# 2011
# Annual Report on
# Carbon Monoxide Poisoning
# In Michigan

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# 2011 ANNUAL REPORT ON CARBON MONOXIDE POISONING IN MICHIGAN

**A Joint Report Of**

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## SUMMARY

This is the third annual report on carbon monoxide (CO) poisoning surveillance in Michigan. This report provides information about the 934 individuals who were unintentionally poisoned by carbon monoxide in Michigan in 2011, including 22 individuals who died from carbon monoxide exposure. It includes a special focus on work-related carbon monoxide poisonings. It is based on data collected as a result of regulations promulgated September 18, 2007 by the Michigan Department of Community Health (MDCH) to address the health hazards of exposure to carbon monoxide. The State's Public Health Code requires health care facilities and health care professionals to report unintentional carbon monoxide poisoning. MDCH regulations also require laboratories to report carboxyhemoglobin test results. Michigan State University's Department of Medicine, Occupational and Environmental Medicine Division (MSU) administers this public health surveillance system for the State.

## BACKGROUND

One of the leading causes of unintentional poisoning deaths in the United States is carbon monoxide poisoning.[1] CO is an odorless and colorless gas produced by all forms of combustion including running gasoline, diesel, natural gas or propane powered equipment, coal or oil fired boilers, smoking of tobacco products and fires. The Environmental Protection Agency (EPA) allowable environmental exposure to CO in outdoor ambient air is 9 ppm for an 8 hour average.[2] Workplace standards set by the Michigan Occupational Safety and Health Administration (MIOSHA) require the CO level be kept below 35 ppm averaged over an eight hour day and a 200 ppm ceiling that should never be exceeded in general industry; for the construction industry, the limit is 50 ppm averaged over an 8 hour work day without a standard for a ceiling level.[3, 4]

During combustion, incomplete oxygenation of the carbon atom in the substance being burned produces CO. When inhaled, CO binds to hemoglobin in the blood as well as other proteins in the body such as myoglobin. This binding reduces the delivery of oxygen to organs such as the brain and heart and all other body tissues. When hemoglobin combines with CO, it forms a bright red compound called carboxyhemoglobin (COHb), which can be measured in the blood. Non-smoking individuals have low levels of COHb in their blood, values generally less than 1.0%, as a consequence of the normal breakdown of red blood cells. Cigarette smokers average 4.0% COHb, with heavier smokers having higher values. Work for eight hours at the allowable MIOSHA standard for general industry time weighted average (TWA) of 35 ppm will cause a 5.4% COHb blood level and 7.4% COHb blood level for the construction TWA of 50 ppm.[5] Alarms on home detectors for carbon monoxide generally do not sound until levels of carbon monoxide reach levels that would cause COHb levels of 5-7%.[5] Exposures to different sources of carbon monoxide are additive (e.g., the average cigarette smoker working at the MIOSHA limit would be expected to have 9.4% COHb level).[5] COHb has a half-life in the blood of 4 to 6 hours. With administration of oxygen the half life is reduced to approximately an hour or to less than a half hour when treated with hyperbaric oxygen.[5] In individuals with atherosclerosis, levels as low as 3-4% COHb can increase the frequency and severity of angina or claudication, at a 6% level cardiac arrhythmias may be induced, and at a 10% level a myocardial infarction may be precipitated.[5] In individuals without atherosclerosis, levels below 30% can cause headaches, nausea and weakness. Above 30% there will be decreased mental alertness and weakness, and, with increasing levels, coma and death.[5]

The Centers for Disease Control and Prevention (CDC) recently summarized data from the National Poison Data System (NPDS).[6] Findings included that most CO poisonings occurred at home, most often involved females and adults aged 18-44, and most frequently occurred between November and February and among persons living in the Midwestern and Northeastern states. Mandated reporting of diagnostic information on carbon monoxide poisoning allows MDCH and its local public health partners to identify and initiate follow-up actions to prevent further morbidity and mortality.

## METHODS

The major data sources for this report were the Michigan Poison Control Center (PCC), Michigan hospitals, and death certificates for the period 1/1/2011 to 12/31/2011. The Michigan Poison Control Center reported all calls where the substance was carbon monoxide, the individual had one or more "clinical effects" (symptoms), and the reason for exposure was "unintentional". Hospitals were required to report patients who had ICD-9 discharge codes of 986, E868.3, E868.8, E868.9, and E982.1. Death certificates were obtained where the underlying cause of death was ICD-10 code T58 ("Toxic effects of carbon monoxide…accidental (unintentional)…").

Hospital medical records and PCC case reports were reviewed to determine if they met the surveillance case definition. A confirmed case of carbon monoxide poisoning was defined as an individual who was treated by a health care provider for symptoms related to unintentional carbon monoxide (CO) exposure. If a person called the poison center about CO and/or CO-related symptoms but did not seek medical care they were excluded. Also excluded were cases where the physician ruled out CO poisoning in the medical record notes, even though CO poisoning may have been suspected initially and thus assigned a CO ICD code in the discharge diagnosis string. It should be noted that individuals were included as cases regardless of laboratory confirmation based on the carboxyhemoglobin result. In many cases the COHb result was not available or the blood specimen from the patient was collected too long after exposure to still be elevated. All death certificate cases with code T58 as the underlying cause of death were considered confirmed cases.

Confirmed cases were abstracted into a uniform data system that included, for each individual case report, demographic information (age, gender and race), admission date, discharge date, exposure date, COHb test result, cigarette smoking status, report source(s), source of CO exposure (e.g. furnace, forklift), treatment (including hyperbaric chamber), and, if occupationally exposed, name and address of employer and assigned industry ("NAICS") code.

For individuals who had multiple reports for the same exposure, records were combined and considered as one case. This was done for individuals who had multiple reports from different reporting sources, (e.g. from HDC, PCC, DC), as well as multiple entries of the same report source (e.g. transfers between hospitals for treatment with hyperbaric oxygen, and multiple hospital visits due to the same exposure). When names were not provided on PCC reports, records were matched by exposure date, hospital where they were treated, carboxyhemoglobin levels, description of exposure, and age (also birth date if available). A minimum of three matching variables were required in order to match the records. However if one of the other variables had conflicting data, they were left as separate records.

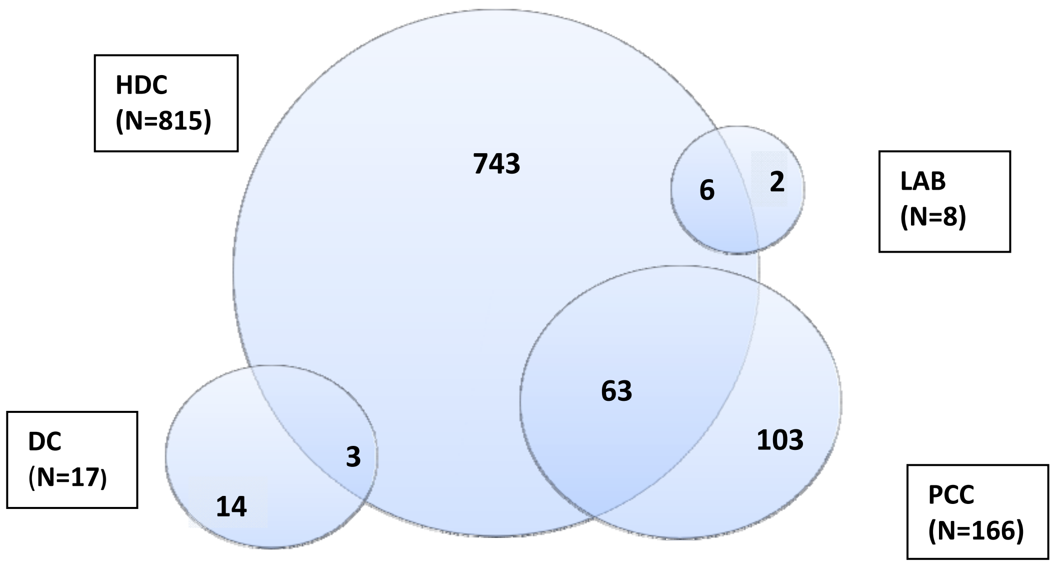
Frequencies and rates of CO poisoning were generated from these data. Denominators used to calculate rates were from the U.S. Census Bureau.[7, 8]

