims and to protect themselves.

It is also important to continue surveillance to measure if efforts are successful. Expanding the surveillance framework for CO might assist in developing effective prevention strategies [2].

4.7. Comparability with other data

The National Center for Environmental Health at CDC has a comprehensive surveillance and prevention program for CO-poisoned people identified through death certificates, hospital discharge records, emergency department records, poison control centers, and hyperbaric oxygen chamber treatment records, among others [5]. HSEES/NTSIP tracks all CO release incidents identified through a variety of sources and identifies injured (poisoned) people from these incidents [7,8]. Although HSEES/NTSIP collects more details on the actual incident causing the injuries, the lack of clinical data means some incidents might not meet the CO poisoning case definition established by the Council of State and Territorial Epidemiologists [30,31]. The injured people in our analysis would be classified as "suspected" CO poisoning; they have symptoms consistent with CO exposures and generally a CO source is identified but we do not collect their medical chart information.

4.8. Limitations

HSEES and NTSIP participating state health departments actively collected data on toxic chemical releases from many sources. However, there were a limited number of funded states (Fig. 1). Because CO is colorless and odorless, it is difficult to detect without a CO detector. Many CO incidents go unnoticed or are not reportable to traditional HSEES/NTSIP reporting sources, unless there is an injury. Therefore, the percent of CO incidents that have at least one injured person is likely an overestimation of the true percent. Also, because of the difficulties in identifying CO incidents through the traditional state reporting sources, many states relied on additional data resources, such as regional poison control center databases and news media, or they instituted state-required reporting of CO incidents. Because of the resulting variance in data collection, any aggregation of data across states and across years should be interpreted with caution. Unlike HSEES, the NTSIP case definition excludes CO incidents in homes (a major location of CO incidents) unless a public health action occurred, such as an evacuation or decontamination. We do not know how many unreported NTSIP cases would have met the old HSEES criteria.

5. Conclusion

Ongoing, comprehensive CO surveillance is needed to obtain accurate estimates of CO poisoning burden and guide prevention efforts.

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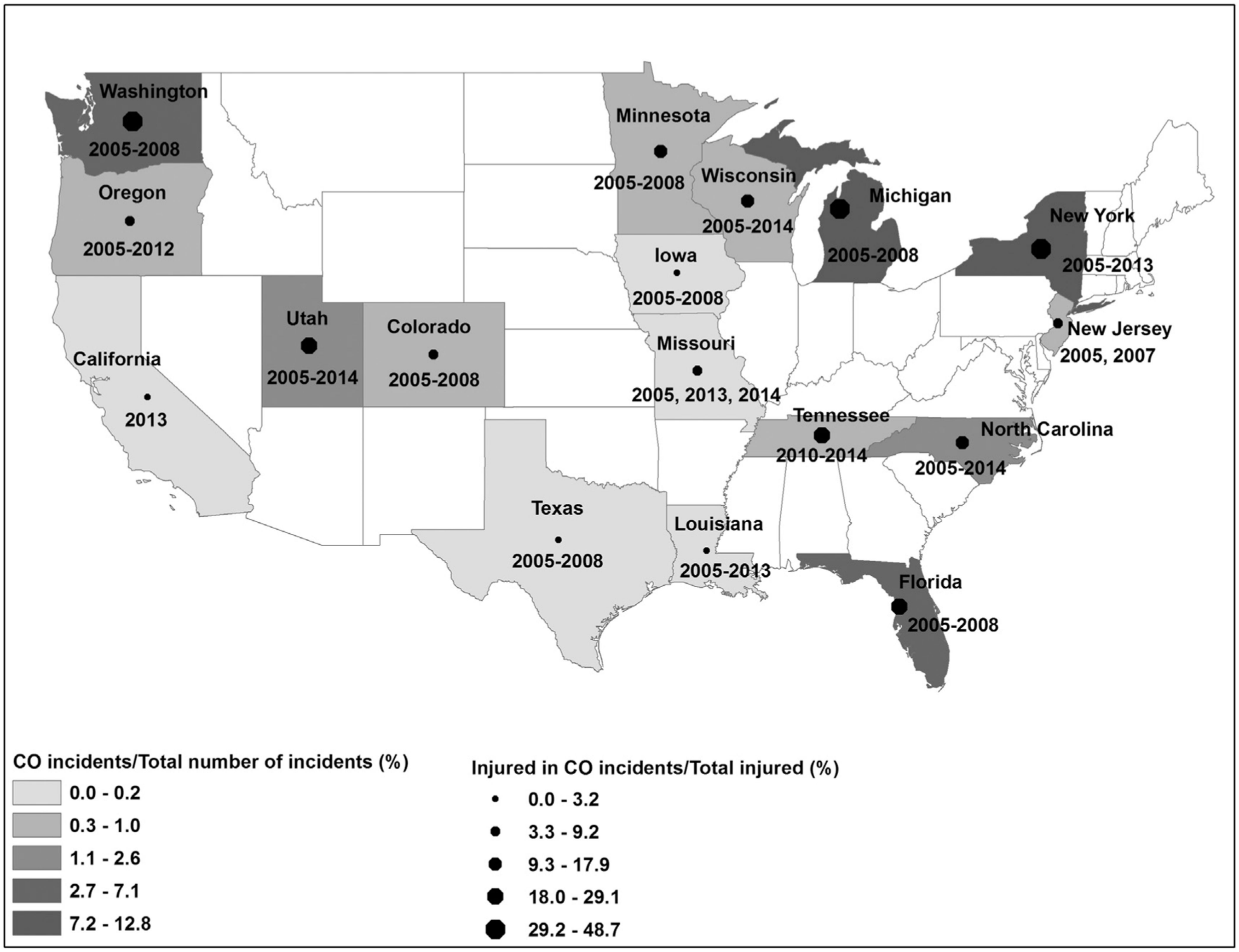

