CARBON MONOXIDE EXPOSURE TO EMERGENCY MEDICAL SERVICES PERSONNEL AND FIREFIGHTERS

By

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Chapter 1: The Proposal

Introduction

Emergency Medical Services and Firefighting Services (EMS-FF) have little choice on what types of environments that they work in. When people have an emergency and call 9-1-1, they expect emergency responders to come to their aid. In many cases the responders come and render aid. When responding, those workers know very little about what is going on with the caller and the location. Much of that information is obtained after they arrive and talk with the victim and their family. Those situations have a magnitude of hazards that can harm the responders. One of those hazards is Carbon Monoxide (CO). Carbon Monoxide is a colorless, odorless gas that can overcome responders before they even know there is a problem (DeBruin 2004). Much research has been done on the effects of Carbon Monoxide on the human body and on its sources. The effects of the gas can produce conditions that range from dizziness to death. There have been limited studies on the exposure of emergency workers to carbon monoxide, many of which are during controlled burns or experimental tests. (Reinhardt, 2000) This study is designed to test the levels of carbon monoxide exposure to emergency responders while they are working their normal shifts; this research is a firsthand look at actual exposure levels of emergency responders by monitoring for CO while they are completing their normal emergency operations. This study will assess EMS-FF whole exposure through normal station duties, training, emergency response and normal living conditions.

Purpose of the Study

The purpose of this study is to identify if EMS-FF personnel are exposed to hazardous levels of carbon monoxide while working on the job. If emergency responders work in areas and situations that can create elevated levels of Carbon Monoxide (CO), they could theoretically be exposed to CO and possibly become incapacitated. Monitors are planned to be placed on emergency responders to compare between daily working activities and their carbon monoxide levels. The study will be used to identify two key questions: 1) are emergency responders exposed to elevated levels of carbon monoxide? and 2) If they are exposed to elevated levels of CO, what situations cause that exposure?

Hypothesis

Hypothesis 1: EMS and Fire personnel are exposed to elevated levels of CO while on duty.

Hypothesis 2: The primary sources of CO that EMS-FF are exposed to are from their emergency vehicles.

Hypothesis 3: Call and training volume will directly correspond with CO exposure levels.

Assumptions

Assumption 1 – That the call type and frequency for the sites being evaluated are similar to other agencies of the same average size

Assumption 2 – Emergency vehicles being used in this study are similar in style and upkeep for the industry

Assumption 3 – Sources of CO will not be deliberately introduced to the monitoring device while testing is taking place after calibration.

Limitations

One of those limitations is that it tests only one type of EMS and firefighting system configuration. Other configurations require responders to stay in their operating unit throughout their whole shift, typically between eight to twelve hours. This can cause workers to be exposed to vehicle exhaust for longer periods of time than 24-hour shift personnel. 24-hour shift personnel configuration was chosen because it is the typical configuration of paid EMS and fire departments.

Another limitation of this study is that it will be conducted only during one period of the year. Seasons can create different exposure hazards to be present. During the winter, heaters and furnaces are often causes of CO in the home. The summer season will be studied due to time constraints of the study. Potential limitation may be participants alter their normal routines due to their knowledge that they are being studied for CO exposure.

Definitions of Terms

American Conference of Governmental Industrial Hygienist — A professional association of industrial hygienists and practitioners with a goal of advancing worker protection by providing timely, objective, and scientific information to occupational and environmental health professionals.

Carboxyhaemoglobin — Haemoglobin coordinated with carbon monoxide, formed as a result of carbon monoxide poisoning. As carbon monoxide is bound in preference to oxygen, tissues are deprived of oxygen.

Cardiotoxicity — The occurrence of heart electrophysiology dysfunction or/and muscle damage.

Coronary Artery Disease — Atherosclerosis of the coronary arteries, which can cause angina pectoris or heart attack. A positive family history, hypertension, smoking, diabetes mellitus, and elevated blood lipids increase the risk of developing coronary artery disease.

Electrocardiogram — The graphic record produced by an electrocardiograph.

Environmental Protection Agency — An agency established by the United States government to coordinate federal programs aimed at combating pollution and protecting the environment.

Haemoglobin — A conjugated protein, consisting of haem and the protein globin, which gives red blood cells their characteristic color,

Hyperbaric Oxygen Therapy — Breathing 100% oxygen while under increased atmospheric pressure.