Where appropriate, employers of occupationally exposed cases were referred to MIOSHA for follow-up to determine if there was on-going risk of CO exposure. Additional analysis is provided for occupationally exposed cases and results of MIOSHA referrals.

## RESULTS

A total of 1,074 reports of unintentional carbon monoxide poisoning were received on 934 individuals. One hundred and sixty-three of these individuals were poisoned at work.

**Figure 1 Overlap of Reporting Sources for 934 CO Poisoning Cases in Michigan, 2011**




N's represent the total number of individuals reported by source.
Reporting Source: HDC = Hospital Discharge, DC = Death Certificate, PCC = Poison Control Center, LAB = Laboratory of one of Michigan's hospitals

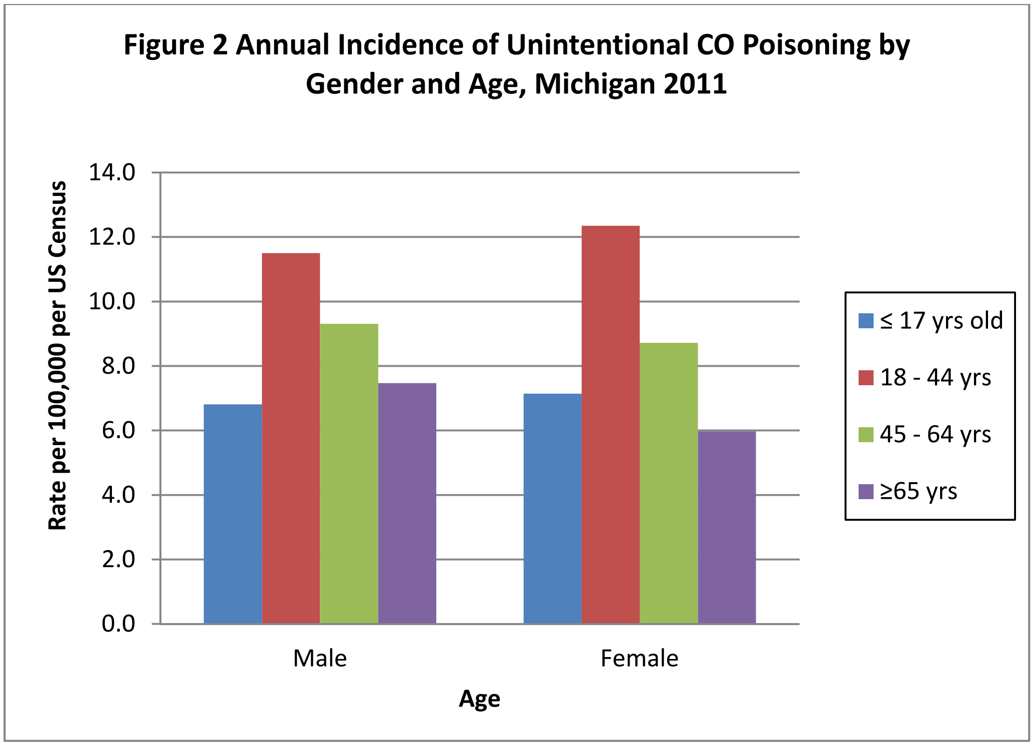
Eight hundred and fifteen unintentional carbon monoxide poisoning reports on 743 individuals were received only from Michigan's 134 hospitals. There were another 103 individuals reported by the PCC only. A smaller number of individuals were identified from death certificates. The overlap of reporting from all of these sources is diagramed in Figure 1.

***Death***

There were 22 (2.4%) deaths from unintentional carbon monoxide poisoning, none of which were work-related. Three deaths were identified both by a death certificate and a hospital discharge report; fourteen deaths were reported only by death certificates; the other five were identified by a hospital discharge report only. Seven deaths were fire related and 15 were non-fire related. Source of CO was unknown for 2 of the 15 non-fire deaths; six were from a generator, three were from a vehicle, two were from a propane-fueled device, one was from a small engine and one was from a stove.

***Gender and Age***

Gender was known for all individuals, 459 (49.1%) were male, 475 (50.9%) were female (Table 1, Figure 2). Of the 909 individuals where age was known, 160 (17.6%) were 17 years old or younger, 406 (44.7%) were 18 – 44, 251 (27.6%) were 45 – 64, and 92 (10.1%) were 65 or older. Females age 18 – 44 (12.35/100,000) and males age 18 – 44 (11.50/100,000) had the highest incidence rates.




| Table 1 Annual Incidence of Unintentional CO Poisoning by Gender and Age, Michigan 2011 | | | | | | | |
|---|---|---|---|---|---|---|---|
| | Gender | | | | | | |
| Age | Male | MI Male Population | Male Rate/100000 | Female | MI Female Population | Female Rate/100,000 | Total |
| Unknown Age | 11 | | | 14 | | | 25 |
| ≤ 17 yrs old | 80 | 1,175,113 | 6.80 | 80 | 1,120,699 | 7.13 | 160 |
| 18 - 44 yrs | 196 | 1,704,445 | 11.49 | 210 | 1,700,611 | 12.34 | 406 |
| 45 - 64 yrs | 127 | 1,364,018 | 9.31 | 124 | 1,422,146 | 8.71 | 251 |
| ≥65 yrs | 45 | 602,369 | 7.47 | 47 | 786,786 | 5.97 | 92 |
| Total | 459 | | | 475 | | | 934 |