Fig. 1.

Years of participation for ATSDR chemical incident reporting states, reported percent of CO incidents and CO-injured people, 2005–2014.

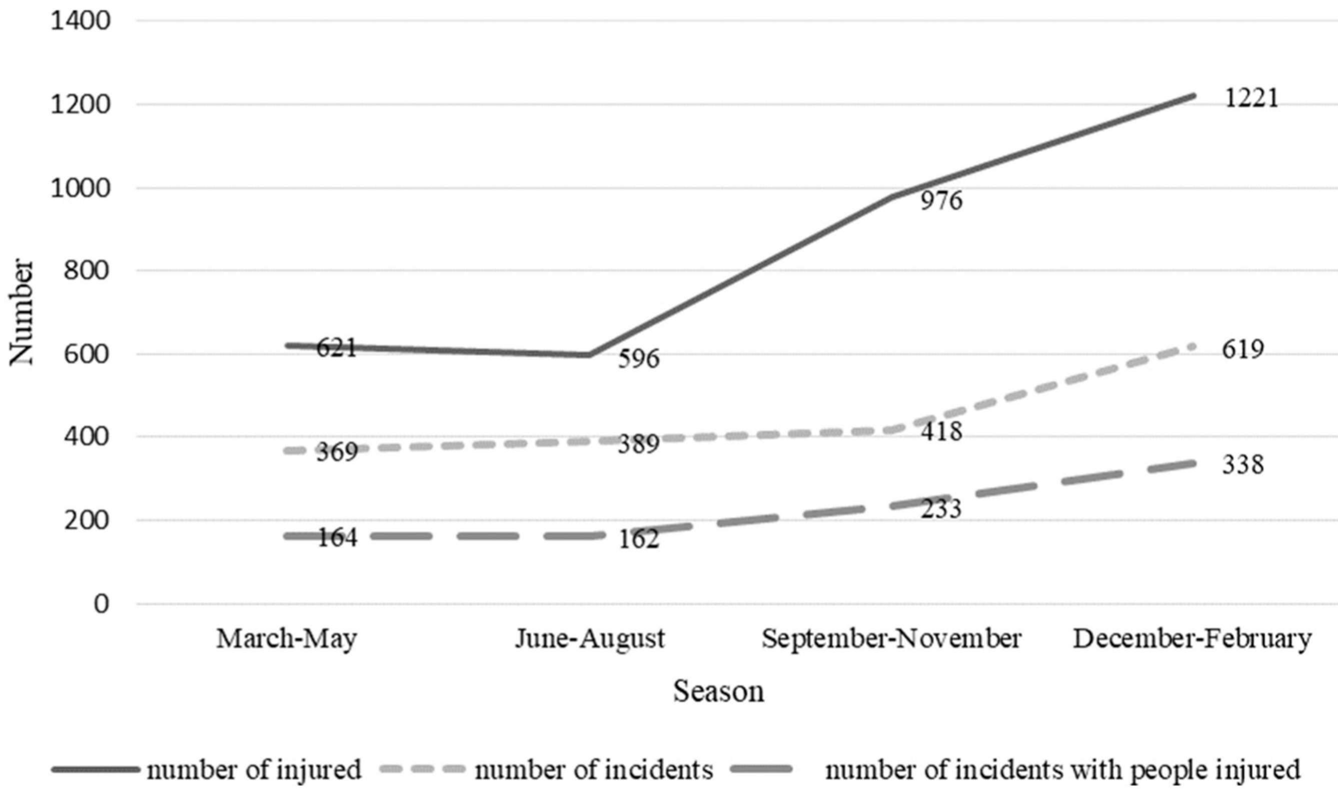

Fig. 2.

