RESEARCH FOUNDATION
RESEARCH FOR THE NFPA MISSION

TECHNICAL NOTES

Carbon Monoxide Incidents: A Review of the Data Landscape

Final Report by:

Jim Milke, PhD, PE
Jamie McAllister, PhD, PE
Department of Fire Protection Engineering
University of Maryland
College Park, MD, USA

October 2022

1 Batterymarch Park, Quincy, MA 02169 | Web: www.nfpa.org/foundation | Email: foundation@nfpa.org

Foreword

There are multiple sources that provide Carbon Monoxide (CO) incident data including but not limited to: Consumer Product Safety Commission (CPSC), Center for Disease Control and Prevention (CDC), U.S. Fire Administration (USFA), and standard development organizations such as the National Fire Protection Association (NFPA) and the International Codes Council (ICC). Each organization contains its own methodology for collecting information and providing statistics; however, it is not clear what specific information is being collected, disseminated, and represented for each incident type. New requirements for the installation of CO detection into several types of occupancies (both new and existing occupancies) are being addressed in the latest editions of NFPA 101 Life Safety Code® and NFPA 5000, Building Construction and Safety Code®. However, there has been a lack of understanding regarding the data available for non-fire CO incidents, specifically for commercial-type occupancies.

This study reviews eight databases and additional data sources hosting information on CO incidents to identify insights and limitations of the data. Databases that contained information on occupancy types experiencing CO incidents were evaluated to identify trends and contributing factors, etc. Overall, it was found that databases hosting CO incident information did not provide a sufficient level of detail to fully understand the CO exposure problem in the U.S.

While all databases show that incidents are occurring in commercial occupancies, and many of these occupancies are not currently required to have detection, these limited datasets do not allow for a national-level appreciation of CO incident occurrences or frequencies. Moreover, the limited datasets do not provide a comprehensive view of injuries and deaths resulting from CO exposure correlated by occupancy type. Therefore, the frequency of injuries occurring in all types of commercial occupancies is unknown; this is a critical piece of information needed to determine if current requirements for CO detection are adequate. Moreover, there is no dataset which details the location of the victim relative to the CO source. As such, there is no way to determine, using these datasets alone, if current CO detection placement criteria, e.g., detector in space with CO source, is adequate.

The Fire Protection Research Foundation expresses gratitude to the report authors Jim Milke and Jamie McAllister, who are with the University of Maryland, Department of Fire Protection Engineering, located in College Park, MD. The Research Foundation appreciates the guidance provided by the Project Technical Panelists, the funding provided by the project sponsors, and all others that contributed to this research effort. Thanks are also expressed to the National Fire Protection Association (NFPA) for providing the project funding through the NFPA Annual Research Fund.

About the Fire Protection Research Foundation

The Fire Protection Research Foundation plans, manages, and communicates research on a broad range of fire safety issues in collaboration with scientists and laboratories around the world. The Foundation is an affiliate of NFPA.

About the National Fire Protection Association (NFPA)

Founded in 1896, NFPA is a global, nonprofit organization devoted to eliminating death, injury, property and economic loss due to fire, electrical and related hazards. The association delivers information and knowledge through more than 300 consensus codes and standards, research, training, education, outreach and advocacy; and by partnering with others who share an interest in furthering the NFPA mission.

All NFPA codes and standards can be viewed online for free.

Keywords: carbon monoxide incidents, data, datasets, commercial occupancies, CDC, CPSC, IHME, NHTSA, NTSB, OSHA, Jenkins Foundation, NFIRS, REM Risk,

Report number: FPRF-2022-11

Project Managers: Victoria Hutchison & Jacqueline Wilmot, PE

Project Technical Panel

Matt Brookman, CPSC, Rockville, MD, USA

Wendy Gifford, Consultant, Chicago, IL, USA

Kris Hauschildt, Jenkins Foundation, Longview, WA, USA

Joshua Lambert, University of Texas – Austin, Austin, TX, USA

James Lathrop, Koffel Associates, Chair of NFPA 101, Niantic, CT, USA

Dave Mills, UL Solutions (Alternate), Northbrook, IL, USA

Jonathan Roberts, UL Solutions (Principal), Oklahoma City, OK, USA

Richard Roberts, Honeywell, St. Charles, IL, USA

Robert Solomon, SLS Consulting, Inc., Boston, MA, USA

Jennifer Sisco, NFPA, Quincy, MA, USA

Project Sponsors

NFPA

NATIONAL FIRE PROTECTION ASSOCIATION

The leading information and knowledge resource on fire, electrical and related hazards

Carbon Monoxide Incidents:
A Review of the Data Landscape

Prepared for

Fire Protection Research Foundation, Inc.
One Batterymarch Park
Quincy, MA 02169-7471

By

James Milke and Jamie McAllister

Department of Fire Protection Engineering

University of Maryland

October 2022

Acknowledgments

Support for this project was provided by the Fire Protection Research Foundation. Oversight of the project was provided by Jacqueline Wilmot and Victoria Hutchison. Appreciation is extended for the guidance and comments provided by the Project Technical Panel. The University of Maryland student team who worked on this project included: Ian Brady, Brent Boscia, Jade Carswell, Kyra Cromwell Reed, Josh Lumpkin, Robert McCandless, Nicholas Mertz, Liora Mervis, Alana Santos, Ethan Tievy, and Melanie Wilkinson.

Executive Summary

There are multiple sources which provide Carbon Monoxide (CO) incident data including but not limited to: Consumer Product Safety Commission (CPSC), Center for Disease Control and Prevention (CDC), U.S. Fire Administration (USFA), and standard development organizations such as the National Fire Protection Association (NFPA) and the International Codes Council (ICC). Each organization contains its own methodology for collecting information and providing statistics; however, it is not clear what specific information is being collected, disseminated, and represented for each incident type.

New requirements for the installation of CO detection into several types of occupancies (both new and existing occupancies) are being addressed in the latest editions of NFPA 101 Life Safety Code® and NFPA 5000, Building Construction and Safety Code®. There is a lack of understanding regarding the data available for non-fire CO incidents, specifically for commercial-type occupancies.

The purpose of this project is twofold: First, review and present the carbon monoxide incident data landscape to clarify the source of information, how it is compiled and present what the data represents. Secondly, identify, summarize, and analyze case studies of non-fire carbon monoxide incidents specific to commercial-type occupancies. This report will provide a greater understanding to the NFPA Safety to Life Technical Committee who is responsible for writing the NFPA 101, Life Safety Code® and the NFPA Building Code Technical Committee who is responsible for writing the NFPA 5000, Building Construction and Safety Code®.

Contents

1. INTRODUCTION

There are multiple sources which provide carbon monoxide (CO) incident data in non-fire events including but not limited to: Consumer Product Safety Commission (CPSC), Center for Disease Control and Prevention (CDC), U.S. Fire Administration (USFA), and the National Fire Protection Association (NFPA). Each organization contains its own methodology for collecting information and providing statistics; however, it is not always clear what specific information is being collected, disseminated, and represented for each incident type.

New requirements for the installation of CO detection in several types of occupancies (both new and existing occupancies) are being addressed in the latest editions of NFPA 101 Life Safety Code® and NFPA 5000, Building Construction and Safety Code®. A systematic collection and review of data available for non-fire CO incidents, specifically for commercial-type occupancies has not previously been conducted. This project seeks to collect and summarize such data from a variety of sources. Occupancies included in this report are all of those covered in the International Building Code and NFPA 101 and 5000, i.e. all occupancies other than one- and two-family dwellings.

These occupancy types were selected because they present a unique challenge in that someone other than the occupant, who is typically a visitor, guest, or employee, is responsible for building safety. Moreover, an occupant of a commercial-type building is not able to know what CO hazards exist within that building, where hazards are located, or if hazards are being addressed adequately. Given that people cannot detect CO until harmful symptoms become apparent, a building occupant is entirely reliant on the building owner/manager for their safety both from the standpoint of hazard identification and mitigation.

2. SCOPE

The research is divided into the following tasks:

Task 1. Identify Currently Available Data Sources:

- Task 1.1: Identify and evaluate information available from each applicable CO incident data source.
- Task 1.2: Address the positive and negative characteristics of currently available data sets from these sources.
- Task 1.3: Identify the insights that can be derived from this data. Also highlight what information cannot be obtained from the existing data sets.

Task 2. CO Incident Data Collection:

- Task 2.1: Identify and collect non-fire CO incident data in commercial-type occupancies from CPSC, USFA, and OSHA, as well as websites hosting information on CO incidents.
- Task 2.2: Identify Contributing Factors: Identify and evaluate the factors that contributed to the non-fire CO incidents in commercial-type occupancies.
- Task 2.3: Gap Analysis: Verify the factors identified in Task 2.2 to evaluate if they are addressed in applicable codes, e.g., NFPA 101 Life Safety Code® and NFPA 5000, Building Construction and Safety Code® and to identify gaps in code requirements for commercial-type occupancies.

Task 3. Final report: Prepare a final report.

3. AVAILABLE CO INCIDENT DATA SOURCES

This section addresses Task 1 and identifies and describes current databases and data sources that host CO incidents information[1]. Section 3.1 highlights databases which contain information on non-fire CO incidents[2]. There are other sources of data which are not hosted in a database; these other sources are highlighted in Section 3.2.

3.1 Databases

Information on CO incidents was found in eight databases. Organizations managing these databases included the Center for Disease Control and Prevention (CDC), Consumer Product Safety Commission (CPSC), Institute of Health Metrics and Evaluation (IHME), National Highway Traffic Safety Administration (NHTSA), National Transportation Safety Board (NTSB), Occupational Safety and Health Administration (OSHA), and United States Fire Administration (USFA). The data points contained in each database, the advantages and limitations of the data sets, and insights that can be derived from the datasets are described in more detail below.

3.1.1 CDC- National Environmental Public Health Tracking

Website: https://ephtracking.cdc.gov/DataExplorer/

The Center for Disease Control (CDC) tracking network uses data from the U.S. Census Bureau, hospital databases, and death certificates to measure and compare state and local data on CO poisonings. The website currently contains data collected between 2000-2020, however, the database is updated annually, presenting data summaries every one year, three years, and five years. To access CO poisoning data, the user can select "Unintentional Carbon Monoxide (CO) Poisoning" under content. The data can be filtered by three indicators: Emergency Department (ED) Visits for CO Poisoning, Hospitalizations for CO Poisoning, and Mortality from CO Poisoning. The data can be further sorted by three measures: Age-adjusted Rate, Annual Number, and Crude Rate. Geographic region, year, and advanced sorting options, such as "Cause: Fire", "Cause: Non Fire", and "Cause: Unknown Mechanism or Intent" are also available. A search can be conducted using the CDC site depicted in Figure 3.1

[1] In this report, "non-fire CO incidents" include events that involved a release of CO not associated with an unwanted fire, e.g., an accidental or incendiary fire.
[2] For the purposes of this research, a database was defined as a collection of electronic data stored as a file or set of files able to be searched and sorted.