***Race***

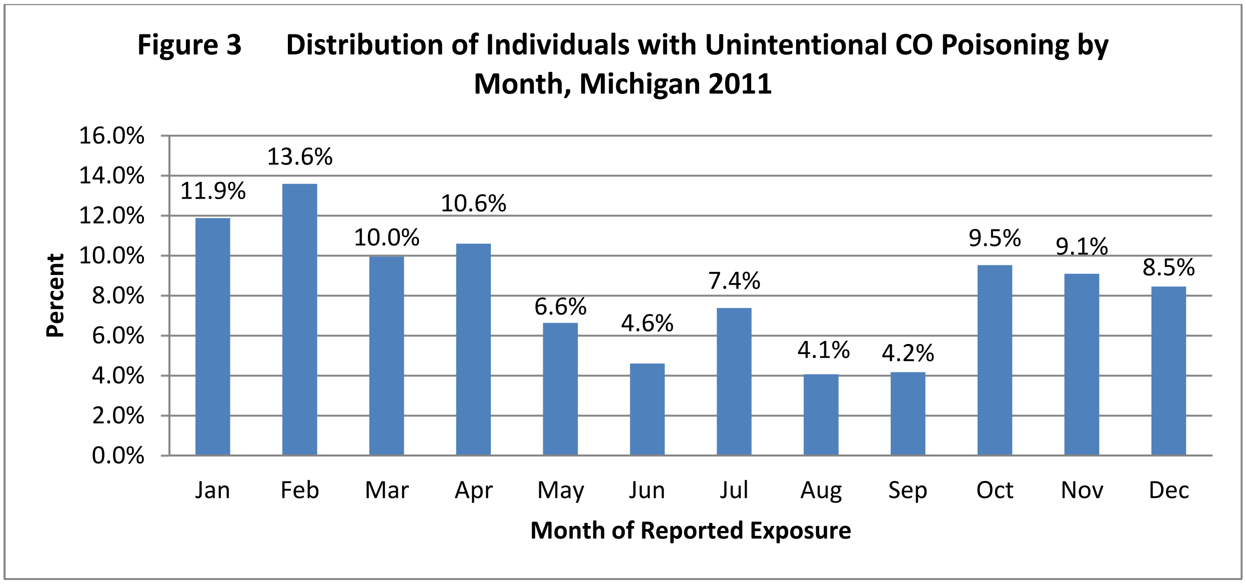
Race was known for 520 (55.7%) individuals (Table 2). 362 (69.6%) were Caucasian, 121 (23.3%) were African American, 33 (6.3%) were Hispanic, and two each (0.4%) were Asian and Native American. African Americans had the highest incidence rate of carbon monoxide poisoning (8.53/100,000).

| Table 2 Distribution and Incidence Rates of Unintentional CO Poisoning by Race, Michigan 2011 | | | |
|---|---|---|---|
| Race | Michigan Population | # Cases | Rate/100,000 |
| WHITE | 7,925,094 | 362 | 4.56 |
| AFRICAN AMERICAN | 1,417,079 | 121 | 8.53 |
| ASIAN | 251,121 | 2 | 0.79 |
| HISPANIC | 447,917 | 33 | 7.36 |
| NATIVE AMERICAN | 68,870 | 2 | 2.9 |

***Month of Poisoning***

Month of exposure was known for all (934) individuals (Table 3 and Figure 3). The most common month for exposure occurred in February, 127 (13.6%), and in the other winter months. The lowest numbers were in the late spring and summer and early fall months, August being the lowest with 38 individuals (4.1%).

| Table 3 Unintentional CO Poisoning by Month, Michigan 2011 | | |
|---|---|---|
| Month | # Individuals | % |
| January | 111 | 11.9 |
| February | 127 | 13.6 |
| March | 93 | 10.0 |
| April | 99 | 10.6 |
| May | 62 | 6.6 |
| June | 43 | 4.6 |
| July | 69 | 7.4 |
| August | 38 | 4.1 |
| September | 39 | 4.2 |
| October | 89 | 9.5 |
| November | 85 | 9.1 |
| December | 79 | 8.5 |
| Total | 934 | 100.0 |



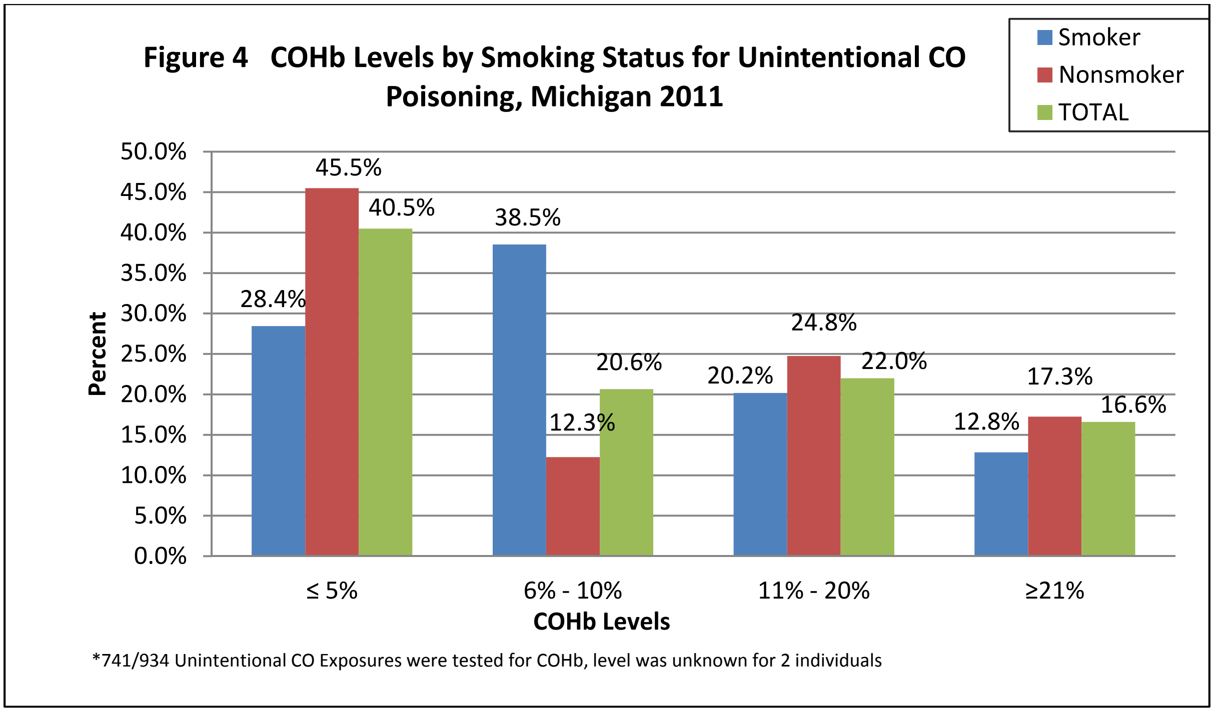

***Carboxyhemoglobin Testing***

Carboxyhemoglobin level (COHb) was known for 739 (79.1%) of the 934 individuals. The average COHb level for all individuals tested was 10.9%. The range of COHb was 0.0% to 72.0%. Two hundred and eighty-six (38.7%) individuals had a COHb level greater than 10% and 123 (16.6%) individuals had a COHb level equal or greater than 21.0%. Smoking status was known for 618 (83.4%) of the 741 individuals tested for COHb, and 741 (79.3%) of all 934 individuals. The distribution of COHb levels by smoking status is shown in Table 4 and Figure 4.

**Table 4 COHb Levels by Smoking Status for Unintentional CO Poisoning, Michigan 2011**

| | Smoking Status | | | | | | |
|---|---|---|---|---|---|---|---|
| COHb Level | Smoker | % | Nonsmoker | % | Unknown | TOTAL | % |
| Unknown level | 0 | -- | 1 | 0.3 | 1 | 2 | 0.3 |
| ≤ 5% | 62 | 28.4 | 182 | 45.5 | 56 | 300 | 40.5 |
| 6% - 10% | 84 | 38.5 | 49 | 12.3 | 20 | 153 | 20.6 |
| 11% - 20% | 44 | 20.2 | 99 | 24.8 | 20 | 163 | 22.0 |
| ≥21% | 28 | 12.8 | 69 | 17.3 | 26 | 123 | 16.6 |
| Total | 218 | 100.0 | 400 | 100.0 | 123 | 741 | 100.0 |
| Average COHb | 10.6 | | 10.7 | | | 10.9 | |
| Median COHb | 8.0 | | 7.0 | | | 7.6 | |

*741/934 unintentional exposure (79.3%) individuals were tested for COHb; smoking status was known for 618/741 individuals




### *Hyperbaric Treatment*

Sixty (6.5%) individuals were treated with hyperbaric chamber oxygen. Fifty-seven patients treated with oxygen in a hyperbaric chamber had their COHb measured. The average COHb level recorded for these individuals was 25.7%.