Number of people injured in CO incidents, all CO incidents and CO incidents with people injured, by season, 2005–2014.

Table 1

Number of CO release incidents, by notification type, by state, 2005–2014.

Notification type	State															
	CO	FL	IA	LA	MI	MN	MO	NC	NJ	NY	OR	TN	TX	UT	WA	WI	Total
Media	1	8	0	0	19	7	1	20	1	324	9	13	3	28	26	15	475
OSC/IC or staff[a]	3	1	0	0	0	0	0	0	0	187	0	0	0	0	0	1	192
Medical facility or poison control center	0	123	0	3	172	0	0	4	0	1	1	0	0	36	43	0	383
Environmental department/division	0	0	0	0	0	0	0	0	9	616	0	0	1	0	0	0	626
Emergency government/services	0	9	0	12	0	5	0	25	0	2	1	0	3	0	2	0	59
Other/unknown	0	12	3	0	7	0	0	0	0	11	0	6	0	4	13	4	60
Total	4	153	3	15	198	12	1	49	10	1141	11	19	7	68	84	20	1795

[a] OSC = on scene commander, IC-incident commander.

Table 2

Category of people injured by severity of injury, 2005–2014.

Category of people	Total CO-injured people	Hospital and prehospital treatment	Hospital admission	Death	Unknown severity
	N (%)	N (%)	N (%)	N (%)	N (%)
General public	2082 (61.0)	1523 (73.2)	335 (16.1)	139 (6.7)	85 (4.1)
Employee	946 (27.7)	816 (86.3)	95 (10.0)	9 (0.9)	26 (2.7)
Student	261 (7.6)	230 (88.1)	29 (11.1)	0 (0)	2 (0.8)
First responder	76 (2.2)	59 (77.6)	16 (21.1)	0 (0)	1 (1.3)
Unknown category	49 (1.4)	43 (87.8)	5 (10.2)	0 (0)	1 (2.0)
Total	3414 (100.0)	2671 (78.2)	480 (14.1)	148 (4.3)	115 (3.4)

Table 3

Category and number of people injured by source of CO release, 2005–2014.

CO release source[a]	Employee	General public	Responder	Student	Category of people unknown	Total number of people injured
	N (%)	N (%)	N (%)	N (%)	N (%)	N (%)
HVAC	262 (27.7)	713 (34.2)	12 (15.8)	200 (76.6)	9 (18.4)	1196 (35.0)
Generator	84 (8.9)	430 (20.7)	14 (18.4)	0 (0.0)	0 (0.0)	528 (15.5)
Vehicle	50 (5.3)	166 (7.9)	8 (10.5)	9 (3.4)	0 (0.0)	233 (6.8)
Forklift	216 (22.8)	5 (0.2)	11 (14.5)	0 (0.0)	0 (0.0)	232 (6.8)
Power machinery	145 (15.3)	56 (2.7)	2 (2.6)	29 (11.1)	0 (0.0)	232 (6.8)
Grills	0 (0.0)	142 (6.8)	3 (3.9)	0 (0.0)	0 (0.0)	145 (4.2)
Space heater	30 (3.2)	82 (3.9)	0 (0.0)	6 (2.3)	0 (0.0)	118 (3.5)
Electric utility/power cable	8 (0.8)	56 (2.7)	10 (13.2)	3 (1.1)	0 (0.0)	77 (2.3)
Appliance	23 (2.4)	45 (2.2)	0 (0.0)	0 (0.0)	0 (0.0)	68 (1.9)
Wood stove/fireplace	18 (1.9)	41 (1.9)	0 (0.0)	0 (0.0)	0 (0.0)	59 (1.7)
Outdoor recreation	0 (0.0)	23 (1.1)	6 (7.9)	0 (0.0)	0 (0.0)	29 (0.8)
Fuel/natural gas line	3 (0.3)	2 (0.1)	0 (0.0)	10 (3.8)	0 (0.0)	15 (0.4)
Source unknown	133 (14.1)	354 (17.0)	16 (21.1)	14 (5.4)	40 (81.6)	557 (16.3)

[a] Due to multiple release sources per incident in some cases, the rows do not add to the total number of people.

Table 4

Incidents involved in CO release, number of people injured, and average of people injured per incident with injury, by industry type, 2005–2014.