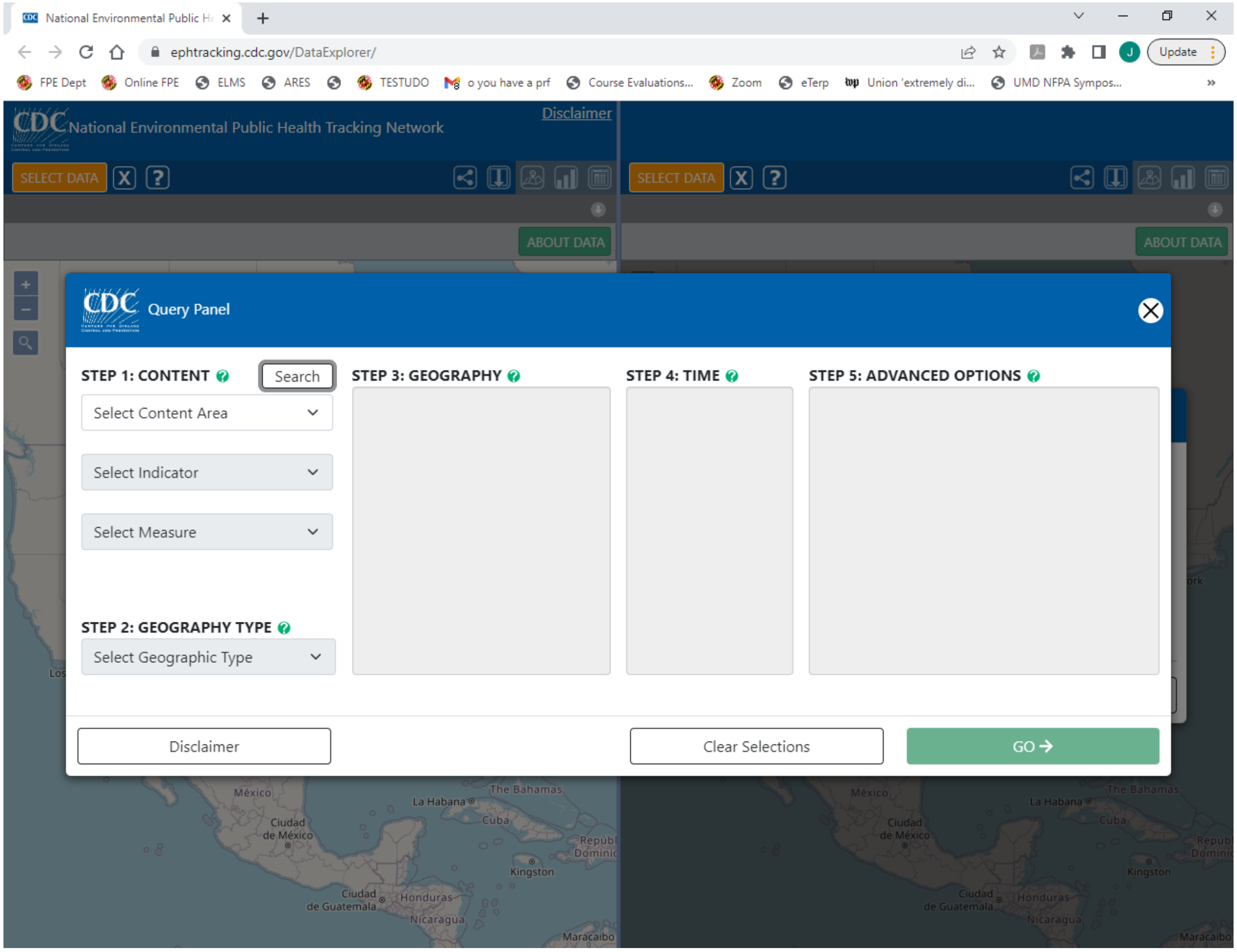

Figure 3.1. CDC Website for Data Search

As an example, a search was performing using Unintentional CO Poisoning → Mortality from CO Poisoning → Average Annual Number of Deaths from CO Poisoning over a 5-year Period → All States → 2015-2019 → Cause: Unintentional Non Fire. A portion of the screen resulting from the example is presented in Figure 3.2.

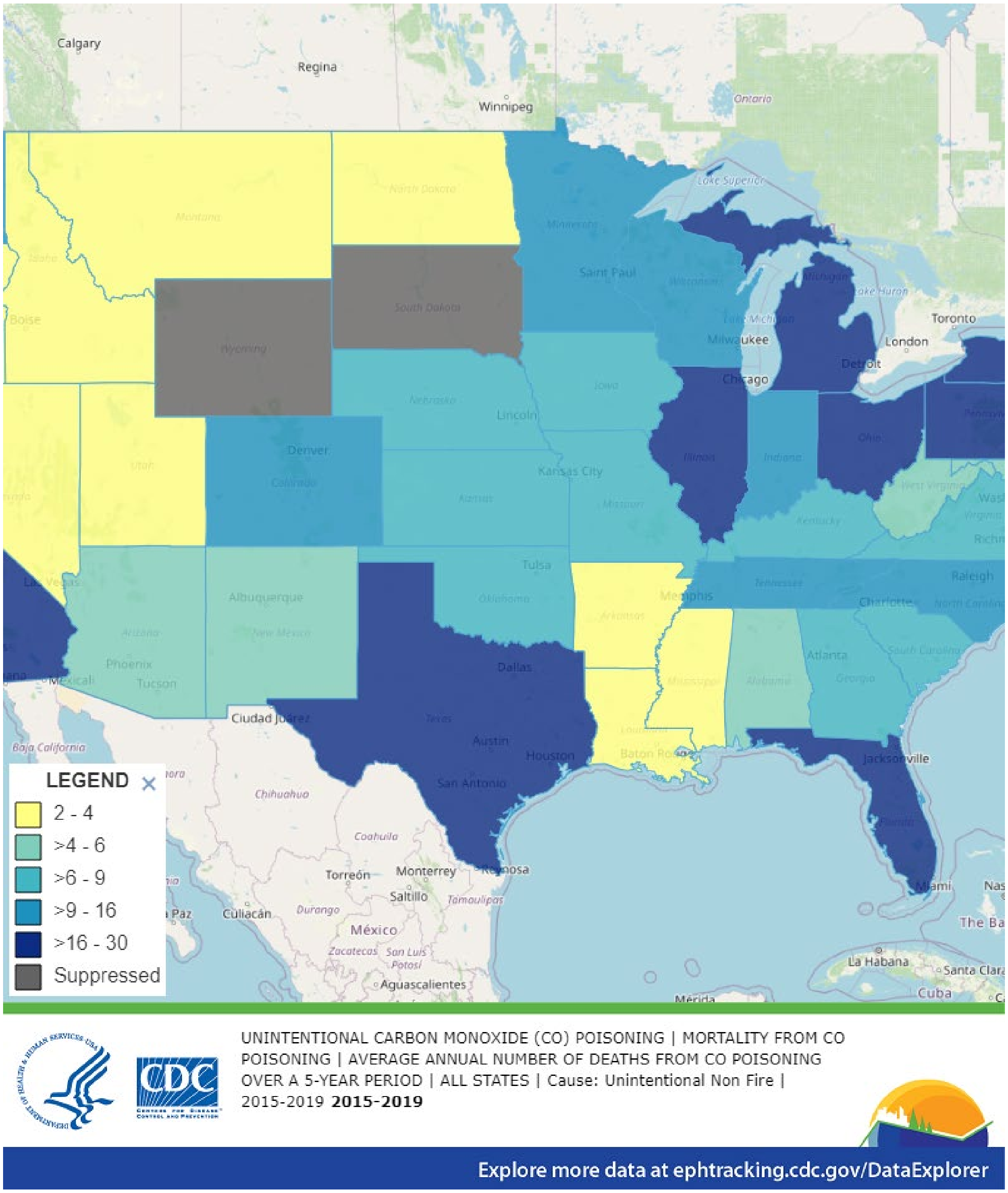

Figure 3.2 Example if Information on CDC Tracking Network

An advantage of the database is that color-coded maps can be created allowing easy visualization of incident severity across the U.S. Side-by-side maps can be generated to compare categories of data, such as the annual number of incidents. The database provides insights into both injury and death rates across the U.S. each year as well as fire and non-fire CO poisoning incidents. A limitation of the database illustrated in Figure 3.2 is that data is suppressed for certain states for confidentiality reasons. The cause category "Unknown Mechanism or Intent" also suggests that some non-fire CO incidents are not captured due to limited information being available. The database does not include information on the type of occupancies where the poisoning occurred or the CO source. The CDC also acknowledges that a limitation of their datasets is not including information on demographics, such as age, gender, race, and ethnicity.

3.1.2 CDC- WONDER

Website: https://wonder.cdc.gov/

The CDC Wide-ranging Online Data for Epidemiologic Research (WONDER) is a detailed mortality database that sources cause of death data from death certificates. CDC WONDER offers three sorted datasets relevant to CO poisoning incidents: Compressed Mortality[3], Multiple Cause of Death, and Underlying Cause of Death. The Compressed Mortality dataset is the oldest, dating back to 1968. The datasets are sortable by a variety of characteristics, such as state, county, age, race, gender, year and month of death, weekday of death, autopsy performed, place of death (medical facility, hospice, home, other, etc.), and underlying cause of death. Cause of death can be filtered using The International Classification of Disease (ICD) 10th revision or ICD-10 Codes, Injury Intent and Mechanism, and Drug/Alcohol Induced Causes.

The CDC[4] indicates that

> "The underlying cause-of-death is defined by the World Health Organization (WHO) as "the disease or injury which initiated the train of events leading directly to death, or the circumstances of the accident or violence which produced the fatal injury." Underlying cause-of-death is selected from the conditions entered by the physician on the cause of death section of the death certificate. When more than one cause or condition is entered by the physician, the underlying cause is determined by the sequence of conditions on the certificate, provisions of the ICD, and associated selection rules and modifications."

The ICD-10 code X47 includes "Accidental poisoning by and exposure to other gases and vapours" and can be used to filter the Compressed Mortality and Underlying Cause of Death datasets. The Multiple Cause of Death dataset has a secondary filter which includes the ICD-10 code T58 "Toxic effect of carbon monoxide".

Under CDC WONDER, the Prevention Guidelines Database can be searched by topic. Searching the topic "carbon monoxide" directs the user to three archived guidelines discussing snow-obstructed vehicle exhaust systems (1996), unintentional CO poisoning in residential settings (1993-1994), and CO poisoning resulting from gasoline-fueled power washer in underground parking garage (1994). The guidelines provide detailed information on specific cases; however, CDC indicates that the archive is being maintained for historical purposes and has no new entries since 1998.

The CDC WONDER datasets provide insight into underlying causes of death in specific demographic populations across the U.S. A limitation of the datasets is that they do not allow for further refinement of the X47 code by subcategories, e.g., X47.0, X47.1, X47.2, etc. As such, deaths listed under the X47 code may include accidental poisoning from helium,

---

[3] The Compressed Mortality File is a county-level national mortality and population database from the period 1968-2016.

[4] https://wonder.cdc.gov/wonder/help/ucd-expanded.html#ICD-10%20Codes

lacrimogenic gas, tear gas, nitrogen oxides, and sulfur dioxides (which is distinguished by subcategory X47.8) and “accidental poisoning by and exposure to unspecified gases and vapors” (which is distinguished by subcategory X47.9). The CDC WONDER database also does not catalog occupancy type in which the death(s) occurred or the CO source.

3.1.3 CPSC- National Electronic Injury Surveillance System (NEISS)

Website: https://www.cpsc.gov/cgibin/NEISSQuery/home.aspx

For approximately 45 years, the CPSC has operated a database known as the National Electronic Injury Surveillance System (NEISS). The database hosts information on consumer product-related injuries that have occurred within the U.S for the most recent 20 years. The database provides statistics and details of incidents to consumers, researchers, and other interested parties. Although the data collected in NEISS dates back to 1977, there have been several modifications to the design and data collection scope since that time. The most recent change to NEISS and its collected information occurred in 2018 when seven new search variables were added to the query system. The new search variables allow users to sort by diagnosis, body part, product, ethnicity, and alcohol and/or drug involvement.

The query builder is used to refine a data search. CO poisoning incidents can be found using Product Code 1899 “Carbon Monoxide Poisoning (when Source is Unknown)” and using Diagnosis Code 65 “Anoxia”; however, the Diagnosis Code can produce results for incidents other than CO poisonings. The database can be filtered by treatment dates (most recent 5 or 10 years of data, etc.), age, sex, body part, diagnosis, and disposition (admitted to hospital, fatality, etc.). After selecting the desired parameters, an estimate of national averages for a specific incident type can be generated.