Immediate Danger to Life and Health — As exposure to airborne contaminants that is likely to cause death or immediate or delayed permanent adverse health effects or prevent escape from such an environment.

Neurology — The medical science that deals with the nervous system and disorders affecting it.

Occupational Safety and Health Administration — A government agency in the Department of Labor to maintain a safe and healthy work environment.

Occupational Safety and Health Act — A U.S. Federal law which governs occupational health and safety in the private sector, enacted by Congress 1970.

National Institute for Occupational Safety and Health – A branch of the Center of Disease Control responsible for conducting research and making recommendations for the prevention of work-related illnesses and injuries.

Permissible Exposure Limit — A legal limit in the United States for exposure of an employee to a chemical substance or physical agent.

Recommended Exposure Limit — A level that National Institute for Occupational Safety and Health believes would be protective of worker safety and health over a working lifetime if used in combination with engineering and work practice controls; exposure and medical monitoring; posting and labeling of hazards; worker training; and personal protective equipment.

Short Term Exposure Limit — The acceptable average inhalation exposure over a short period of time, usually 15 minutes as long as the Time weighted average is not exceeded.

Time Weighted Average — The average exposure to a contaminant or condition (such as noise) to which workers may be exposed without adverse effect over a period such as in an 8-hour day or 40-hour week.

Abbreviations and Acronyms

ACGIH — American Conference of Governmental Industrial Hygienists

CAD — Coronary Artery Disease

CDC — Center for Disease Control and Prevention

CO — Carbon Monoxide

COHb — Carboxyheamoglobin

ECG — Electrocardiogram

EMS — Emergency Medical Services

EPA — Environmental Protection Agency

IDLH — Immediate Danger to Life and Health

NIOSH — National Institute of Occupational Safety and Health

OSHA — Occupational Safety and Health Administration

OSH Act — Occupational Safety and Health Act

PEL — Permissible Exposure Limits

PPM — Parts Per Million

REL — Recommended Exposure Limit

SCBA — Self Contained Breathing Apparatus

TWA — Time Weighted Average

WHO — World Health Organization

CHAPTER 2: REVIEW OF RELATED LITERATURE

Introduction

There are many reasons for a literature review. First, it allows researchers to evaluate what has been studied in the past. This evaluation allows them to obtain a clear view of past results and theories. As time goes by, new research methods, equipment, and theories can disprove previously researched material. This possibility is why it is important for a researcher to investigate deep into the material to find all relevant data. A second reason for literature review is that it allows the researcher to gain an in-depth knowledge on the subject being researched. Lastly, it is important to perform a literature review as it allows researchers to see room for improvement in previous studies that would provide a more clear result in the current study.

The literature review will be divided up into six main categories. The first of those categories will be a basic history of Emergency Medical Services (EMS) and fire departments in the United States. This section will also talk about the history of carbon monoxide exposure. The next section will discuss the sources of carbon monoxide in the community. This will allow us to evaluate what types of situations emergency responders could be exposed in. The third section will focus on the toxicity of carbon monoxide. Such exposure may cause health hazards, some of which can potentially take a person's life. The fourth section will talk about what government regulations, laws, and standards were promulgated in the United States in relation to carbon monoxide. The fifth section will discuss studies that were done on the exposure of firefighters and EMS personnel as well as situations in which they could potentially be exposed.

The last section will be a summary of the findings in the literature review and a discussion on how it relates to this research.

History

Carbon monoxide is a colorless, odorless, and tasteless gas. It can be emitted from a variety of sources throughout the world. It is produced in nature as well as by man-made activities. Between 2001 and 2002 an average of 480 people died in the United States from carbon monoxide poisoning that was unrelated to fires. (National, 2008) An additional 15,200 were treated annually at hospitals between 2001 and 2003 (National, 2008). Carbon monoxide cannot be seen and is often not identified until it causes symptoms in the population near the source or in a closed space with the gas.

Carbon monoxide was discovered in the 1300s by Arnold of Villanova (World, 2006). Villanova, a Spanish scientist, noticed that poisonous fumes were being produced when he was burning wood in a poorly ventilated building. In the 1770s both Joseph Marie Francosi de Lassone, a French scientist, and Joseph Priestley, a British scientist, were able to independently prepare the gas in a laboratory (World, 2006). Carbon monoxide was first chemically mapped in the 1800s by William Cumberland Cruikshank.