Fifty-seven (95.0%) of the hyperbaric treatments were non-occupational exposures; 15 were from generator exposures, 11 were from a fire, 7 were from a vehicle exposure, 6 were from a furnace or water heater exposure, and 12 were from assorted other sources including a pressure washer, a gas operated pump, portable cement cutter, a gas fireplace, a space heater, a stove, and a portable grill. For 6 individuals the source of non-occupational exposure was unknown. There were three occupational exposures that were treated with hyperbaric oxygen; a snow plow worker exposed to the truck's exhaust fumes (COHb – 30.0%), a tree service worker sitting in the back of a truck with a gas-powered air compressor running (COHb – 17.9%), and a warehouse security guard at a car lot sitting in a running vehicle (COHb – 27.0%).

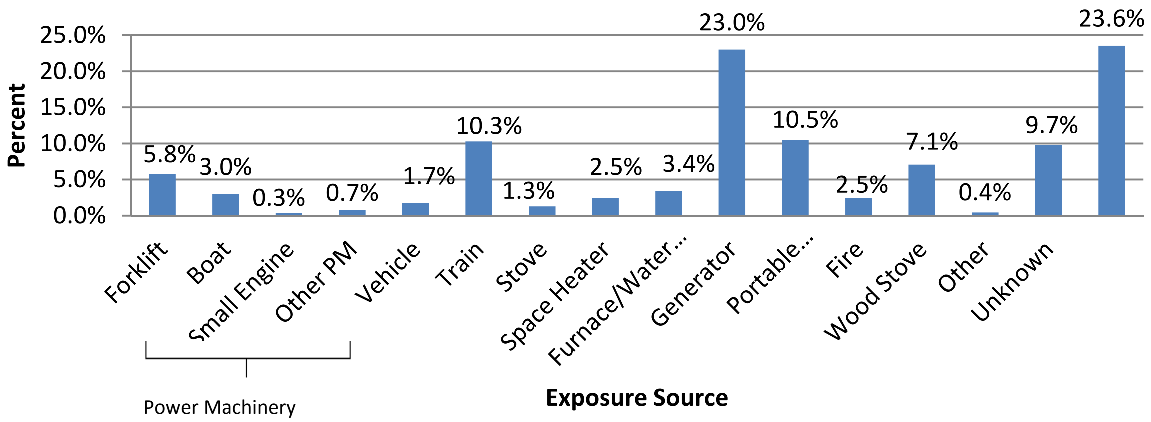
### *Source of Exposure*

Exposure source was known for 714 (76.4%) of the 934 individuals (Table 5, Figure 5). The most common exposure source was furnace/water heater (23.0%), followed by exposure from a generator (10.5%) and then vehicle (10.3%). There were 220 (23.6%) individuals with CO exposure where the source of exposure was unknown.

| Table 5 Unintentional CO Poisoning by Source of Exposure, Michigan 2011 | | |
|---|---|---|
| Source | # | % |
| Power Machinery (PM):* | 54 | 5.8 |
| Forklift | 28 | 3.0 |
| Boat | 3 | 0.3 |
| Small Engine | 7 | 0.7 |
| Other PM | 16 | 1.7 |
| Vehicle | 96 | 10.3 |
| Train | 12 | 1.3 |
| Stove | 23 | 2.5 |
| Space Heater | 32 | 3.4 |
| Furnace/Water Heater | 215 | 23.0 |
| Generator | 98 | 10.5 |
| Portable Grill/Heater | 23 | 2.5 |
| Fire | 66 | 7.1 |
| Wood Stove | 4 | 0.4 |
| Other | 91 | 9.7 |
| Unknown | 220 | 23.6 |
| Total | 934 | 100.0 |

* Indicates that the number is not included in the totals at the bottom of the table. They are just there to show the totals of the power machinery listed with the right indent.

**Figure 5 Unintentional CO Posioning by Source of Expsoure, Michigan 2011**




### *Fire*

Fire was the source of carbon monoxide exposure for 66 (7.1%) individuals. There were 12 (18.2%) work-related fire exposures and the location of the exposure was known for 11 of the occupational fire exposures; five individuals exposed to carbon monoxide were fire fighters, three individuals worked in a steel factory, one was a police officer, one was a store owner and one was a home daycare provider. Seven (10.6%) fire related exposures resulted in death; none of these deaths were work-related.

***Hospitalizations***

Of the 934 individuals with reported CO exposure, 111 (11.9%) were hospitalized overnight. The most common source of CO requiring overnight hospitalization included twenty-nine (26.1%) from a fire exposure, eighteen (16.2%) from power machinery, seventeen (15.3%) from a generator, and eight (7.2%) from a space heater. For the 56 individuals where length of stay was known, both the average and median stay was 2 days. The longest hospitalization was for 30 days following a fire related exposure. Twenty-eight (50.0%) stayed two days or less, eighteen (32.1%) stayed 3 to 7 days, five (8.9%) stayed 8 to 14 days, and five (8.9%) stayed more than two weeks.

Twelve (10.8%) of the 111 hospitalizations were due to occupational CO exposure. Of the twelve occupational exposure-related hospitalizations, four (33.3%) were from a space heater, three (25.0%) were from vehicle exhaust, two (16.7%) were from a chain saw, one (8.3%) was from a forklift, one (8.3%) was from a fire, and there was one with unknown source of CO.

## ANALYSIS OF OCCUPATIONAL EXPOSURES

Exposure location was known for 863 individuals in 2011 and 163 (18.9%) were identified as work related. Gender was known for all of the work-related cases; 102 (62.6%) male, 61 (37.4%) female (Table 6). One hundred and four individuals (63.8%) were between the age of 18 and 44, and 50 (30.7%) were between age 45 to 63.

**Table 6 Percent by Gender and Age of Unintentional Occupational CO Poisoning, Michigan 2011**

| | Gender | | | | | |
|---|---|---|---|---|---|---|
| Age | MALE | % | FEMALE | % | Total | % |
| Unknown Age | 4 | 3.9 | 2 | 3.3 | 6 | 3.7 |
| ≤ 17 yrs old | 2 | 2.0 | 1 | 1.6 | 3 | 1.8 |
| 18 - 44 yrs | 67 | 65.7 | 37 | 60.7 | 104 | 63.8 |
| 45 - 63 yrs | 29 | 28.4 | 21 | 34.4 | 50 | 30.7 |
| Total | 102 | 100.0 | 61 | 100.0 | 163 | 100.0 |

Race was known for 87 occupationally exposed individuals; sixty-six (75.9%) were Caucasian, eleven (12.6%) were African American, seven (8.0%) were Hispanic, two (2.3%) were Asian and one (1.2%) was Native American/Alaskan.

Carboxyhemoglobin tests were reported for 122 individuals with occupational exposure. The average COHb level for occupationally exposed individuals tested was 10.1%. Smoking status was known for 100 (81.9%) of the 122 occupationally exposed individuals with COHb levels. The distribution of COHb levels by smoking status for occupationally exposed individuals is shown in Table 7.