One must be aware of NEISS Product Codes and the ways they are updated and changed from year to year to effectively use the database. While the database provides insight into consumer product related CO poisoning incidents, this is also a limitation of the dataset. Not all CO incidents result from combustion devices that are consumer products and not all consumer products that are combustion devices fall under the purview of CPSC. As such, the dataset is not inclusive of all possible CO incidents in the U.S. For example, the database does not capture CO incidents related to aircraft, automobiles, boats, industrial/commercial products, motorcycles, or trucks as these devices are outside of CPSC’s jurisdiction. Additionally, while occupancy type can sometimes be gleaned from the case narrative, it is not a search variable or output.

3.1.4 IHME- Global Health Data Exchange Registry

Website: https://www.healthdata.org/data-and-tools / http://ghdx.healthdata.org/

The Global Health Data Exchange (GHDx) is a catalog of surveys, censuses, and other health-based data collections. It is meant to provide researchers with access to a large volume of health-related data that can be used to improve health practices. The database is far-reaching, allowing the user to search by Country, and includes data from as early as 1900. However, the database does not allow for a filter of particular incident types. The only available data on CO deaths is in the form of two data visualizations for deaths attributed to CO poisoning. The Global Burden of

Disease Compare tool[5] has data going back to 1990, and the Causes of Death visualization has data from 1980.

Both sources compile results from a variety of surveys, and can be sorted by age, sex, and location (the first by country or state, the second by country only). The main advantage of the database is that the visualizations can be customized to compare by age, sex, and location. The database as a whole does not focus on CO incidents, and the Compare visualization is meant to compare CO to another cause of death. The datasets are limited in that they offer no further breakdown of the data (for example, by ethnicity, occupancy type of incident, or CO source). Furthermore, the remainder of the website beyond the visualization yields no results for 'Carbon Monoxide'. It is very difficult to find particular papers or reports on a particular cause of death other than those in the preselected list (CO is not included). The main insights are drawn from the comparisons, but the data can also give outputs in Deaths, Years Living with Disability (YLDs) or Disability-Adjusted Life Years (DALYs).

3.1.5 NHTSA- Non-Traffic Surveillance

Website: https://www.nhtsa.gov/crash-data-systems/non-traffic-surveillance

The National Highway Traffic Safety Administration (NHTSA) Non-Traffic Surveillance (NTS) database catalogs the number of fatalities and injuries that occur in vehicles not involved in crash incidents. Non-traffic crash data is obtained from NHTSA's Fatality Analysis Reporting System, General Estimates System, and National Automotive Sampling System. Non-crash injury data is obtained from emergency department records via CPSC's NEISS All Injury Program, and non-crash fatality data is obtained from death certificates via the CDC National Vital Statistics System. The website provides access to FTP files for non-crash fatalities, non-crash injuries, and non-traffic crash incidents occurring between 2003 to 2011, 2003 to 2019, and 2007 to 2015, respectively.

The Non-crash Fatalities data can be downloaded as a .CSV file with counts and annual percent of "Carbon monoxide poisoning from exhaust" by decedent age and gender, external cause (e.g., poisoning), and location (e.g., inside, outside, side enter exit, other enter exit, unknown). The Non-crash Injuries data can also be downloaded as a .CSV file and includes counts and annual percent of "Carbon monoxide from vehicle exhaust" by age, locale (home, other public property, street, farm, industrial, school, sports, and unknown), and person position (person in/on vehicle, person not in/on vehicle, unknown). The datasets provide insight into the number of deaths and injuries that occur each year from exposure to vehicle exhaust gases in non-crash incidents. A limitation of the dataset is that it does not distinguish between intentional exposures (e.g., suicide) and unintentional exposures to vehicle exhaust gas. Additionally, while it does provide information on occupancy type, the classifications are not highly specific. For example, a "home" could be a single-family residence, a townhouse, an apartment building, or some other type of residence. The main limitation of this database, as it relates to the scope of this project, is that it only contains vehicle-related CO-incidents.

[5] The GBD Compare tool is applied to compare causes and risks of mortality causes within a country.

3.1.6 NTSB- Aviation Accident Database & Synopses

Website: https://www.ntsb.gov/Pages/AviationQuery.aspx

The Aviation Accident Database and Synopses, operated by the National Transportation Safety Board, collects reports summarizing civil aviation accidents and incidents. The results are presented as a list of reports which can be downloaded individually as PDFs to view the details of the accident or incident. An "accident" is defined as an event that results in a death or serious injury or in significant damage to the aircraft, whereas an incident is defined as an occurrence of lesser severity and danger to safety than an accident.

The database includes reports from as early as 1962, but full datasets are only available for events after 1982. Each report includes a wide variety of information, such as the location, date and time of the accident, the type, make, and model of the aircraft, the reason for the flight, the weather conditions during the flight, any damage sustained by the aircraft, and injuries sustained by the pilot or passengers, and the results of any drug or substance testing conducted on the pilot or passengers.

The major advantage of this database is the detail that it provides in each summary of an accident or incident; the reports are extensive and detailed. However, it is difficult to search and filter the reports for specific events, such as CO incidents. While a search can be generated by keyword for reports including the phrase "Carbon Monoxide," the results include any report where testing for CO occurred, including events where these tests were negative. The main limitation of this database, as it relates to the scope of this project, is that it only contains aviation-related CO incidents.

3.1.7 OSHA- Fatality and Catastrophe Investigation Database

Website: https://www.osha.gov/pls/imis/accidentsearch.html

The Occupational Health and Safety Administration (OSHA) creates the Fatality and Catastrophe Investigation Summaries to provide descriptions of OSHA investigations into fatal or injurious incidents in the workplace. OSHA has been writing incident summaries since 1984. Searching the database by keyword "Carbon Monoxide," one of OSHA's suggested search terms, returns a list of summaries which can be viewed individually. It is also possible to view selected summaries at the same time, with the details of each summary presented one after the other on the same page.

The summaries list the date and time of the incident, the employer of the injured worker, some demographic information about the injured worker, and the degree of injury suffered by the worker, described as either non-hospitalized injury, hospitalized injury, or fatality. The summaries include a description of the type of work being done at the time of injury, as well as the events leading up to and following the incident, such as emergency response. Some of the summaries also include other relevant information, such as the type of machinery being used by the worker when they were injured. The OSHA summaries include only incidents that occurred in the workplace, including company buildings, vehicles, and job sites, affecting employees.

An advantage of this database is that the summaries offer clear descriptions of the incidents, allowing for a detailed understanding of how people came to be injured by the exposure to CO. There are some challenges associated with database usability; while the database can be filtered to show reports related to CO exposure or can be filtered to show only fatalities, it cannot be filtered by occupancy type and searching by keyword offers limited success. Furthermore, some of the CO-related summaries that result from a "Carbon Monoxide" keyword search are for incidents in which CO was suspected as the cause of injury but later found not to be the cause. Additionally, details on the degree of injury suffered by employees cannot always be derived nor can the effect of CO on any non-employees present during the incident.

It is also worth noting that the database only contains incidents where OSHA conducted an inspection. OSHA[6] defines a fatality as "An employee death resulting from a work-related incident or exposure; in general, from an accident or an illness caused by or related to a workplace hazard" and a Catastrophe as "The hospitalization of three or more employees resulting from a work-related incident or exposure; in general, from an accident or an illness caused by a workplace hazard." OSHA[7] defines a workplace as "a physical location where the agency's work or operations are performed" Hence, if the incident does not occur within a workplace, is not considered work-related, or otherwise falls outside of the definition of a fatality or catastrophe, it would not be included in the database.

3.1.8 USFA- National Fire Incident Reporting System (NFIRS)

Website: https://www.fema.gov/about/openfema/data-sets/fema-usfa-nfirs-annual-data

The National Fire Incident Reporting System (NFIRS) is a voluntary reporting standard that fire departments use to uniformly report on the full range of their activities, from fire to emergency medical services to severe weather and natural disasters. The USFA publishes an annual public data release file of incidents reported by nearly 24,000 fire departments across the U.S. (there are approximately 27,000 to 29,000 fire departments in the U.S.)[USFA, 2022][Haynes, 2017]. The purpose of NFIRS is to help state and local governments collect and analyze data regarding fire department responses and to aid in a larger scale analysis of the U.S. fire problem. The 1980 to 1998 data releases only include fire incidents. The 1999 to 2003 data releases were expanded to include all incidents. The 2004 to 2013 data releases were restricted to only include fire and hazardous materials (HAZMAT) incidents. Then, in 2014 to present, the data releases were again expanded to include all incidents and HAZMAT incidents.

The data collected for each incident includes incident type, address, property use, and actions taken. However, other data elements such as property loss, death and injury counts, cause, and number of people evacuated may only be completed for certain incident types. The data is given in the form of a delimited text file that can be downloaded and viewed using statistical software. There is one main dataset, i.e., the NFIRS Basic Module, that includes all reported incidents and provides some information on the property use, incident type, and actions taken.. The NFIRS Basic Module does not include information on equipment involved or cause-related data elements. Rather, those data elements are found in the various other NFIRS modules such as the

[6] https://www.osha.gov/enforcement/directives/cpl-02-00-137

[7] https://www.osha.gov/laws-regs/regulations/standardnumber/1960/1960.2

Fire Module or Hazmat Module. For example, in HAZMAT incidents, there is information on what chemical was involved and the method of disposal.

An advantage of the database is the volume data it contains for each year across the U.S. A limitation of the database is that each output is coded. As such, certain relevant aspects of the incident may go undiscovered because they have no associated code. Further, NFIRS does not collect the number of injuries and deaths that result from non-fire CO incidents in the Basic Module. Another limitation of the database is that inputs are based on information that was available to first responders at the scene and their interpretation of that information; information provided is usually not the result of a detailed analysis of suspected equipment and the CO source is often unknown. Lastly, while this is an extensive database, it does not cover all incidents in the U.S. Not all fire departments utilize NFIRS nor choose to record all incidents in the NFIRS system.

3.2 Other Data Sources

An internet search was performed to identify other sources of data related to CO poisoning incidents. Several websites were found which host information related to CO poisoning incidents. A sample is provided below.

3.2.1 CPSC- Collection of Injury Statistics and Technical Reports

Website: https://www.cpsc.gov/Research--Statistics/Carbon-Monoxide

CPSC provides a collection of published reports on CO incidents associated with consumer products. The collection includes several reports. The two most prevalent reports related to this project are the 'Non-Fire Carbon Monoxide Deaths Associated with the Use of Consumer Products Annual Estimates', which have been published from 1995 to 2018, and the "Generators and OEDT CO Poisoning Fatalities Reports,"[8] which have been published in different formats from 1990 to 2021. The two main data types are technical reports or test findings and fatality statistics from death certificates. The specific demographics vary between reports. CO poisonings identified on the death certificate as unintentional or indeterminate intention are included in the reports.

Typically, the Non-Fire CO Deaths reports analyze incidents by product type, e.g. fuel-burning, fuel type, engine-drive tools (EDT). The reports also include an evaluation of victim demographics, such as age, gender, race/ethnicity, population density, and geographical region. The Generators and OEDT reports typically evaluate fatalities by EDT product type, socio-demographic characteristics of victims, presence of CO alarms, reason for generator use, ventilation conditions, and home characteristics. One limitation of the Non-Fire CO Deaths reports is the age of the data being analyzed; the most recent report includes annual estimates from 2018. Another limitation is the narrow scope of the data, as the majority of incidents are related to consumer product used in residential occupancies. Some insights that can be derived from the reports include number of deaths resulting from a particular product, demographic, trends between years, and circumstances associated with the event.