The full understanding of the gas' hazards was not fully understood until the 1850s. It was then when a French physiologist, Claude Bernard, identified how the gas interacts with the body (World, 2006). He showed that the when carbon monoxide is present, it prevents oxygen from absorbing into the blood stream. The toxicology of carbon monoxide will be discussed later in the chapter. Carbon monoxide is produced through the incomplete combustion of petroleum products or other sources containing carbon (National, 2010). For example, the combustion of Methane:

$CH_4 + 2\ O_2 \rightarrow CO_2 + 2\ H_2O$ = complete combustion

$CH_4 + 1.5\ O_2 \rightarrow CO + 2\ H_2O$ = incomplete combustion

The fire service was developed out of necessity. The first identified fire protection force was developed by the ancient Romans after Rome was hit by an uncontrollable fire. Around 64 AD, Rome developed a group of about 7,000 paid firefighters to protect the city. In addition to fighting fires, they would patrol the streets and enforce fire prevention codes. The first recorded fire in the United States of America was in 1608 in the colony of Jamestown (Fire, n.d.). Through the years the fire service would grow into a volunteer group of people that would fight fires as a bucket brigade. These groups would form a line from the well to the fire and pass buckets full of water to douse the flames. This activity exposed the people to hazards that ranged from being close to the unstable building to being exposed to toxic gases and fumes from the fire (Fire, n.d.).

In 1679 the first fire engine was imported to the United States from London. This engine consisted of a hand drawn cart with a two-person operated piston pump. The pump allowed people to fight fires with leather hoses rather than buckets. Buckets were still sometimes required to fill the water tank on the pump. In 1829, the first steam fire engine was built to fight fires. These engines were still drawn by hand but did not require two people to operate the pump (Fire, n.d.), The New York Mutual Hook and Ladder Company No. 1, in 1822, decided to purchase a horse to pull the engine. This practice caught on, and many departments followed in this path. Soon after the 1872 Great Fire of Boston, steam-and gasoline-powered engines started replacing horse-drawn carts. In 1923, the last horse-drawn engine made its run in Chicago at 12.40 P.M. Firefighting has had many developments since the start of time. Those developments have ranged from uses for pumps to the implementation of high tech personal protective equipment. This all is used to help keep the public and responders safer (Fire, n.d.).

The first recorded use of an ambulance was in Spain during the Siege of Malaga in 1487. At that battle they used a cart to move wounded soldiers from the battlefield; however, they would not give emergency care. In the 1860s, the first ambulance was used in the United States during the Civil War. The first civilian ambulance service was in 1865 in Cincinnati, Ohio. The ambulance was a hospital-based service which did little care in the field beyond getting the person to the hospital (Florida, 2009).

In 1964, there was a national call to make EMS a national priority. In 1965, the National Academy of Sciences/National Research Council published the “Accidental Death & Disability: The Neglected Disease of Modern Society.” This publication pointed out many areas lacking in the EMS system. Just one year later, 1966, the National Highway Traffic Safety Administration published guidelines for the development of an EMS system. Two years later a Federal task force developed training standards for EMS personnel. In 1970, the National Registry of Emergency Medical Technicians was established to create unified training, exams, and certifications. EMS would grow through the years into the complex service it is today. Today some services operate with doctors on site and provide a wide variety of procedures and skills.

EMS agencies have many tools to save lives, to keep people safe, and work diligently at prevention and community preparedness to help save lives even faster (Florida, 2009).

Sources of Carbon Monoxide

The purpose of reviewing the sources of carbon monoxide is two-fold. First, if a person can identify a situation that has the potential to cause carbon monoxide exposure, they are then able to take precautions to prevent injury or illness to themselves. Second, identifying the sources of CO will give the researcher information for gaining further data in situations that could present higher levels of carbon monoxide. The three main categories of sources of CO are engine exhaust, controlled fires, and uncontrolled fires. These categories will each be identified and researched below.

Motorized Transport Equipment

Motorized transport equipment, such as automobiles and trucks, are the primary modes, of transportation though the United States and much of the world. They also produce a majority of the carbon monoxide found outdoors. In 2005, the Environmental Protection Agency (EPA) found that 75% of the outdoor carbon monoxide in Phoenix, AZ, was a result of cars on the road (Tax, 2005). Some states now require that cars output only a maximum CO producing level.