**Table 7 Unintentional Occupational CO Poisoning by Reported COHb Levels and Smoking Status, Michigan 2011**

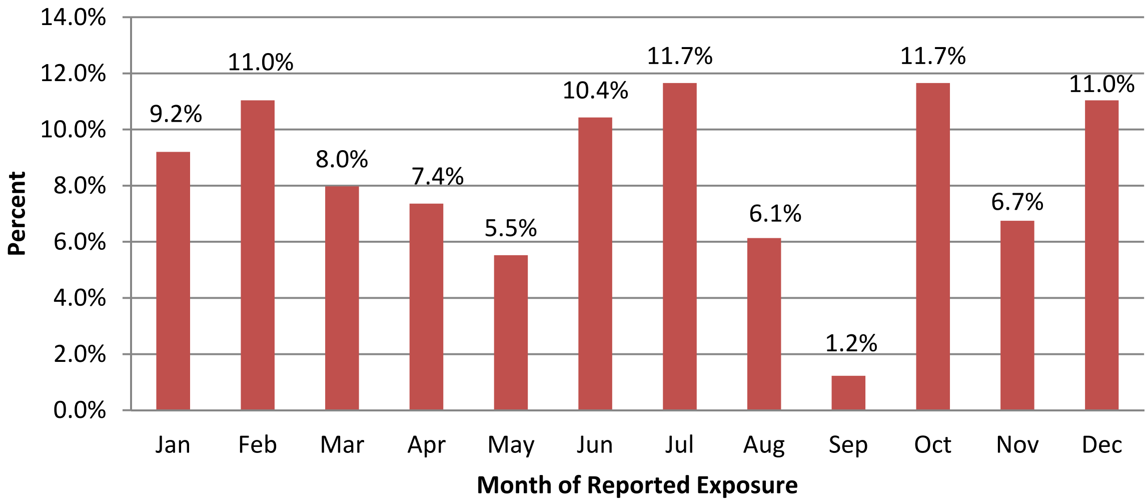
| | Smoking Status | | | |
|---|---|---|---|---|
| COHb % | Smoker | Nonsmoker | Unknown | Total |
| Unknown level | 0 | 0 | 1 | 1 |
| ≤ 5% | 12 | 30 | 11 | 53 |
| 6-10% | 9 | 4 | 5 | 18 |
| 11-20% | 8 | 24 | 4 | 36 |
| ≥ 21% | 0 | 13 | 1 | 14 |
| Total | 29 | 71 | 22 | 122 |

Of the 163 individuals occupationally exposed, month of exposure is shown in Table 8 and Figure 6. The largest percentage of reported exposure occurred in July and October (11.7%), the lowest amount of exposures were in spring months.

**Table 8 Unintentional Occupational CO Poisoning by Month, Michigan 2011**

| Month | # Individuals | % |
|---|---|---|
| January | 15 | 9.2 |
| February | 18 | 11.0 |
| March | 13 | 8.0 |
| April | 12 | 7.4 |
| May | 9 | 5.5 |
| June | 17 | 10.4 |
| July | 19 | 11.7 |
| August | 10 | 6.1 |
| September | 2 | 1.2 |
| October | 19 | 11.7 |
| November | 11 | 6.7 |
| December | 18 | 11.0 |
| Total | 163 | 100.0 |

**Figure 6 Distribution of Individuals with Unintentional Occupational CO Poisoning by Month, Michigan 2011**




NIOSH's National Occupational Research Agenda defines ten industry sector groupings based on the industry classifications of the North American Industry Classification System (NAICS). Sufficient information was available for 137 of the 163 work related exposures to assign NAICS codes and thus group into NORA sector groupings (Table 9). The largest number of exposures occurred in the Manufacturing and Services sectors.

**Table 9 NORA Sector Codes, Occupational CO Poisoning, Michigan 2011**

| Industry | NAICS Code | # Cases | % |
|---|---|---|---|
| Agriculture, Forestry, Fishing and Hunting | 11 | 16 | 9.8 |
| Construction | 23 | 7 | 4.3 |
| Health Care and Social Assistance | 62, 541940 | 19 | 11.7 |
| Manufacturing | 31-33 | 27 | 16.6 |
| Mining (Except Oil and Gas Extraction) | 21 | 0 | -- |
| Oil and Gas Extraction | 211, 213 | 0 | -- |
| Public Safety | 922 | 1 | 0.6 |
| Services (except Public Safety) | 51-56, 61, 71, 72, 81, 92 | 27 | 16.6 |
| Transportation, Warehousing and Utilities | 22, 48, 49 | 15 | 9.2 |
| Wholesale and Retail Trade | 42, 44, 45 | 25 | 15.3 |
| Unknown | | 26 | 16.0 |
| Total | | 163 | 100.0 |

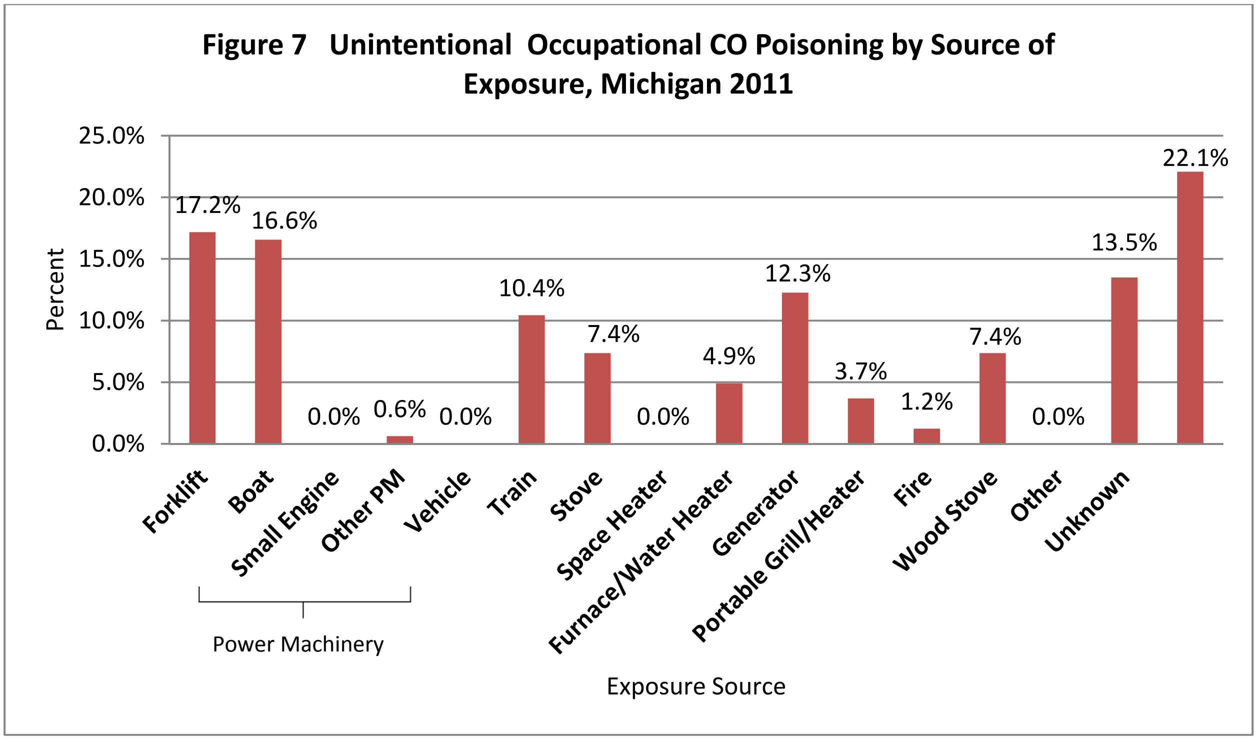
Of the 163 individuals occupationally exposed, source of exposure was known for 127 (77.9%) individuals. The most common exposure source for work-related exposure was power machinery powered by combustion engines (17.2%). Forklifts were the most frequent exposure identified as occupational power machinery. There were 36 individuals with work exposures where the source of exposure was unknown (Table 10, Figure 7).