---

[8] OEDT is an acronym for "other engine-driven tools."

3.2.2 The Jenkins Foundation- Hotel Incident Data

Website: https://thejenkinsfoundation.com/travelsafe/hotel-co-incident-data/

The Jenkins Foundation was formed in 2013 after Daryl and Shirley Jenkins were poisoned by CO in their hotel room. The hotel room had no CO detector, and the CO leak went undiscovered until, several weeks later, another death occurred in the same room. The Jenkins Foundation investigates and reports on CO related deaths and injuries in hotels and motels. The website contains a database of incidents dating back to 1967 which are sourced from web searches and literature. The database is updated as new incidents occur or as past ones are discovered.

Each incident is ordered by date and includes the location, name of victims, type of hotel, source and location of the CO, and an excerpt providing the details of the incident. Numerical data includes the number of deaths, number of injuries, age of each victim, and number of victims that were age 18 and younger. The database is highly detailed and several newer reports include the CO level measured during the incident. One limitation of the database is that it pertains only to hotels, only lists incidents of public record, and includes limited detail (based on what is contained in public record sources). Some incidents do include detail about the presence and operability of CO detectors, though this detail is seldom reported in the news and therefore not represented in all incidents.

3.2.3 REM Risk Consultants Data

Website: https://remrisk.com/resources/carbon-monoxide-hotels/

REM Risk Consultants have a website resource that can be used to search a collection of data on CO incidents in hotels and motels in the United States. The data is sourced from the Jenkins Foundation and NFIRS. The Jenkins Foundation data dates back to 1967 and data from NFIRS dates back to 1999. The search tool can be used to plot CO incidents on a map, and incidents can be filtered by data source, year, CO source, state, number of deaths/injuries, and name of the facility. The Jenkins Foundation and NFIRS differ in the way incidents are described with the Jenkins Foundation giving a more descriptive narrative of the event and NFIRS, primarily, providing actions taken by first responders.

The REM Risk Consultants search tool has the same limitations as the data sources that feed it. NFIRS does not provide the number of injuries or deaths that result from non-fire CO incidents in the basic module, and there is very limited reporting in the Hazardous Materials module. Additionally, not every fire department utilizes NFIRS and every incidents is not entered by those departments that utilize NFIRS. Additionally, the Jenkins Foundation extracts information from the web, and not all incidents are reported in the news. The REM Risk search tool provides insight into most prevalent geographic regions for hotel and motel CO incidents and CO sources, as well as trends between years.

4. ANALYSIS OF DATABASES

This section presents an in-depth analysis of data from the CPSC, NFIRS, OSHA and Jenkins Foundation databases to address Tasks 2.1 and Task 2.2. The specified databases were chosen because they contain information related to occupancy type which allowed for some level of evaluation of incidents in commercial-type occupancies.

4.1 Databases

The most recent ten-years of data was obtained from the CPSC, NFIRS, and OSHA databases. When available, information such as incident date, time, city, state, occupancy type, CO source, number of deaths or injuries, location of decedent relative to source, presence of CO alarm, operability of CO alarm, and contributing factors was retrieved from the databases.

4.1.1 CPSC- NEISS On-Line Query System

The CPSC NEISS On-Line Query System can be used to access incidents that meet particular criteria. This system sorts the database of CPSC incidents, and compile a list of incidents that contain the particular tags in the query.

For this project, the user affiliation 'Researcher' was used, and data from the past 10 years (2011-2020) was selected. Each incident in the CPSC database is tagged with at least one product code describing the product involved in the injury. Examples of products include home appliances, home workshop tools, generators, etc. These are organized into categories in the builder, and can be added in any number to build the query. The filter uses an OR operator for these tags, meaning that incidents including any of the selected tags will be included in the results. Using the 'NEISS Product Code' tags are not immediately intuitive, but the query builder provides some resources to help users, e.g. the Coding Manual. For this research, Product Code 1899- "Carbon Monoxide Poisoning (when Source is Unknown)" was utilized in the query along with Product Code 712- "Carbon Monoxide Alarms". The latter code was used, because CO alarms are typically mentioned in incidents involving a CO release.

The query results were outputted to Microsoft Excel. Each incident in the spreadsheet included the case number, the tags, a brief description of the event, a few statistical measurements, and a short narrative with other information such as the incident location. The query builder cannot filter by locations, but the incidents can be organized by location within the spreadsheet. Given CPSC's jurisdiction, most incidents occurred in residential occupancies. Unfortunately, the tag "Location 1: Home" includes both single family homes and apartment buildings. The focus of this research was incidents occurring in commercial-type occupancies, which was defined as any occupancy covered under the IBC, NFPA 101 and NFPA 5000. Incidents in single family homes (covered under IRC) were filtered from the dataset by reviewing each case narrative to identify those cases that specifically referenced apartments.

A total of 2,226 incidents were identified between 2011 and 2020 using the NEISS database. The distribution of occupancies in which the incidents occurred (using the same terms used by CPSC to describe the occupancy) is provided in Table 4.1.

Table 4.1 Number of Incidents by Occupancy in NEISS Database

Occupancy	Number of Incidents	Proportion of Total Incidents (%)
Home (including One and Two-Family Dwellings)	1,840	82.7
School or Daycare	36	1.6
Mobile or Manufactured Home	6	0.3
Place of Recreation or Sports	5	0.2
Other Public Property	164	7.4
Not Recorded	175	7.9
Total	2,226	

Excluding single family homes from the “homes” category, it was determined that 260 CO incidents related to consumer products occurred in apartments over the last 10 years. The short narrative that is included in the data download did not provide a sufficient level of detail to identify contributing factors that led to the release of CO nor did it identify the location of the victim relative to the CO source. In some cases, an incident with Product Code 712 or 1899 did include secondary and tertiary product codes identifying the CO sources; however, because the CO source was not routinely identified, it was not evaluated in more detail in this report.

4.1.2 NFIRS

The NFIRS data was prepared for analysis by filtering the “basicincident” dataset, which is a compilation of incidents included in NFIRS Basic Module. The data was filtered to only include the “424” incident type (the code for non-fire CO incidents) and excluded any incidents where nothing else was entered. The data was also filtered to exclude the “400” and “419” property use codes, corresponding to “Residential, other” and “1 or 2 family dwellings,” respectively, because the property use codes were outside the scope of this analysis.[9]

In total, there were 678,265 CO incidents that occurred between 2011-2020. Of these, 468,901 incidents (69.1% of the total) occurred in single family dwellings, 199,473 incidents (29.4%) occurred in commercial-type occupancies, and the remainder occurred outdoors or were identified as unknown, none or other. Of the commercial-type occupancies, the three leading property uses were restaurant or cafeteria (3,686 incidents, 1.8%) hotel/motel (3.140 incidents, 1.6%) and mercantile/business/other (3,125 incidents, 1.6%). The listing of the number of incidents in each property use code is shown below.

[9] In NFIRS, no distinction is made for townhomes, rowhomes, apartment buildings, etc. so these are all presented in the dataset even though some do not fall under the "commercial-type occupancy" definition.

Table 4.2- NFIRS Number of Incidents by Property Use Code.

Property Use Code	Number of Incidents	%
1 or 2 family dwelling	468901	69.1
Multifamily dwellings	131632	19.4
Residential, other	22625	3.3
Restaurant or cafeteria	3686	0.5
Hotel/motel, commercial	3140	0.5
Mercantile, business, other	3125	0.5
Business office	2817	0.4
Food and beverage sales, grocery store	2369	0.3
Manufacturing, processing	2034	0.3
24-hour care Nursing homes, 4 or more persons	1767	0.3
Warehouse	1281	0.2
Dormitory type residence, other	1198	0.2
Boarding/rooming house, residential hotels	1154	0.2
Motor vehicle or boat sales, services, repair	1132	0.2
Church, mosque, synagogue, temple, chapel	1131	0.2
Specialty shop	1128	0.2
Residential board and care	942	0.1
Elementary school, including kindergarten	871	0.1
High school/junior high school/middle school	762	0.1
Mental retardation/development disability facility	733	0.1
General retail, other	632	0.1
Eating, drinking places	622	0.1
Professional supplies, services	582	0.1
Personal service, including barber & beauty shops	577	0.1
Day care, in commercial property	573	0.1
Public or government, other	553	0.1
Convenience store	518	0.1
Bank	504	0.1
Clinics, Doctors offices, hemodialysis centers	455	0.1
Department or discount store	446	0.1
Service station, gas station	431	0.1
Adult education center, college classroom	414	0.1
Fire station	391	0.1
Police station	367	0.1
Doctor, dentist or oral surgeons office	359	0.1
Bar or nightclub	351	0.1
All others	18062	2.7
	678265	100.0

Of the incidents that occurred in occupancies other than 1-2 family dwellings, there were 276 incidents that included at least one injury. There was a total of 475 injuries in these 276 incidents. The distribution of the non-fatal casualties is presented in Figure 4.1.

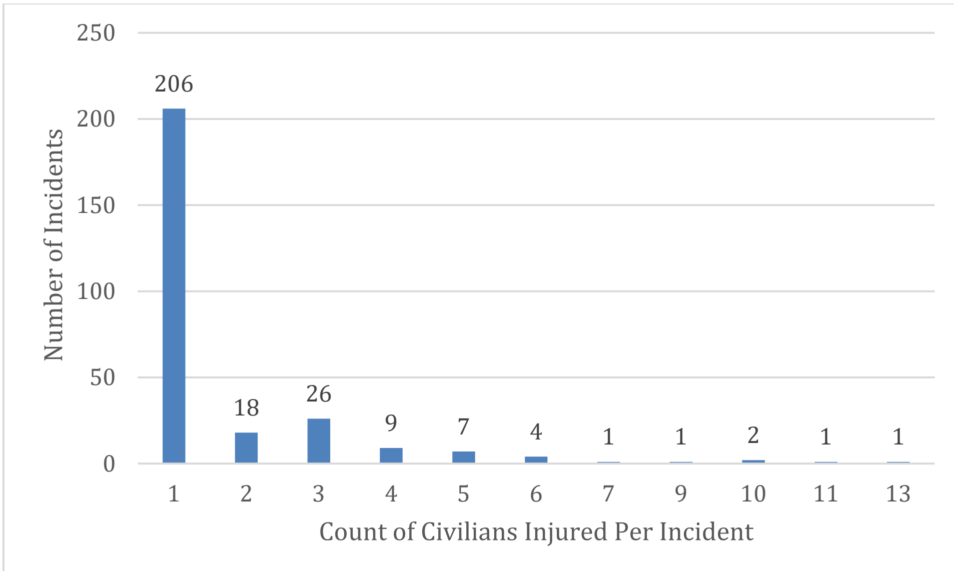

Figure 4.1 Civilian Injuries in Commercial-Type, Non-Residential Incidents[10]

The proportion of occupants alerted by a detector is presented in Figure 4.2.[11] In the 172,746 incidents included in this field, the detector response was only noted in 14,0601 incidents. For the incidents where either “yes” or “no” was provided, a detector is noted as having alerted occupants in 12,321 incidents, or 88% of the incidents.

One possible reason for the small number of entries regarding CO detector presence and operability may be attributable to guidance provided in the NFIRS manual (USFA, 2015):

> "Check or mark the box if a detector alerted the occupants in this incident (regardless of whether the detector was smoke, heat, carbon monoxide, etc.). This block can be left blank for non-fire incidents, and can optionally be used for a carbon monoxide (CO) incident and whether a CO detector operated."

[10] Many of the incident reports left this field blank. The 42 incidents with no injuries reflect only those incidents where “zero” was indicated for the number of injuries.

[11] The DET_ALERT field is only required to be completed in the NFIRS Basic Module for confined fires (Incident Types 113-118).