Alm, Jantunen, and Vartiainen studied the exposure of particulate matter and carbon monoxide to urban commuters while inside an automobile. Their research found that often people operating vehicles are exposed to levels of CO that are greater than the outdoor and indoor microenvironment (Alm, 1999). The study shows that a person operating at slower speeds, in a rush hour commute, is more likely to be exposed to higher levels of CO. A study by

Flachsbart et al. (1987) viewed the same results as Alm et al. A study by Clifford et al. (1997) contradicts Alm, Jantunen, Vartiainen and Flachsbart findings. Clifford showed no correlation between the CO exposure and speed of a vehicle. The results of Alm, Jantunen, and Vartiainen (1999) showed concentrations 50-85% higher in 11 of their runs.

One step that the Federal government has taken to reduce the level of carbon monoxide produced by vehicles is to require catalytic converters be placed on the exhaust stream of the car. The catalytic converter uses a catalyst to convert the CO into CO_2, a less harmful greenhouse gas (Nice, 2010). This converter along with better fuels and cleaner-running engines help reduce the exhausted CO levels from vehicles. These systems do have faults. If the engine is cold, it can cause a less complete combustion, thus causing more CO emissions. Hot catalytic converters are a potential source of brush fires. If the catalytic converter is cold as well, it will not catalyze completely and will let more CO pass unconverted (Nice, 2010). This effect is hypothesized to be the cause of higher readings in the Alm et al. (1999) study.

A study by DeBruin, Carrer, Jantunen, Hanninen, Marco, Kephalopoulos, Cavallo and Maroni in 2004 showed that people on their normal commute to and from work were exposed to higher levels of CO. Their study showed that commuters spent an average of 7.5% of their day in transit but had a total contribution of their recorded CO at 16.1% (DeBruin, 2004). In their study, like Alm et al (1999), they found higher exposures when walking and using a car/taxi. It contrasted with Alm in that they still saw elevated levels of CO when using the bus, in which Alm had found lower levels than the car/taxi.

Controlled Fires

Carbon monoxide from controlled fires is known to be hazardous. A controlled fire would include a furnace, gas stove, and fireplace. These are all sources that can be normally seen inside a home, commercial building, or other location that people are intended to occupy. These are all intended to operate with limited exposure, but events such as poor ventilation (i.e., dirty or blocked flues) can cause the fuel to burn less completely. In 1989, Baron, Backer and Sopher conducted a case study on 62 fatal carbon monoxide incidents in West Virginia. They found that they were “almost always (from) heating or cooking appliances” (Baron et al., 1989). Liu, Paz, Flessel, Waldman and Girman did a similar case study in California in 2000 and found similar results. They showed that nearly one third of the incidents involved charcoal grills and hibachis, and that nearly one third of all deaths were related to indoor, fixed heaters (Baron et al., 1989).

The use of CO producing sources such as a portable generator or grill has been known to overexpose workers and residents. The National Institute for Occupational Safety and Health (NIOSH) has many documented cases of CO poisoning happening even in large, partially-vented locations. One such study was a man working in a 58,000 square foot room with an 8 horse power gasoline-powered pump. The door on the other end of the room was open for ventilation. The worker was overcome with CO poisoning and lost consciousness (National, 2009). These types of situations are common in the world, and they all typically involve emergency responders.

Uncontrolled Fires

Uncontrolled fires, such as house, business, field or forest fires, are a significant source of CO. These fires, unlike controlled fire and motorized transport vehicles, are not designed and built to create complete combustion. They are free-burning sources that can cause a hazard to emergency responders. Much research has been done on CO levels near these types of events, but they typically do not involve real fires. Rather, they are generally done on test burns or forest clearing burns.

When burning, CO is released into the microenvironment and will build up over time. A study by Austin, Wang, Ecobichon and Dussault in 2001 was done to evaluate the levels of volatile organic compounds in smoke at experimental fires. They found in Class A fires (i.e., a bed mattress and cardboard boxes) that the carbon monoxide levels reached over 400 ppm within the first 12 minutes after ignition. In class B fires (i.e., gasoline), the CO levels reached only about 60 ppm in the first 12 minutes.

In the 2001 World Trade Center attacks, there was extensive monitoring of responding personnel's exposure to hazardous airborne gases and vapors. One of those monitored and discussed in Wallingford and Snyder's 2001 study was on CO. Wallingford (2000) stated that the concentration in the air of CO was found to be between 0.16 and 242 ppm out of 99 samples. All these readings were in direct rescue and firefighting operations.