In fourteen events multiple employees (N=53) were affected by the same source at the same facility. Of the 53, twenty-two were exposed from using or working near fork lifts at a fruit processing factory, a farm and an unspecified factory. Six employees working in a barn were exposed due to a space heater. Four employees were exposed from an air conditioner. A furnace was the source of exposure in two employees working in a hospital and two employees working in a metal stamping factory. Two employees of a steel factory were exposed after hydraulic fluid caught fire. Two employees were exposed while cleaning a plugged chimney. Two employees were exposed from vehicle's exhaust while working in a garage. Two employees were exposed from an unspecified leak. The source of exposure was unknown for nine employees, four of whom worked in a factory, three worked in a stamping plant, and two worked in a veterinary hospital.

**Table 10 Unintentional Occupational CO Poisoning by Source of Exposure, Michigan 2011**

| Source | # | % |
|---|---|---|
| Power Machinery (PM):* | 28 | 17.2 |
| Forklift | 27 | 16.6 |
| Boat | 0 | – |
| Small Engine | 1 | 0.6 |
| Other PM | 0 | – |
| Vehicle | 17 | 10.4 |
| Train | 12 | 7.4 |
| Stove | 0 | – |
| Space Heater | 8 | 4.9 |
| Furnace/Water Heater | 20 | 12.3 |
| Generator | 6 | 3.7 |
| Portable Grill/Heater | 2 | 1.2 |
| Fire | 12 | 7.4 |
| Wood Stove | 0 | – |
| Other | 22 | 13.5 |
| Unknown | 36 | 22.1 |
| Total | 163 | 100.0 |

* Indicates that the number is not included in the totals at the bottom of the table. They are just there to show the totals of the power machinery listed with the right indent.



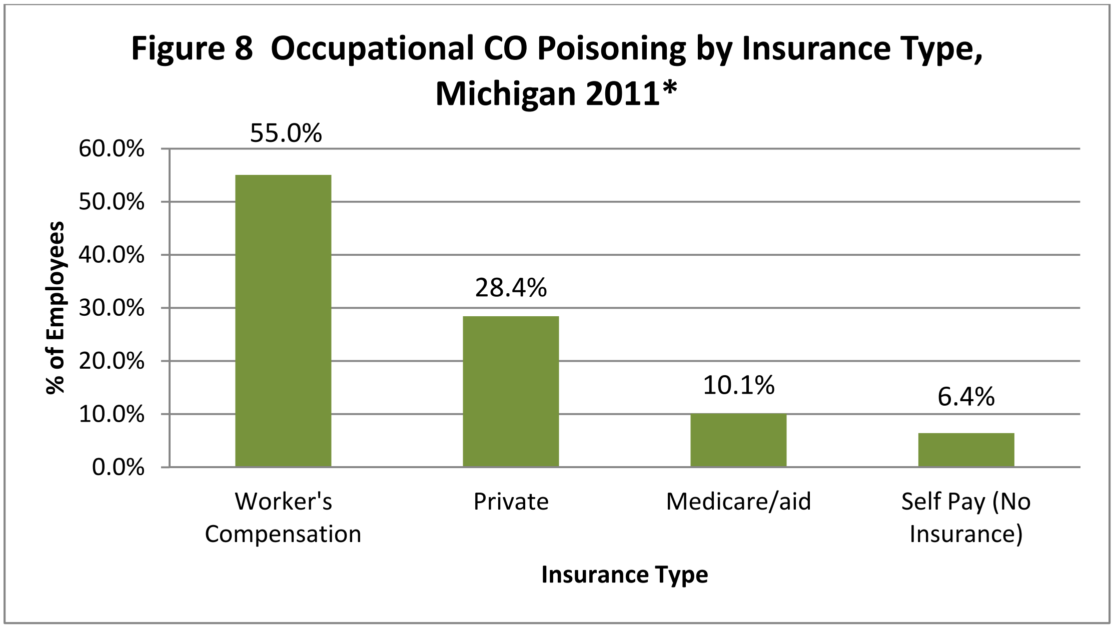

The two highest carboxyhemoglobin levels reported from occupational exposure were in an employee using a power washer (37.0%), and an employee working near a generator (35.0%).

Of the 163 individuals occupationally exposed, insurance type was known for 109 employees (66.9%). For 60 (55.0%) of these 109 individuals, Worker's Compensation was the expected payer, 31 (28.4%) had private insurance, 11 (10.1%) had Medicare or Medicaid, and 7 (6.4%) did not have insurance (Table 11, Figure 8).

**Table 11 Occupational CO Poisoning by Insurance Type, Michigan 2011***

| Insurance type | # | % |
|---|---|---|
| Worker's Compensation | 60 | 55.0 |
| Private | 31 | 28.4 |
| Medicare/aid | 11 | 10.1 |
| Self Pay (No Insurance) | 7 | 6.4 |
| TOTAL | 109 | 100.0 |

*109/163 (66.9%) occupational CO poisonings had known insurance type.




*There were 109 occupational CO poisoning cases with known insurance type.

## WORK SITE INVESTIGATIONS, 2011

In this third year of the carbon monoxide surveillance system, five cases of workplace CO poisoning were investigated by MIOSHA. One of the workplace investigations involved an employee whose carboxyhemoglobin level was 20.0%, and who was fixing a piece of steel equipment with a spool of stainless steel and a MIG welder in a repair shop. The employee was exposed to the fumes from the welding and needed medical attention. Inspection of this work site resulted in no citations.

A second incident involved 12 employees of a cherry plant, whose carboxyhemoglobin levels ranged from 13.1% to 24.5%, who were exposed to fumes from a fork lift being operated in an enclosed factory. The company repaired the forklift and installed CO detectors at the work site. No citations were issued for the company.