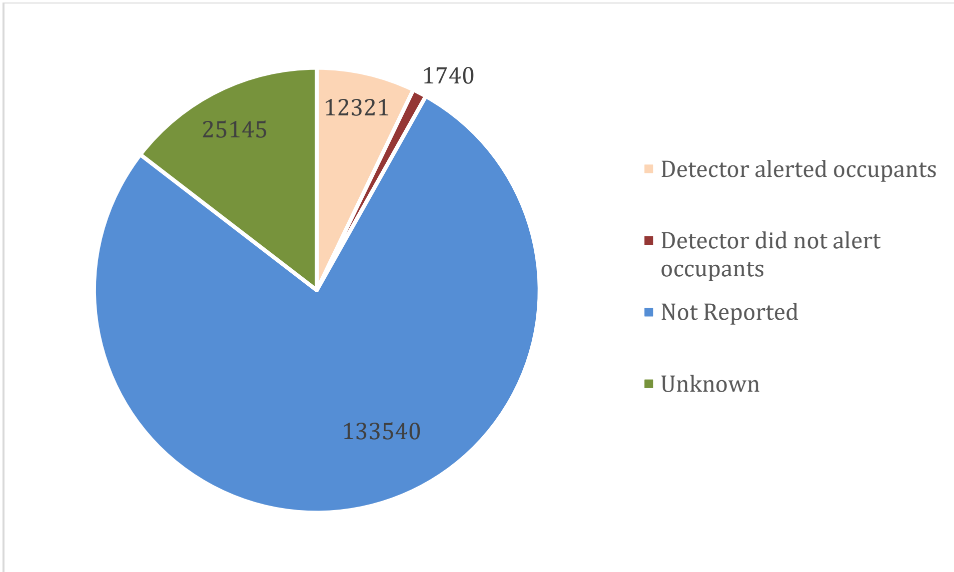

Figure 4.2 Notification of Occupants by Detector

4.1.3 OSHA- Fatality Catastrophe Investigation Summaries

A total of 130 non-fire CO incidents were located in the OSHA database between 2011 to 2020. Incidents occurred in a wide variety of occupancies, with 115 incidents occurring in commercial-type occupancies. The proportion of incidents in each of the IBC and NFPA occupancy types is depicted in Figures 4.3. and 4.4. The IBC occupancy type with the greatest proportion of incidents was Factory/Industrial (F-1) at 24%. The second most frequent occupancy was Business (B) at approximately 16%.

The most common contributing factor in commercial-type, non-residential occupancies was limited ventilation of the work area (39%). These were predominantly cases involving renovation or construction activities. Maintenance and product misuse were the next two most commonly cited contributing factors (15% and 10% respectively). The distribution of contributing factors in commercial-type, non-residential and residential occupancies is provided in Figures 4.5 and 4.6 respectively. For the 11 incidents where the injured or deceased occupant was found in a different room, in seven of these incidents, "maintenance" was a contributing factor. In these cases, the source was a boiler, heat exchanger or water heater.

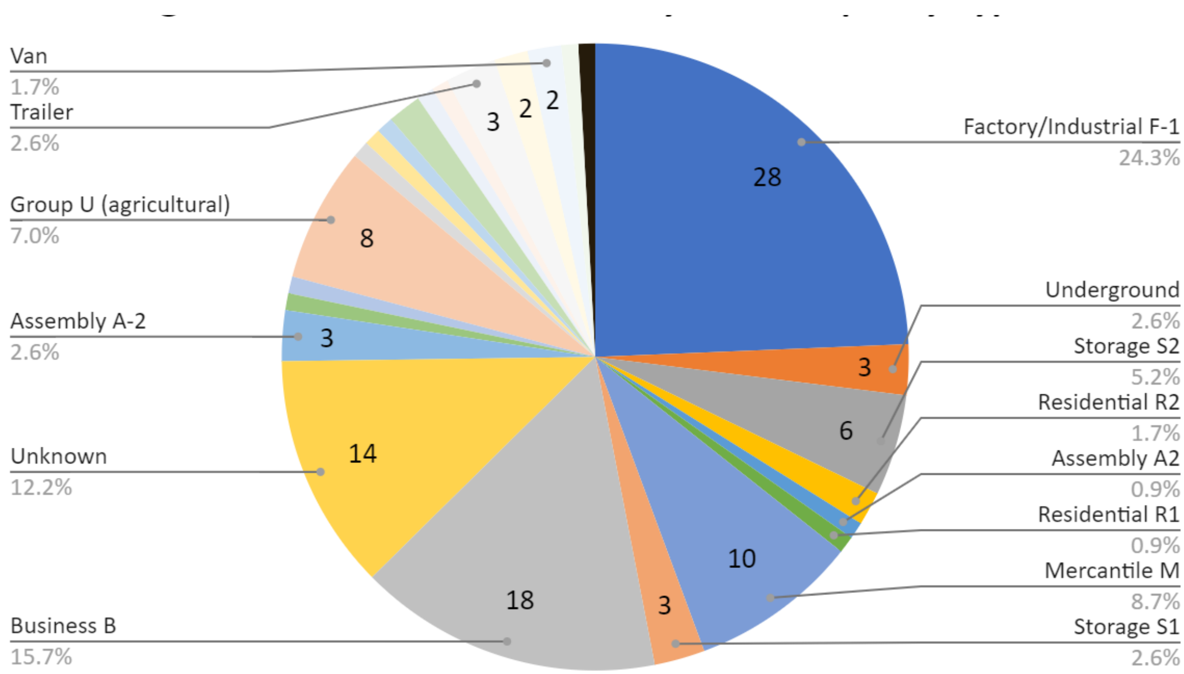

Figure 4.3 Non-Fire CO Incidents by IBC Occupancy Type

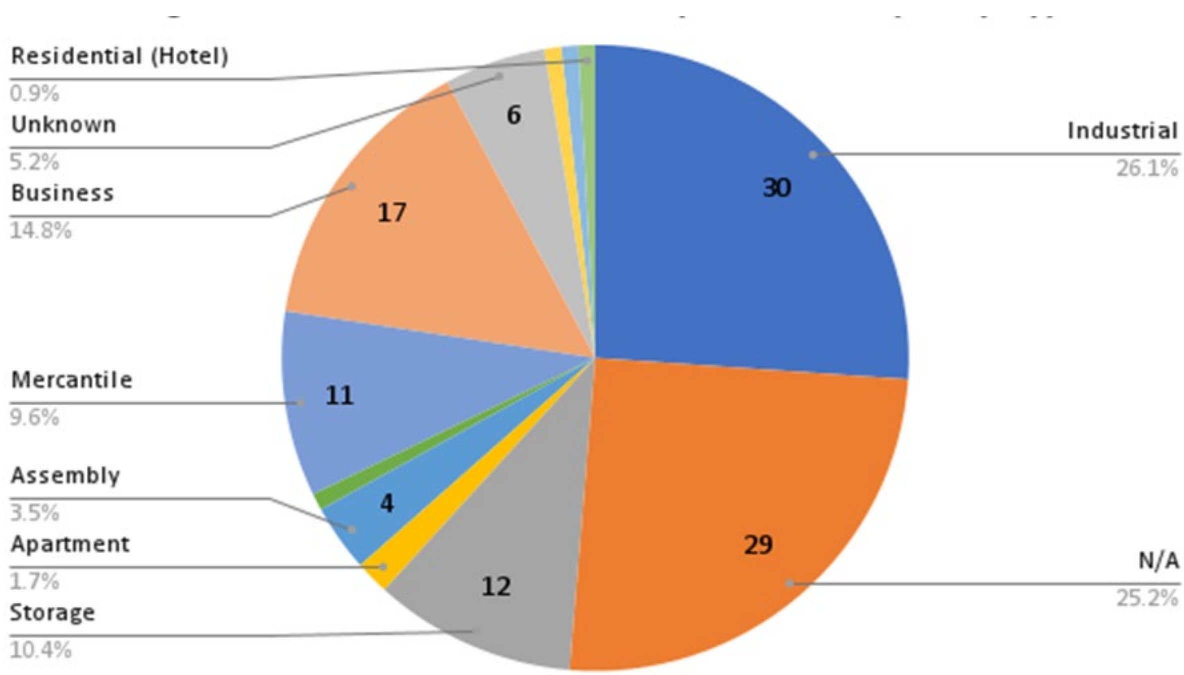

Figure 4.4 Non-Fire CO Incidents by NFPA Occupancy Type

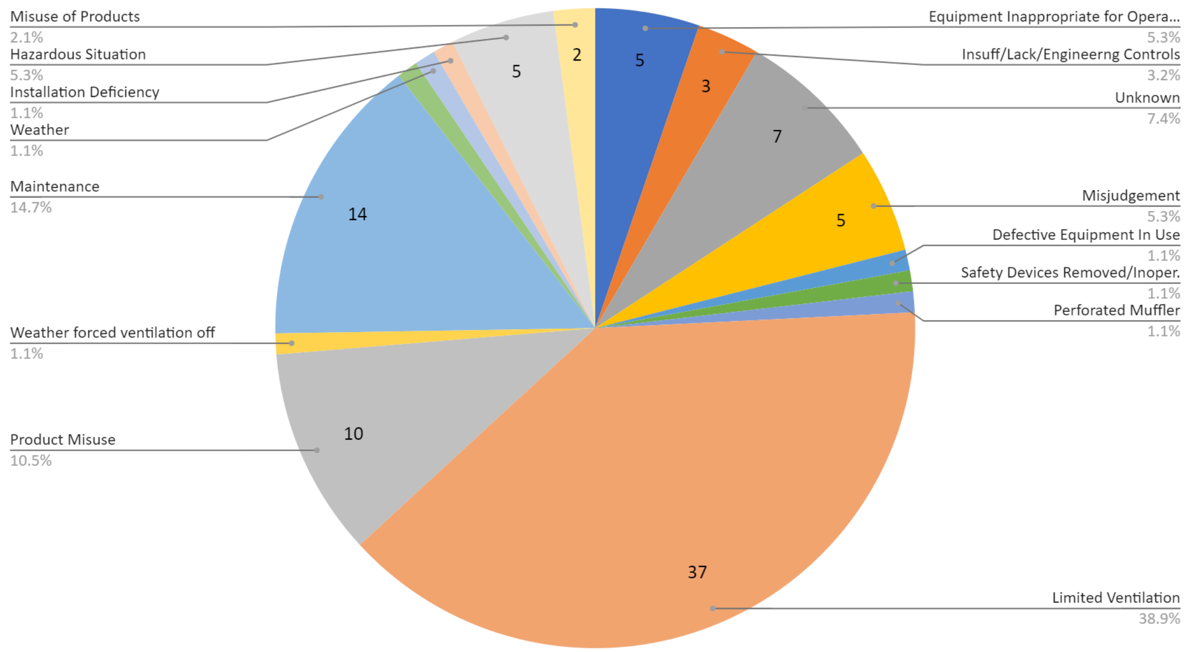

Figure 4.5 Contributing Factors in Non-Residential CO Incidents

The OSHA database included incidents that occurred in commercial-type, residential occupancies (e.g., apartment buildings) when workers were employed in those buildings, as shown in Figure 4.6.