Toxicology

Carbon monoxide Poisoning

Inhalation of carbon monoxide poisoning is the primary cause of illness from exposure to high levels of carbon monoxide. CO poisoning can cause a number of problems within the body. These problems can range from respiratory to neurological. CO poisoning can be present in a human in a number of ways. Respiratory symptoms can manifest as shortness of breath, rapid respiratory rate, or no breathing. CO poisoning's neurological symptoms can present as confusion, dizziness, drowsiness, headache, hyperactivity, impaired judgment, and/or irritability. The cardiac symptoms of CO poisoning can include shock, low blood pressure, rapid or no heartbeat, or chest pain (U.S., 2010).

Thousands of people are treated each year for carbon monoxide-related incidents. Previously it was hard to identify CO poisoning without blood tests. Newer equipment has become available for noninvasive field-testing for CO. Between 2001 and 2003 the Center for Disease Control and Prevention (CDC) reported and estimated 15,200 people were treated annually for nonfatal CO poisoning. They also estimate around 480 people died annually from non-fire-related CO poisoning between 2001 and 2002 (Flynn, 2008).

Respiratory System

The primary route of exposure for carbon monoxide is through the respiratory track. When CO is breathed in, it travels through the trachea into the lungs. When the carbon monoxide reaches the lungs, it rapidly passes through the alveolar and capillary membranes (Theakston, 2000). When the CO reaches one of the haem proteins, it binds approximately 80-

90% of the time over the oxygen. This binding reduces the levels of oxygen the haemoglobin can carry. When the two bind, it turns into carboxyheamoglobin (COHb). There are many models to estimate the absorption and elimination of carbon monoxide from the body. The most prevalent of these models is Coburn-Foster-Kane's exponential model (Theakston, 2000). This model considers the concentration of the CO in the air the most important variable. Theakston's (2000) study shows that at a steady concentration, the COHb starts to level off after about three hours and reaches a steady level at around six to eight hours (Theakston, 2000). This depleted level of oxygen in the body causes problems such as difficulty breathing. The body is able to fully expand the lungs with air but is absorbing little oxygen, thus making it feel as if little air is being inhaled.

CO is eliminated through breathing, as well. The World Health Organization (WHO) states there are many factors that affect the rate of CO elimination. Those factors include: rate of CO release from the heam protein, alveolar ventilation, oxygen concentration in inhaled air, duration of CO exposure, and level of COHb saturation (Theakston, 2000). The "elimination half-life of CO in heamoglobin in breathing air is between two to six and a half hours depending on the initial COHb level" (Theakston, 2000). The clinical treatment of CO poisoning will be discussed later in this chapter.

Cardiotoxicity

There are many documented studies on the effects of carbon monoxide on the cardiac muscle in the human body. Although some of the material is contradictory, much of the material is supported by the studies. In a study of carbon monoxide cardiotoxicity by Gandini, Castoldi, Candura, Locatelli, Butera, Priori and Manzo (2001), the researchers found that carbon monoxide exposure even at low levels can cause cardiac issues such as electrocardiogram (ECG) changes, heart damage, and even cardiac arrest. These problems seem to be increased by exercise and in patients with coronary artery disease (CAD) (Gandini et al., 2001).

ECG changes have been noted in patients after carbon monoxide exposure. Those changes include depolarization disturbances (i.e., QT interval prolongation). Gandini et al. (2001) stated that there was little connection found between the COHb levels in the blood and ECG changes. They further stated that changes in ECG can lead to identifying a CO poisoning patient, but are also indicative of a number of other ailments. Other tests should be done as well in order to identify CO poisoning as the primary illness (Gandini et al., 2001). The testing can reveal arrhythmias, either supraventricular or ventricular, in humans. These arrhythmias can cause sudden death in patients. Patients with CAD are more susceptible to these arrhythmias (Gandini et al., 2001).

Heart changes and damage has been noted since the 1940s when W. Ehrich, S. Bellet and F. Lewey identified that dogs were found to have myocardial damage when exposed to high levels of CO. These dogs had COHb levels at high as 75%. (Ehrich, 1944). In humans, COHb levels of only 2.5-3%, considered low levels, can cause cardiac damage (Theakston, 2000). As Butera et al. (2001) stated, “people with CAD are particularly susceptible to very low CO concentrations.” Exercise in subjects that are both healthy and have CAD increases the effects of CO (Gandini et al., 2001).