Industry (NAICS)	Number of CO incidents	CO incidents with injuries N (%)	Total number of people injured	People injured per CO incident
Real estate & rental and leasing (53)	467	134 (28.7)	555	4.1
Private households (814)	459	300 (65.4)	807	2.7
Utilities (22)	208	13 (6.3)	46	3.5
Not an industry	175	160 (91.4)	312	1.9
Accommodation and food services (72)	87	48 (55.2)	327	6.8
Retail/wholesale trade (42, 44, 45)	60	32 (53.3)	216	6.8
Manufacturing (31, 32, 33)	57	37 (64.9)	228	6.2
Educational services (61)	49	21 (42.9)	343	16.3
Health care and social assistance (62)	49	18 (36.7)	88	4.9
Unknown	38	37 (97.4)	61	1.6
Transportation and warehousing (48, 49)	36	26 (72.2)	119	4.6
Construction (23)	25	21 (84.0)	51	2.4
Art, entertainment, and recreation (71)	18	13 (72.2)	98	7.5
Public administration (92)	16	10 (62.5)	74	7.4
Agriculture, forestry, fishing and hunting (11)	15	12 (80.0)	40	3.3
Administrative and support and waste management and remediation services (56)	15	7 (46.7)	20	2.9
Finance and insurance (52)	10	2 (20.0)	6	3.0
Professional, scientific and technical services (54)	5	4 (80.0)	15	3.8
Mining (21)	3	1 (33.3)	1	1.0
Information (51)	2	1 (50.0)	7	7.0
Management of companies and enterprises (55)	1	–	0	0
Total	1795	897 (50.0)	3414	3.8

Table 5

Category and number of people injured in CO incidents by industry involved in CO release, 2005–2014.

Industry (NAICS)	Employee	General public	First responders	Students	Category unknown	Total
	N (%)	N (%)	N (%)	N (%)	N (%)	N (%)
Private households	2 (0.2)	780 (37.5)	24 (31.6)	0 (0)	1 (2.0)	807 (23.6)
Real estate and rental and leasing (53)	58 (6.1)	494 (33.7)	3 (3.9)	0 (0)	0 (0)	555 (16.3)
Educational services (61)	45 (4.8)	50 (2.4)	1 (1.3)	247(94.6)	0 (0)	343 (10.0)
Accommodation and food services (72)	112 (11.8)	198 (9.5)	0 (0)	0 (0)	17 (34.7)	327 (9.6)
Not an industry	15 (1.6)	284 (13.6)	13 (17.1)	0 (0)	0 (0)	312 (9.1)
Manufacturing (31, 32, 33)	222 (23.5)	2 (0.1)	4 (5.2)	0 (0)	0 (0)	228 (6.7)
Retail/wholesale trade (42, 44, 45)	165 (17.4)	19 (0.9)	1 (1.3)	0 (0)	31 (63.3)	216 (6.3)
Transportation and warehousing (48, 49)	110 (11.6)	3 (0.1)	0 (0)	6 (2.3)	0 (0)	119 (3.5)
Art, entertainment, and recreation (71)	11 (1.2)	85 (4.1)	0 (0)	2 (0.8)	0 (0)	98 (2.9)
Health care and social assistance (62)	29 (3.1)	47 (2.3)	6 (7.9)	6 (2.3)	0 (0)	88 (2.6)
Public administration (92)	13 (1.4)	56 (2.7)	5 (6.6)	0 (0)	0 (0)	74 (2.2)
Unknown	44 (4.7)	17 (0.8)	0 (0)	0 (0)	0 (0)	61 (1.8)
Construction (23)	41 (4.3)	10 (0.5)	0 (0)	0 (0)	0 (0)	51 (1.5)
Utilities (22)	12 (1.3)	26 (1.2)	8 (10.5)	0 (0)	0 (0)	46 (1.3)
Agriculture, forestry, fishing and hunting (11)	26 (2.7)	3 (0.1)	11 (14.5)	0 (0)	0 (0)	40 (1.2)
Administrative and support and waste management and remediation services (56)	18 (1.9)	2 (0.1)	0 (0)	0 (0)	0 (0)	20 (0.6)
Professional, scientific and technical services (54)	15 (1.6)	0 (0)	0 (0)	0 (0)	0 (0)	15 (0.4)
Information (51)	7 (0.7)	0 (0)	0 (0)	0 (0)	0 (0)	7 (0.2)
Finance and insurance (52)	0 (0)	6 (0.3)	0 (0)	0 (0)	0 (0)	6 (0.2)
Mining (21)	1 (0.1)	0 (0)	0 (0)	0 (0)	0 (0)	1 (0.03)
Total	946 (27.7)	2082 (60.9)	76 (2.2)	261 (7.6)	49 (1.4)	3414 (100.0)