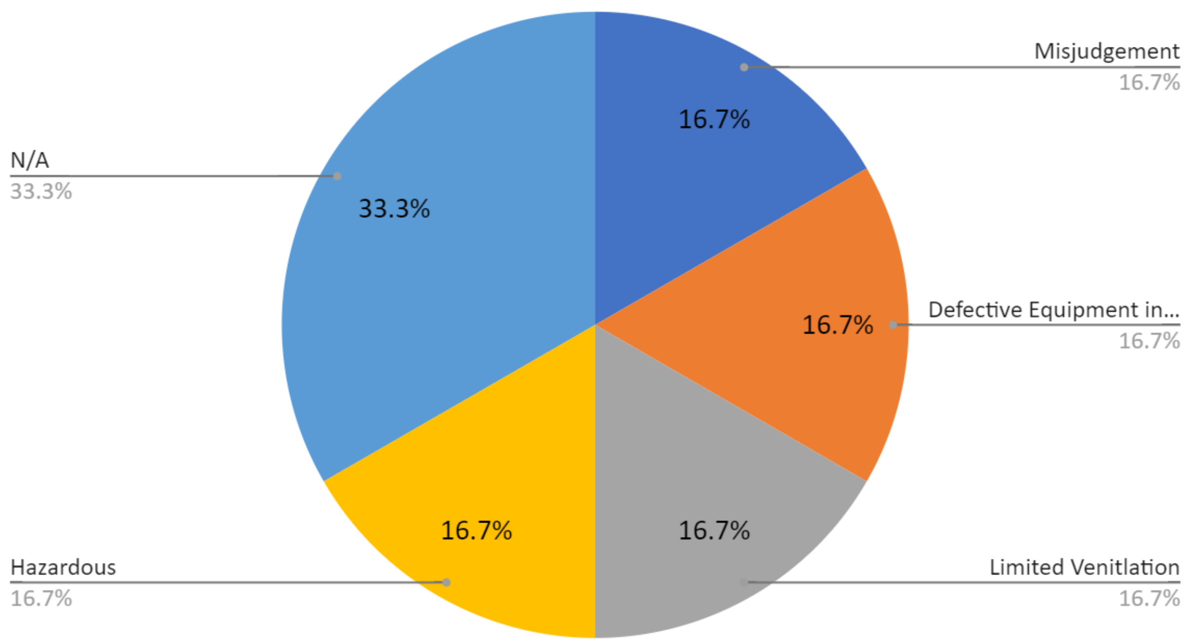

Figure 4.6 Contributing Factors in Residential CO Incidents

The distribution of the sources of CO in commercial-type, non-residential incidents is provided in Figure 4.7. Forklifts were the source in 14% of incidents while saws and generators were sources in 7% of the incidents each.

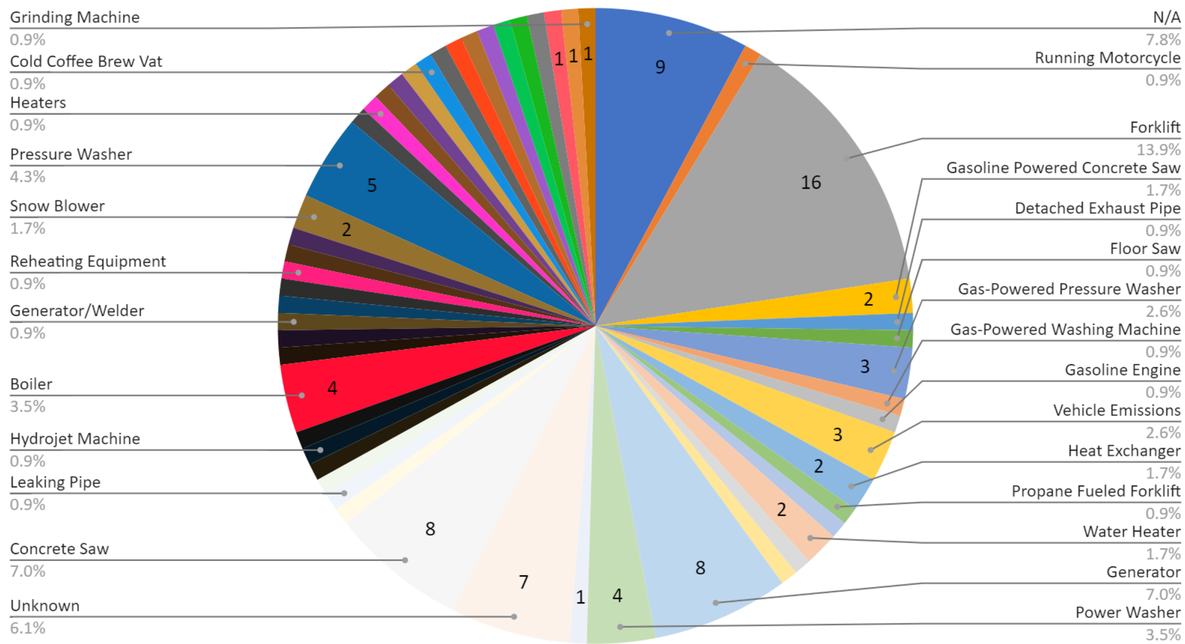

Figure 4.7 Sources in Non-Residential Incidents

The source of the CO was found to be in the same room as the person harmed in 80 of the 115 cases studied (70% of the incidents) (see Figure 4.8).

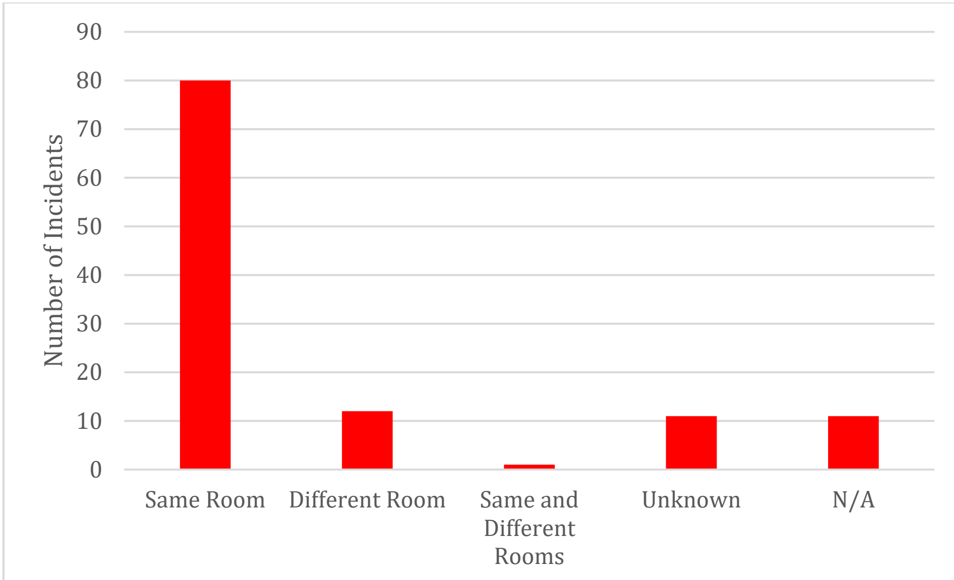

Figure 4.8 Location of Decedent/Injured Relative to Source

There were 46 deaths and 242 total injuries reported in the OSHA database from exposure to CO in non-fire incidents in commercial-type, non-residential occupancies (i.e., all incidents included in the database minus those in multi-family residences). The distributions of deaths and injuries in the OSHA database are provided in Figures 4.9 and 4.10. In 43 of the 115 cases in commercial-type, non-residential occupancies (37% of the incidents), there was at least one reported death. In three cases, there were two deaths. There was at least one reported injury in 69% of the incidents. In one case, there were 37 reported injuries.

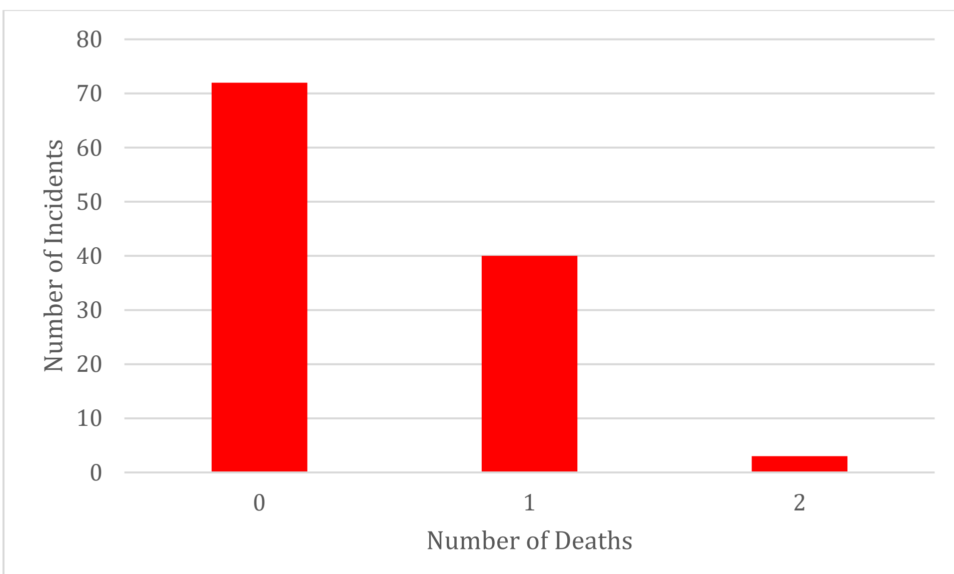

Figure 4.9 Number of Deaths in Each Non-Fire CO Incident

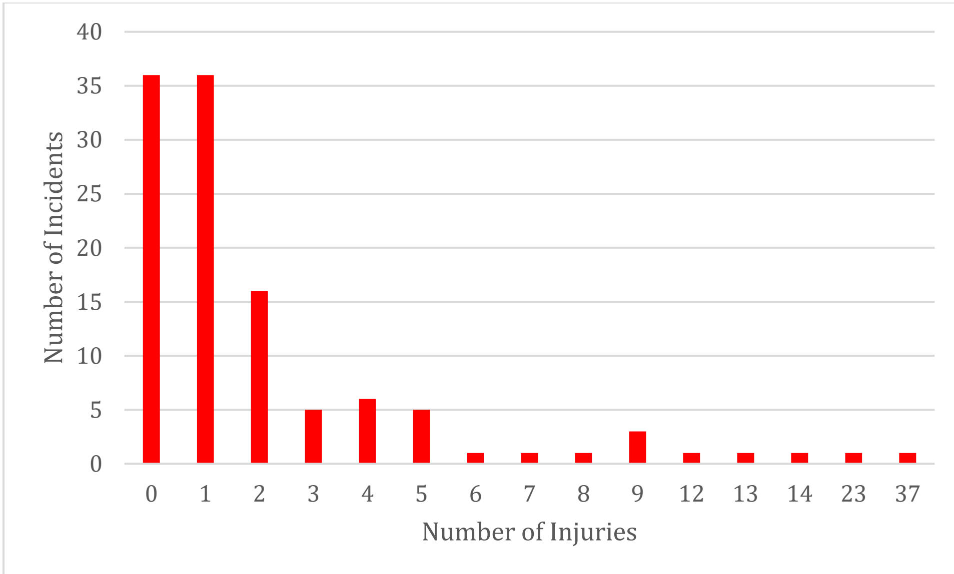

Figure 4.10 Number of Injuries in Each Non-Fire CO Incident

4.1.4 The Jenkins Foundation

A summary of the data from the Jenkins Foundation is provided in this section. The database includes 165 incidents that occurred in hotels between January 2011 and March 2022. In 11 of those incidents, there were a total of 15 deaths, and in 96 incidents, there were a total of 681 injuries. The distribution of deaths and injuries are presented in Figures 4.11 and 4.12. While there were a significant number of incidents with a single death or single injury, some incidents were far reaching and resulted in multiple deaths or injuries.