Cole, in a 2002 report, stated that 50% of all firefighter-related deaths had a primary cause of heart attack and a secondary cause of CAD. Firefighters have a high risk of CO exposure due to their direct fire contact and other duties such as responding to CO calls as well as working on and near large vehicles. This exposure, in combination with the frequency of CAD in firefighters, would lead one to believe that firefighters are at high risk for CO poisoning, based on the finding of Gandini et al. (2001). The number of CAD deaths related to CO in the fire service is unknown.

Neurological

COHb levels as low as 10% can cause neurological problems starting with a headache. With slightly elevated levels, dizziness, nausea, and vomiting present themselves. At levels near 40% the CO will cause the person to go into a coma and collapse. Levels near 50-60% COHb are considered lethal (Theakston, 2000). A study conducted by the WHO (2000) showed that levels near 18% caused a healthy person to exhibit little visual or behavioral impairment. Other neurological problems, such as reduced coordination, tracking, and driving ability have been seen in levels as low as 5.1 to 8.2% (Theakston, 2000). These effects are caused by the lower levels of oxygen in the blood and the onset of hypoxia. Many of these problems can be reversed but can leave long-term damage on the body.

Treatment

After a person is exposed to carbon monoxide, there is a relatively standard protocol for the treatment of the poisoning. The person should first be removed from the hazardous atmosphere and treated with 100% oxygen at normal atmosphere (Sinkovic et al., 2006). This procedure reduces the half-life from around six hours to about one hour. The implementation of hyperbaric oxygen therapy, at three atmospheres, should be done as soon as possible. This procedure reduces the half-life of the CO to near 20 minutes (Sinkovic et al., 2006).

The use of hyperbaric oxygen therapy provides two key factors for fighting CO poisoning. First, it aids in reducing the COHb levels in the blood by dissolving enough oxygen into the plasma to support the body tissues' needs (Doherty, 2000). Doherty also states that the high levels of oxygen help reverse the effects of hypoxia in the body tissue. There is controversy on the effectiveness of hyperbaric oxygen treatment over normobaric oxygen treatment. Doherty (2000) and Emerson (2000) both agree that there have been few, if any, effective double blind studies on the subject. They both state that there is little evidence showing one is better than the other.

Government Regulations, Standards, and Guidelines

There are many government regulations and guidelines in relation to carbon monoxide in the workplace and in the home. This section will evaluate how government regulations will relate to this study. As discussed earlier in this chapter, CO can be produced by many sources that are found in both homes and businesses. EMS and the fire service, emergency responders work in homes, businesses, on the side of the road, and inside their own stations. Many EMS and fire stations are set up to be a temporary home for the employees. They include full kitchens, bedrooms, and garages. Due to this home-like atmosphere, first responders’ work places typically follow Occupational Safety and Health Act (OSH Act) standards in order to identify all sources and situations that may produce CO in order to protect the employees from excessive CO exposure.

Occupational Safety and Health Administration (OSHA), a federal agency, has as its core mission the entitlement to a safe and healthy workplace for every working man and woman in the nation. OSHA covers all private services, but does not have jurisdiction over governmental agencies. States have the ability to set their own guidelines for their employees, and about half of the states do (Occupational, 2006). Typically local and county agencies use OSHA standards as guidelines to keep employees safe.

OSHA standards for chemical exposure are called Permissible Exposure Limits (PEL). The OSHA PEL is based on an eight hour time-weighted average (TWA) exposure. This means that a person's average exposure cannot exceed the limit for the chemical they are being exposed to (Permissible, 2010).   The OSHA PEL for carbon monoxide is 50 ppm (Occupational, 1989). There are other recommended exposure limits set by other agencies on the subject. The NIOSH sets recommended exposure limits (REL) for hazardous substances. NIOSH's REL for carbon monoxide is 35 ppm. They also set a ceiling of exposure at 200 ppm (Occupational, 1989). OSH Act standards apply in the workplace, but are not applicable to the home. Due to the nature of the EMS/firefighting job, workers are required to enter homes as part of their job, so these recommendations should be followed to ensure worker safety.

The Environmental Protection Agency (EPA) estimates the normal levels of carbon monoxide in a home to be on average 0.5 and 5 ppm without a gas stove. Homes with a gas stove are on average between 5 to 15 ppm, and with poorly-adjusted stoves up to 30 ppm or higher (U.S., 2009) EPA states that there are no standards for indoor air quality, but do state that the U.S. National Ambient Air Quality Standards for outdoor air is 9 ppm for eight hour, and 35 ppm for one hour. (U.S., 2009).