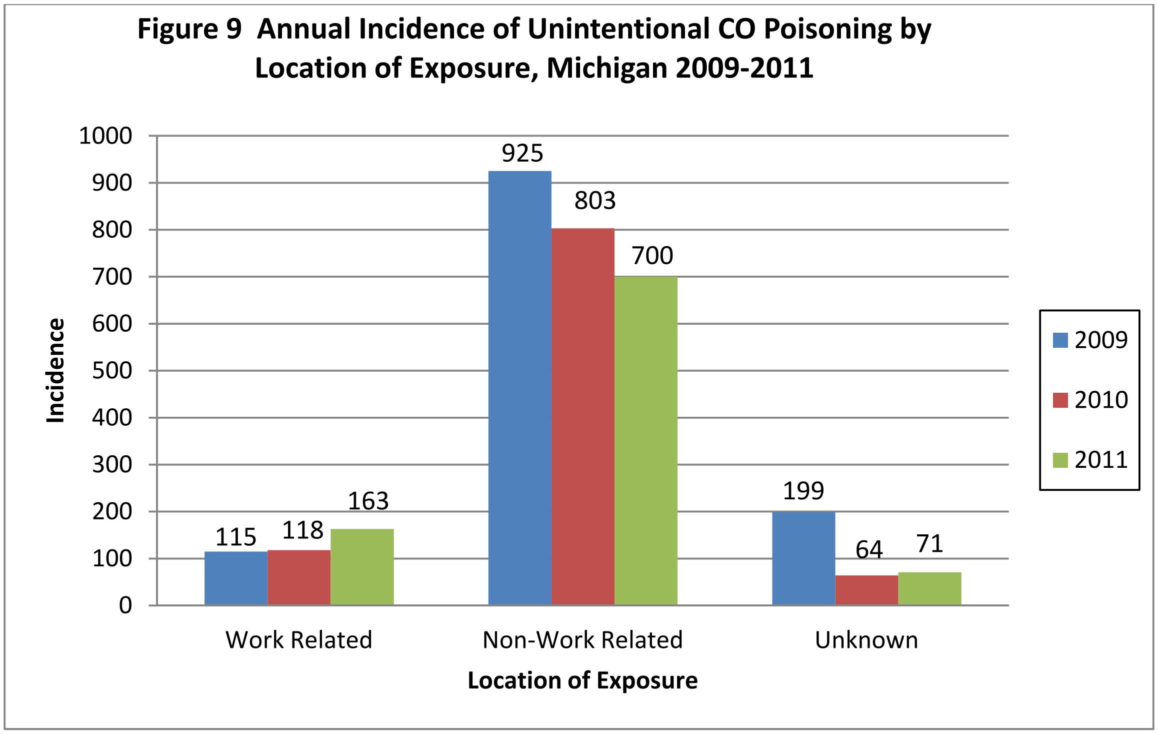
A third incident occurred when an employee of a meat company, whose carboxyhemoglobin level was 37.5%, was exposed to the fumes from a gasoline-operated power washer used to clean meat cutting equipment and facilities. The employee was cleaning one of the rooms the company uses for about half of an hour, when he started feeling dizzy and lightheaded. During the MIOSHA inspection, the CO exposure calculation resulted in a ceiling concentration of 295 ppm and 8-hour, time-weighted average (TWA) concentration of 111 ppm. These CO exposure concentrations were in excess of the ceiling limit of 200 ppm and the 8-hour TWA permissible exposure limit (PEL) of 35 ppm. Five citations were issued to the company, one of which was directly related to the unacceptable CO levels at the work site (CO exceeded MIOSHA standards).

A fourth incident occurred when an employee, whose carboxyhemoglobin level was 11.5%, was operating a forklift in a cold storage warehouse. CO exposure for this employee was calculated to exceed the MIOSHA standards of 200 ppm for a five minute time-weighted average. The employer received 11 citations, two of which were directly related to toxic concentrations of CO and lack of ventilation in the warehouse.

In the fifth incident, an employee, whose carboxyhemoglobin level was 10.8%, was exposed to CO while operating a powered industrial truck with a lift to clean in a warehouse. The company properly documented the incident and stated that the employee did not open the warehouse doors as instructed to ventilate the area prior to using the hi-lo. The inspection revealed that CO emissions from the company's two hi-los were above the recommended 0.5% CO concentration and the company was asked to address these emissions. Further, the company installed a ventilation system in the warehouse that could be operated automatically or manually. No citations were issued for the company.

## DISCUSSION

Carbon monoxide (CO) is one of the leading causes of unintentional poisoning deaths in the United States and 68,316 CO exposures were reported to poison centers in the U.S. during 2000—2009.[6] In Michigan, for the year 2011, reports were received on 934 individuals with confirmed unintentional CO poisoning. Twenty-two (2.4%) deaths were reported: seven (31.8%) were fire related and fifteen were non-fire related (68.9%). These numbers have decreased from the 985 individuals poisoned and 25 deaths in 2010 (Figure 9). However, there were 45 more occupational poisonings, a 38% increase from 2010 (Figure 9). There was a decrease in the number of cases from 2009, which is at least partly attributed to the matching performed for the first time in the 2010. Beginning in 2010, matching was performed for cases from the Poison Control Center where no name was provided with cases from other reporting sources. This matching was done using at least three variables such as date of incident, hospital and age. If these variables matched than the report was considered a duplicate, and deleted. Better matching of case reports from multiple sources also resulted in more complete data on cases; thus in 2009 there were 275 records for which the location of exposure could not be determined whereas in the 2010 data, there were only 64 unknowns, and in the 2011 data there were only 71 unknowns.




The most common exposure source was a furnace or water heater in 215 individuals (23.0%) with only 20 individuals being exposed at work (Table 5 and Figure 5 – source of exposure of all CO poisonings, Table 10 and Figure 7 – occupational sources of exposure). The known source at occupational settings was most commonly power machinery powered by combustion engines (28, 17.2%).

Most unintentional CO poisoning exposures occurred in February (127, 13.6%).

The largest number of individuals, 815 (87.3%), were reported by hospitals. In 2011, Michigan hospitals and health care facilities were required to report 2011 information on a quarterly rather than annual basis, thus improving timely response to identify sources of CO poisoning.

Carboxyhemoglobin (COHb) testing was reported for 741 individuals with actual COHb levels reported for 739. COHb reports are indicators of exposure; however levels reported cannot be considered an accurate measure of the true extent of the exposure for several reasons. Results from hospital records are most likely lower than the level an individual would have at the time of exposure due to time elapsed between exposure and medical evaluation, and the administration of oxygen in the ambulance or emergency department (ED) prior to the COHb test. In the general non-smoking population, normal levels of COHb are less than 1%. Approximately half (40.5%) of the COHb measured levels were less than or equal to 5% (Table 4).

Most of Michigan's unintentional carbon monoxide exposures occurred in non-occupational settings. There are no non-occupational indoor air standards for CO in Michigan. For the workplace, the Michigan Occupational Safety and Health Administration (MIOSHA) standard for General Industry is 35 parts per million (ppm) as an 8 hour time-weighted-average (TWA) exposure limit, with a 200 ppm ceiling, and, for construction there is a 50 ppm TWA, with no ceiling limit. An advisory committee of the Michigan Occupational Health Standards Commission recommended the standard be changed to a 25 ppm 8 hour TWA and a 200 ppm ceiling for both general industry and construction.

Several limitations have been identified with Michigan's CO surveillance system: 1) Information may be missing in the different reporting sources (e.g., source or COHb level). A questionnaire has been developed to contact individuals to obtain missing information but resources are not available to interview the large number of individuals reported with missing data. As surveillance continues and electronic medical records become more universal, we are hopeful that we will receive more complete reports. 2) Hospitals and other sources may not be reporting all cases; some cases are just simply missed. For 2011, in order to evaluate if cases of carbon monoxide exposure were not reported, one large hospital provided laboratory reports of carboxyhemoglobin results of 10% or greater. Of the eight cases reported from the lab, hospital discharge records were received on six of the eight, indicating that the other two individuals were not reported through review of hospital discharge codes. 3) The surveillance system does not capture Michigan residents who were treated for CO poisoning in out-of-state hospitals. 4) Carbon monoxide poisoning, particularly at lower levels of exposure, is a difficult condition to diagnose. In addition, some individuals exposed to CO may not seek medical attention. Thus we presume there are additional cases of unrecognized carbon monoxide poisonings.