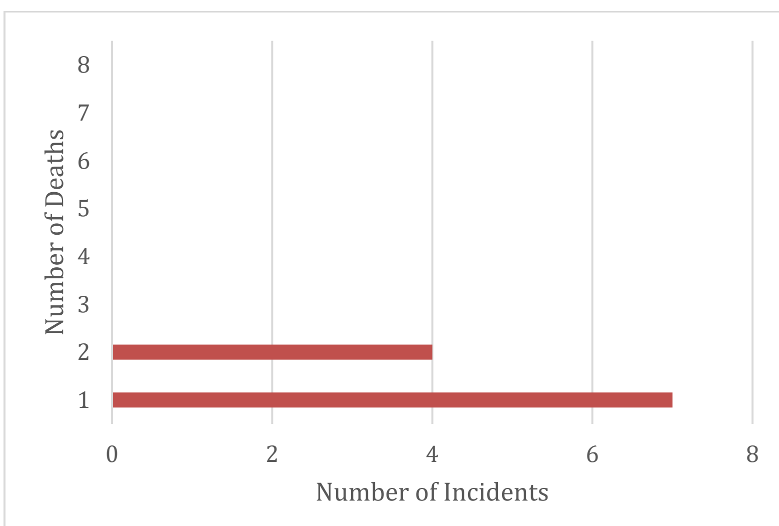

Figure 4.11 Distribution of Deaths in Incidents in Jenkins Foundation Database

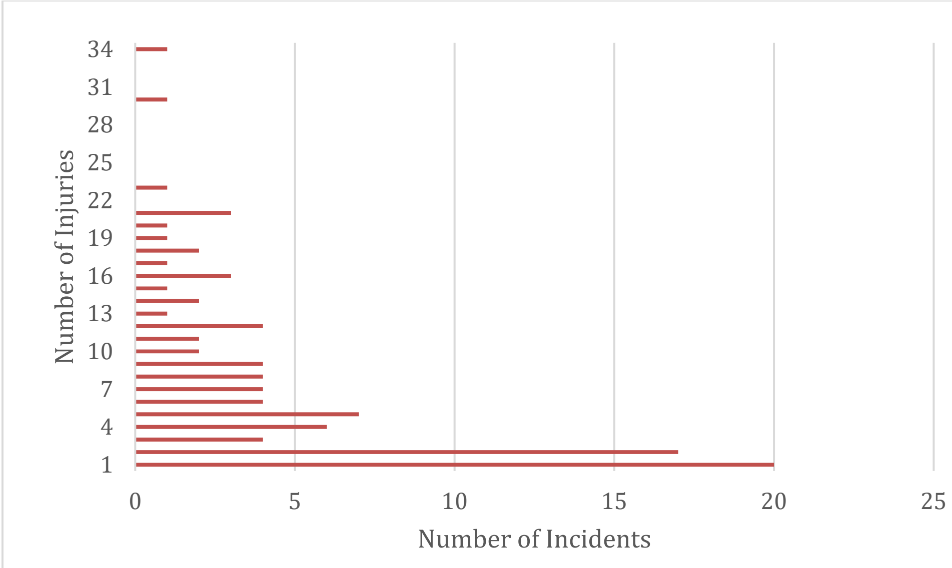

Figure 4.12 Distribution of Injuries in Incidents in Jenkins Foundation Database

For the 59 incidents in which a source for CO was identified, the distribution of sources, incidents is presented in Figure 4.13 (no information on the source was provided in 106 incidents). Pool heaters, water heaters, and boilers were the leading known sources.

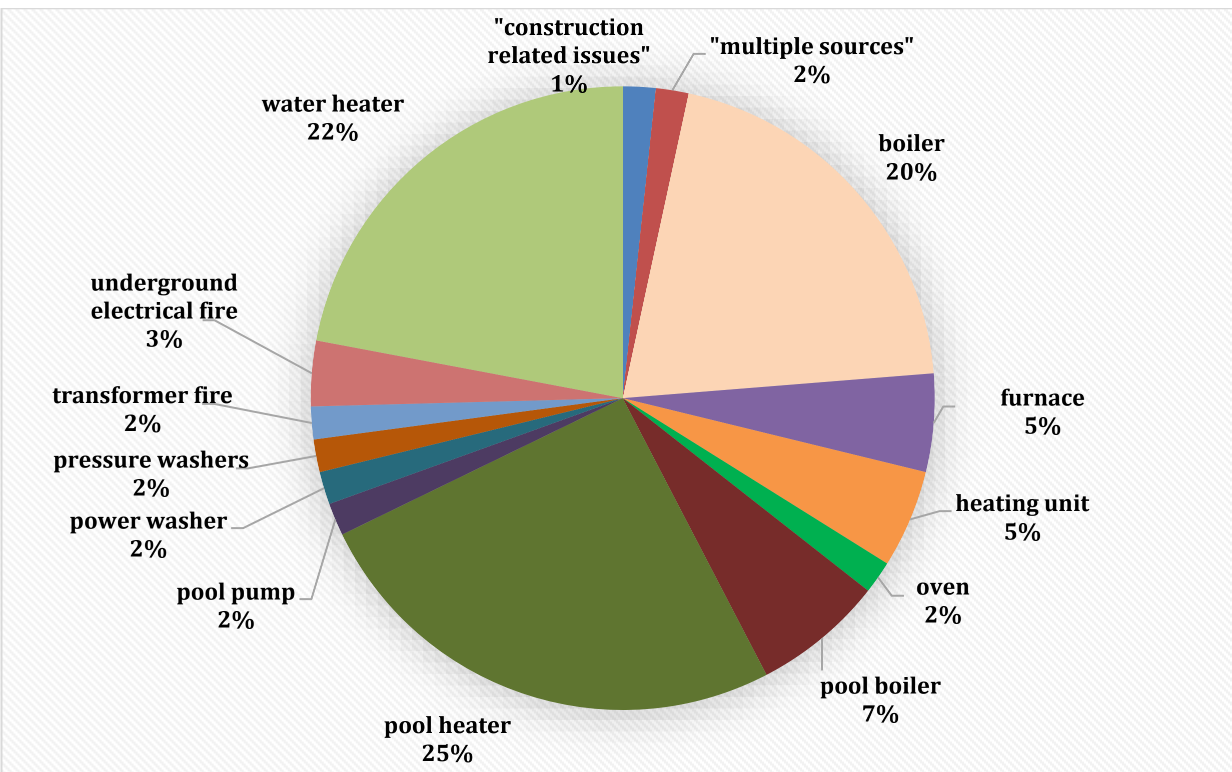

Figure 4.13 Distribution of Sources of CO in Jenkins Foundation Database

5. GAP ANALYSIS

In this section, the findings from Section 4 are compared against the CO detection requirements in NFPA 101, NFPA 5000, and the IFC for commercial occupancies.[12] The main objective of the gap analysis is to compare the available data on CO incidents and occupancy types against the current requirements for CO detection in different occupancy types[13]. A summary of CO detection requirements by occupancy type is presented below based upon a review of the current editions of NFPA 101, NFPA 5000, and the IFC:

- Per NFPA 101 and NFPA 5000, CO detection is required in **New Assembly, Education, Daycare, Healthcare, Detached One and Two-Family Dwellings, Lodging/Rooming, Hotels/Dormitories, Apartment Buildings, and Residential Board and Care** occupancies when fuel burning appliances/fireplace, fireplace alone, or attached garage are present giving consideration for specific conditions of code.
- Per NFPA 101, CO detection is only required in **Existing Healthcare and Hotels/Dormitories**.
- Per NFPA 101 and NFPA 5000, CO detection is not required in any **Mercantile, Business, Industrial, Detention/Correctional, and Ambulatory Healthcare** occupancy.
- Per IFC, CO detection is required in **New and Existing Educational, Daycare, Healthcare, Detached One and Two-Family Dwellings, Lodging/Rooming, Hotels/Dormitories, Apartment Buildings, and Residential Board and Care** occupancies when fuel burning appliances/fireplace, fireplace alone, or attached garage are present giving consideration for specific conditions of code.
- Per IFC, CO detection is not required in any **Assembly, Mercantile, Business, Industrial, Detention/Correctional, and Ambulatory Healthcare** occupancies.

5.1 CPSC

A total of 1,840 incidents (or approximately 82% of the total evaluated) occurred in "homes", i.e., apartments or single-family homes. All new residential occupancies would be required to have CO detection under both NFPA and ICC requirements. Figures 5.1 and 5.2 show that approximately 3.7% of incidents occurred where CO detectors would not be required (except for New Assembly under NFPA). These incidents include bars, restaurants, sport arenas, garages, pharmacies, water restoration facilities, parking lots, jail, churches, gyms, dinner halls, and hookah bars. The remaining 9.5% occurred in unknown or otherwise unrecorded occupancies.

[12] Requirements for CO detection in local jurisdictions may vary from those included in these model codes.
[13] Evaluation is based upon codes in effect at the start of this project. New requirements in the 2024 editions of the IFC and NFPA codes may address some of the gaps identified in this report.

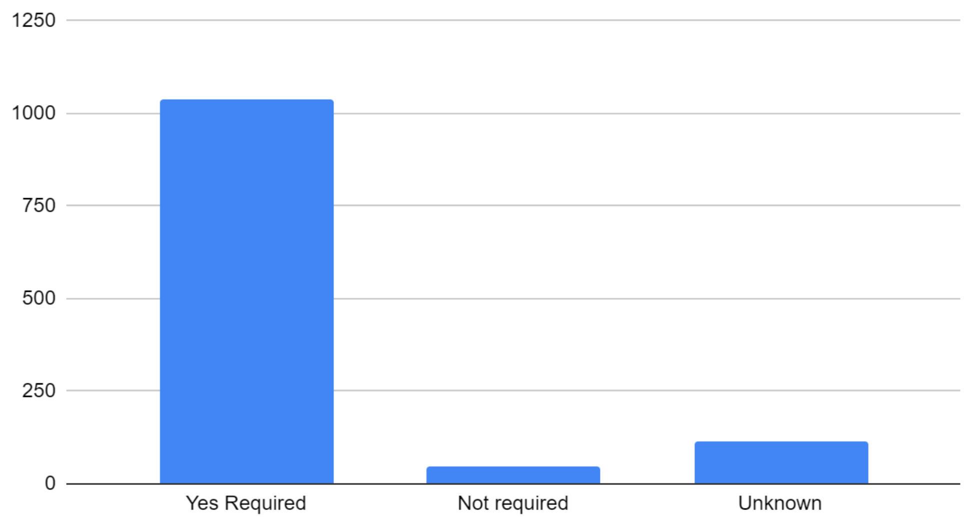

Figure 5.1 Number of Incidents with CO Alarm Requirements

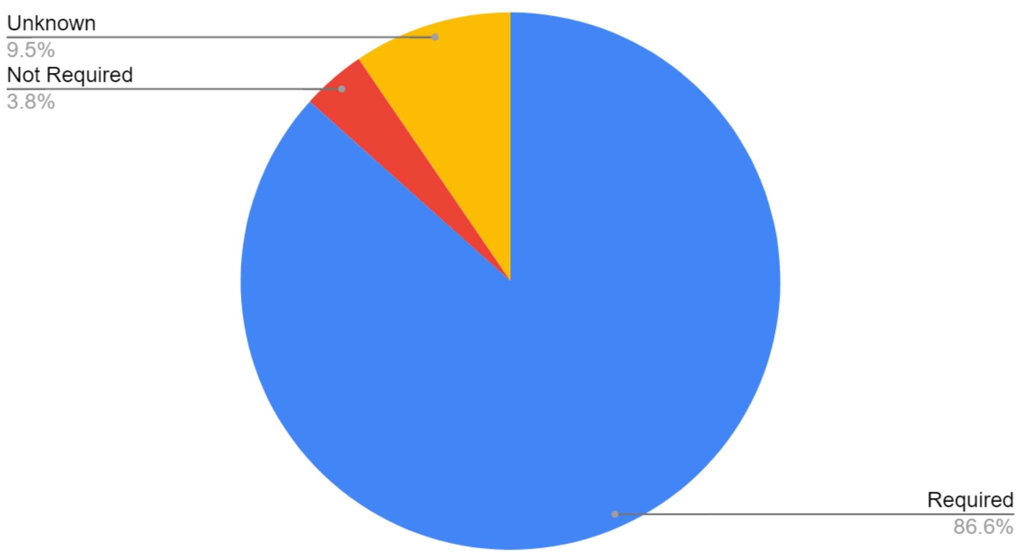

Figure 5.2 Percentage of Incidents with CO Alarm Requirements

The CPSC dataset does not comprehensively identify if CO alarms were present and where they were present to support a more detailed gap analysis. Additionally, the extent of the injury cannot be surmised from the CPSC data. Although it would be expected, the dataset does not allow one to determine if injuries that resulted when an alarm was present were less severe than injuries that resulted when an alarm was not present.

Based upon the CPSC data, it can be concluded that CO incidents occur in commercial occupancies that currently are not required to have CO detection (e.g., Assembly (Existing), Business, and Mercantile). While the percentage of these incidents is small, the limitations of the data source should be considered; it is expected that more consumer product related incidents will occur in residential occupancies where consumer products are routinely utilized. As it relates to residential occupancies, the high number of CO incidents in these occupancies justifies the need for CO detection in new and existing structures. However, it is recognized that a jurisdiction must adopt, in full, the requirements set forth in the newest editions of applicable code before requirements take effect in new or existing structures. Unfortunately, the CPSC data set is not detailed enough to determine if current requirements for CO detector placement are sufficient. Moreover, the extent of the injuries that result from CO incidents cannot be established from the dataset.

5.2 NFIRS

In the NFIRS database, the mercantile and business office occupancies included the greatest proportion of incidents with casualties. However, because injury and fatality data are rarely entered into NFIRS for non-fire CO incidents, these values are not reliable indicators of in-the-field experience. In those incidents with casualties in mercantile occupancies, business offices, and "manufacturing, processing" occupancies, it is noteworthy that CO detectors are not required in any of these occupancies. The only occupancy type where a death/injury occurred where a CO detector was required was a hotel/motel; However, it is recognized that a jurisdiction must adopt, in full, the requirements set forth in the newest editions of these code before requirements take effect in new or existing structures.

5.3 OSHA

The two most common occupancies experiencing a CO incident were Factory/Industrial (24%) and Business (16%). The limitations of the database should be taken into considerations in that more workplace related incidents are likely to occur in Business and Industrial occupancies rather than Residential occupancies. Under both the IFC and NFPA, CO detectors are not required in Factory/Industrial or Business occupancies. Based upon the OSHA data, it can be concluded that CO incidents occur in commercial occupancies and these occupancy types are not required to have CO detection. The extent of injuries that result from these CO incidents, however, cannot be surmised from the information provided in the database.

5.4 The Jenkins Foundation

The Jenkins Foundation dataset clearly shows a high number of occurrences of CO related incidents in hotels and motels. Both new and existing hotels are required to have CO detections per NFPA and ICC requirements. However, it is recognized that a jurisdiction must adopt, in full, the requirements set forth in the newest editions of these code before requirements take effect in new or existing structures.

6. SUMMARY

Eight databases and additional data sources hosting information on CO incidents were reviewed to identify insights and limitations of the data. Databases that contained information on occupancy types experiencing CO incidents were evaluated to identify trends and contributing factors, etc. Overall, it was found that databases hosting CO incident information did not provide a sufficient level of detail to fully understand the CO exposure problem in the U.S.

Of the databases that capture information on occupancy type, NFIRS is the only database that includes incidents occurring in a full range of occupancies. CPSC, because it is consumer product centric, is biased towards residential incidents, and OSHA, because it is workplace-related, is biased towards commercial occupancies. As such, neither of these two databases offer a balanced view of the issue at hand.

While all databases show that incidents are occurring in commercial occupancies, and many of these occupancies are not currently required to have detection, these limited datasets do not allow for a national-level appreciation of CO incident occurrences or frequencies. Moreover, the limited datasets do not provide a comprehensive view of injuries and deaths resulting from CO exposure correlated by occupancy type. Therefore, the frequency of injuries occurring in all types of commercial occupancies is unknown; this is a critical piece of information needed to determine if current requirements for CO detection are adequate. Moreover, there is no dataset which details the location of the victim relative to the CO source. As such, there is no way to determine, using these datasets alone, if current CO detection placement criteria, e.g., detector in space with CO source, is adequate.

References

Haynes, H., 2017. Number of U.S. Fire Departments by State. Quincy, MA: National Fire Protection Association, November.

USFA, 2022. National Fire Department Registry Quick Facts. https://apps.usfa.fema.gov/registry/summary. accessed October 6, 2022

USFA, 2015. National Fire Incident Reporting System 5.0 - Complete Reference Guide. U.S. Fire Administration National Fire Data Center. January.

APPENDIX A: SUMMARY OF CODE REQUIREMENTS FOR CO DETECTION BY OCCUPANCY TYPE

<u>NFPA 101 and 5000 (2021)</u>

New Assembly

1. CO **detection and warning** equipment required in the following locations:
    a. On the ceilings of rooms containing permanently installed fuel-burning appliances or fuel-burning fireplaces
    b. Centrally located within occupiable spaces served by the first supply air register from permanently installed fuel-burning HVAC systems
    c. Centrally located within occupiable spaces adjacent to an attached garage. Unless the garage is an open parking structure or mechanically ventilated.

New Educational

1. CO **detection** required in the following locations:
    a. On the ceilings of rooms containing permanently installed fuel-burning appliances
    b. Centrally located within occupiable spaces served by the first supply air register from permanently installed fuel-burning HVAC systems
    c. Centrally located within occupiable spaces adjacent to a communicating attached garage. Unless the garage is an open parking structure or mechanically ventilated.
    d. Centrally located within occupiable spaces adjacent to an attached garage with a separation wall constructed of gypsum wallboard. Unless the garage is an open parking structure or mechanically ventilated.

2. Where carbon monoxide detectors are installed, the alarm signal shall be automatically transmitted to an approved on-site location or to an off-premises location in accordance with NFPA 72.

New Day-Care

1. Single-station or multiple-station CO alarms or detectors shall be provided where client sleeping occurs and one or both of the following conditions exist:
    a. Fuel-fired equipment is present.
    b. An enclosed parking structure is attached to the day-care home.

New and Existing Health Care

1. Electrically supervised CO detection shall be provided in rooms with direct-vent gas fireplaces or solid fuel-burning fireplace when such fireplaces are located inside of smoke compartments containing patient sleeping areas.

Lodging or Rooming Houses

1. If either of the following conditions exists:
    a. Lodging or rooming houses with communicating attached garages. Unless the garage is an open parking structure or mechanically ventilated.
    b. Lodging or rooming houses containing fuel-burning appliances or fuel-burning fireplaces

    Then, CO alarms or detectors shall be provided:
    c. Outside of each separate sleeping area in the immediate vicinity of the sleeping rooms
    d. On every occupiable level, including basements, and excluding attics and crawl spaces

New and Existing Hotels and Dormitories

1. If either of the following conditions exists:
    a. Guest rooms or guest suites with communicating attached garages. Unless the garage is an open parking structure or mechanically ventilated
    b. Guest rooms or guest suites containing a permanently installed fuel-burning appliance or fuel-burning fireplace

    Then, CO alarms or detectors shall be provided:
    c. On every occupiable level of a guest room and guest suite and in the immediate vicinity of the sleeping rooms.

2. Where fuel-burning appliances or fuel-burning fireplaces are installed outside guest rooms or guest suites, CO detectors shall be installed:
    a. On the ceilings of rooms containing permanently installed fuel-burning appliances or fuel-burning fireplaces
    b. Centrally located within occupiable spaces served by the first supply air register from a permanently installed, fuel-burning HVAC system
    c. Centrally located within occupiable spaces adjacent to a communicating attached garage

3. Where CO detectors are installed outside of guest rooms or suites, the alarm signal shall be automatically transmitted to an approved on-site location or to an off-premises location in accordance with NFPA 72.

New Apartment Buildings

1. If either of the following conditions exists:
    a. Dwelling units with communicating attached garages. Unless the garage is an open parking structure or mechanically ventilated
    b. Dwelling units containing a permanently installed fuel-burning appliance or fuel-burning fireplace

    Then, CO alarms or detectors shall be provided:
    c. Outside of each separate dwelling unit sleeping area in the immediate vicinity of the sleeping rooms
    d. On every occupiable level of a dwelling unit

2. Where fuel-burning appliances or fuel-burning fireplaces are installed outside dwelling units, CO detectors shall be installed:
    a. On the ceilings of rooms containing permanently installed fuel-burning appliances or fuel-burning fireplaces
    b. Centrally located within occupiable spaces served by the first supply air register from a permanently installed, fuel-burning HVAC system
    c. Centrally located within occupiable spaces adjacent to a communicating attached garage.

3. Where CO detectors are installed outside of dwelling units, the alarm signal shall be automatically transmitted to an approved on-site location or to an off-premises location in accordance with NFPA 72.

New Residential Board and Care Occupancies

1. If either of the following conditions exists:
    a. Where small board and care facilities have communicating attached garages. Unless the garage is an open parking structure or mechanically ventilated.
    b. Where small board and care facilities contain fuel-burning appliances or fuel-burning fireplaces

    Then, CO alarms or detectors shall be provided:
    c. Outside each separate sleeping area in the immediate vicinity of the sleeping rooms
    d. Within sleeping rooms containing fuel-burning appliances or fuel-burning fireplaces

e. On every occupiable level, including basements and excluding attics and crawl spaces
f. Centrally located within occupiable spaces adjacent to a communicating attached garage. Unless the garage is an open parking structure or mechanically ventilated.

<u>NFPA 5000 (2021)</u>

Enclosed Parking Garages

1. An enclosed parking structure shall have a ventilation system designed to limit the concentration of carbon monoxide to not more than 35 parts per million of air when measured between 36 in. and 48 in. from the floor.

IBC 2021

New and Existing Group I-1, I-2, I-4, R, and E occupancies

CO detection is required in:

1. Dwelling units, sleeping units, and classrooms that contain a fuel-burning appliance or fuel-burning fireplace.
2. Dwelling units, sleeping units, and classrooms served by a fuel-burning, forced-air furnace.
    a. Not required if CO detection is provided in the first room or area served by each main duct leaving the furnace and alarm signals are automatically transmitted to an approved location
3. Dwelling units, sleeping units, and classrooms located in buildings with fuel-burning appliances or fuel-burning fireplaces.
    a. Not required if the room does not have communicating openings with the fuel-burning appliance or fireplace
    b. Not required within the dwelling units, sleeping units, or classrooms when a CO detector is provided in one of the following locations:
        i. An approved location between the appliance and the room
        ii. On the ceiling of the room containing the appliance
4. Dwelling units, sleeping units, and classrooms with attached private garages. Unless the garage is an open parking structure or mechanically ventilated.
    a. Not required when the room does not have communicating openings with the garage
    b. Not required when the room is located more than one story above or below the garage
    c. Not required when a CO detector is provided in an approved location between openings to the garage and the room.

When required, CO detection shall be installed in the locations specified as follows:

1. Dwelling Units (alarms or detectors)
    a. Outside each separate sleeping area in the immediate vicinity of the bedrooms.
    b. Where a fuel-burning appliance is located with a bedroom or its attached bathroom, detection shall be in the bedroom
2. Sleeping Units (alarms or detectors)
    a. In the sleeping unit; **Or**
    b. Outside each separate sleeping area in the immediate vicinity of the sleeping unit where the sleeping unit or its attached bathroom does not contain a fuel-burning appliance and is not served by a forced air furnace.
3. Group E Occupancies (detectors)
    a. In classrooms
    b. For occupancies with an occupant load over 30, CO alarm signals shall be automatically transmitted to an on-site location that is staffed by school personnel.