Identification of individuals diagnosed with carbon monoxide poisoning is the first step to initiate preventive interventions. The four most common elevated CO exposures were from furnaces (23.0%), generators (10.5%), vehicles (10.3%), and fires (7.1%). After natural disasters or during prolonged periods of power interruptions, including construction projects, winter storms, and floods, the use of generators is quite common, increasing the potential of excessive CO exposure. Educational materials and campaigns to address this issue have been developed by CDC and MDCH.[9, 10] Additional topics for public education include the potential sources of CO exposure, common symptoms associated with CO poisoning, and the hazards associated with CO, especially in the colder months when the frequency of adverse effects is greatest. Prevention strategies include not allowing motor vehicles to idle in enclosed areas, regularly checking and maintaining motor vehicle emissions, ensuring all gas appliances are installed correctly and are located in properly ventilated areas and substituting electric powered forklifts and other equipment for fuel powered equipment during indoor work, both at home and in the work place. In areas that are likely to have CO exposures, installation of a CO detector is recommended at home and work.

Fuel burning heating appliances (i.e. furnaces and water heaters) have become more efficient as a result of the transition from a natural-draft venting system (gravity-driven), to a forced-draft venting system (fan-propelled).[11] Carbon monoxide "spillage" occurs when the products of combustion, flue gas, spill back into a building usually due to a blockage in the flue. Some of these newer appliances are required by ANSI standard ASTM E1998 – 11 to have a spillage prevention mechanism. However there is no single well-accepted method that is recognized in preventing spillage.[12] One current option is to install a "spill switch" with fuel-burning heating appliances. When installed correctly, these spill switches detect any blockages in the flue that prevent the products of combustion from exiting a building. Once detected, the spill switch automatically shuts off the fuel supply of the heating system, preventing the build-up of CO.[13] While the older fuel-burning heating systems with natural draft venting do not require a spillage prevention mechanism; their flues are still prone to blockage. This engineering change, along with the addition of these spill switches to older appliances, would decrease the incidence of CO poisoning caused by a faulty furnace/water heater, which was the leading cause of CO poisoning for all cases in 2011.

From the data, it was also evident that a substantial amount of the work-related cases were due to the use of power machinery, whereas in the non-work related cases, power machinery was not as significant. A possible intervention to decrease carbon monoxide exposure could be using automatic shut-off devices with the gas-powered machinery that automatically shut off the machine in use after a dangerous level of carbon monoxide has been detected.[14] This would be useful when using gas-powered machinery and could prevent CO poisoning, especially when these machines are used in closed environments.

Effective March 23, 2009, a modification to Michigan's Uniform Construction Code (Act 230 of 1972) mandated that all single-family and multi-family dwellings have carbon monoxide detectors installed at the time of initial construction, addition of a bedroom, or other renovation in which a permit is required. The location of these detectors and other specifics are outlined in section 125.1504f of Michigan Compiled Laws (Appendix A). Regulations and ongoing educational programs to encourage the installation of carbon monoxide detectors and spill switches in existing dwellings would address the major source of non-occupational exposure.

Data from future surveillance of CO poisoning will help determine the effectiveness of preventive activity and identify new sources of exposures.

## REFERENCES

1. CDC. Carbon Monoxide –Related Deaths -- United States, 1999-2004. MMWR 2007; 56:1309-12
2. http://www.epa.gov/airquality/carbonmonoxide/
3. http://www.michigan.gov/documents/CIS_WSH_part301_35589_7.pdf
4. http://www.michigan.gov/documents/CIS_WSH_part601_35654_7.pdf
5. Rosenman KD. Cardiovascular Disorders in Occupational and Environmental Health, 6th Edition. Eds Levy B, Sokas R, Wegman D, Baron SL. Philadelphia: Lippincott Williams & Wilkins. 2011; 492-504.
6. CDC. Carbon Monoxide Exposures --- United States, 2000-2009. MMWR August 5, 2011; 60 (30): 1014-1017.
7. Michigan Gender/Age http://www.census.gov/popest/data/state/asrh/2011/SC-EST2011-02.html
8. Michigan Race http://www.census.gov/popest/data/state/asrh/2011/SC-EST2011-03.html
9. http://www.cdc.gov/co/
10. www.michigan.gov/carbonmonoxide
11. Johnson, William, and Kevin Standiford. Practical Heating Technology. 2nd Edition. Clifton Park: Delmar, 2009. 140-155. Print.
12. http://www.astm.org/Standards/E1998.htm
13. http://www.nachi.org/spill-switch-inspection.htm
14. http://www.cpsc.gov/volstd/engine/COaslpostvet2.pdf

**Appendix A** Michigan Uniform Construction Code (Act 230 of 1972) section 125.1504f of Michigan Compiled Laws

## Appendix A

**STILLE-DEROSSETT-HALE SINGLE STATE CONSTRUCTION CODE ACT (EXCERPT)**
**Act 230 of 1972**

**125.1504f Single-family or multifamily dwelling; installation of operational and approved carbon monoxide device; requirements; failure to comply; penalty; liability; definitions; name of section.**

Sec. 4f. (1) The director may provide for, at the time of initial construction of a single-family dwelling or a multifamily dwelling, or at the time of renovation of any existing single-family dwelling in which a permit is required, or upon the addition or creation of a bedroom, the installation of at least 1 operational and approved carbon monoxide device within the single-family dwelling or within each unit of the multifamily dwelling. A carbon monoxide device shall be located in the vicinity of the bedrooms, which may include 1 device capable of detecting carbon monoxide near all adjacent bedrooms; in areas within the dwelling adjacent to an attached garage; and in areas adjacent to any fuel-burning appliances.

(2) The carbon monoxide device described in subsection (1) may be battery-powered, plug-in with or without battery backup, wired into the dwelling's AC power line with secondary battery backup, or connected to a system by means of a control panel. If the international residential code is adopted by the director as part of a code adopted after the effective date of the amendatory act that added this section, those requirements apply and shall be followed upon the effective date of the code.

(3) An enforcing agency shall not impose a penalty for the failure of a person to comply with subsection (1) until the effective date of the code that may be adopted after the effective date of the amendatory act that added this section that incorporates that requirement.

(4) A person licensed under article 24 of the occupational code, 1980 PA 299, MCL 339.2401 to 339.2412, who is in compliance with this section or rules promulgated under the code and installs, in accordance with manufacturer's published instructions at the time of installation, a carbon monoxide device shall have no liability, directly or indirectly, to any person with respect to the operation, maintenance, or effectiveness of the carbon monoxide device.

(5) As used in this section:

(a) "Approved" means a carbon monoxide device that is listed as complying with either ANSI/UL 2034 or ANSI/UL 2075 and that is installed in accordance with the manufacturer's instructions.

(b) "Carbon monoxide device" means a device that detects carbon monoxide and alerts occupants via a distinct and audible signal that is either self-contained in the unit or activated via a system connection.

(c) "Operational" means working and in service.

(6) This section shall be known and may be cited as the "Overbeck law".

**History:** Add. 2008, Act 377, Eff. Mar. 23, 2009.

**Popular name:** Act 230

**Popular name:** Uniform Construction Code

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