Emergency Medical Services and Fire Service Exposure

As stated previously in this paper, there is not much information available on the exposure levels of emergency responders to carbon monoxide. Situations exist that could potentially expose emergency responders to hazardous levels of carbon monoxide. This section will address studies conducted on direct fire service-related activities and numbers of potentially hazardous situations that could harm emergency responders. This section will also address some activities that are not commonly considered hazardous to emergency responders but have proven to be.

Research on active (non-training related) building fires are difficult to obtain due to the fact that it is difficult to predict the timing and location and ensure a research response team is on-site. Much research has been done in regard to wildfire burns. These studies evaluate the levels of hazardous gases, including CO, to which emergency responders are exposed, and levels downwind of the event. One study by Naeher, Achtemeier, Glitzenstein, Streng and Macintosh, completed in in 2006, showed that fires in peak levels of a prescribed burn peaked at 29 ppm. This study concluded that the levels of CO did not exceed OSHA PEL (Naeher, 2006). Reinhardt, Ottmar, and Hanneman conducted a similar study in 2000 on prescribed burns. Their study placed monitors on workers and evaluated their exposure in the breathing zones. They found average exposure levels of 4.1 ppm for the workers' shift and 6.9 ppm while at the burn. They saw a high shift average at 38 ppm and a high fire line average of 58 ppm (Reinhardt, 2000).

These incidents were all at controlled, prescribed burns in open fields. Firefighters also have a requirement to fight building fires. These fires are typically in an enclosed space that contains the CO and allows concentrations to build. Austin (2001) showed levels of up to 465 ppm inside training burns, and a study by Cone et al. (2005) showed inside CO readings of 1,290 ppm. This study also tested the COHb levels' of responders. The ones who were wearing self-contained breathing apparatuses (SCBA) had COHb median levels of 1%. One instructor who removed his mask multiple times to give instructions had a COHb level of 15%. (Cone et al., 2005).

There are many potential situations in which emergency responders can become victims of CO poisoning. In 1990, three firefighters died attempting to retrieve the remains of a dead animal in a well. They were using a 9-horsepower gasoline-powered pump, a known CO source, to pump out the water in the well. The pump was located in the well where the worker was operating. After the first rescuer was overcome, multiple firefighters attempted rescue of the first, and two died as a result. All died of CO poisoning. Their COHb levels are unknown, but the estimated level of CO in the well was at 20,500 ppm. This is more than 13 times the immediate danger to life and health (IDLH) concentration set by NIOSH. IDLH level for CO is 1,500 ppm (National, 2010).

There are many types of calls that firefighters and EMS personnel have to respond to. In Johnson County, KS, there are 14 fire departments and one EMS agency that respond to calls. In 2009 they responded to 4,940 calls where there was a known potential of CO. Table 1 shows the calls by type. Not all calls for emergency response are classified under one of the call types shown in Table 1. There were 189 headaches, 3,280 unconscious/syncope, 2,646 difficulty breathing, and 4,501 sick and ill calls. All these have the potential to be a CO poisoning. All these are signs and symptoms of CO poisoning as stated above (Johnson, 2010).

Table 1
2009 - Johnson County, KS, Calls with known CO sources

Call Type	# of Calls
Injury Accident	2,637
CO Investigation	656
Vehicle Fire	391
House Fire	250
Building Fire	195
Modified Response – Building Fire	157
Appliance Fire	140
Modified Response – House Fire	138
Investigate Smoke Oder Inside	110
Dumpster/Trash Fire	104
Investigate Smoke Oder Outside	57
Flue Fire	38
CO Medical – Suspected CO poisoning	27
Transport Vehicle Fire	24
Outbuilding/Detached Fire	15
Confined Space	1
TOTAL	**4,940**

Summary

Since the 1300s, carbon monoxide has been identified as a hazardous substance. Through the years its physical properties have been identified and realized more and more as a hazard to specific industries. Those hazards were found to be from a number of sources. Vehicles are the main producer of carbon monoxide into the environment. That gas is typically dispersed outside so the exposure is mixed into the air, thus creating a lower concentration of exposure. When a source of CO is released indoors, such as using a grill or generator indoors, it causes the concentrations to be contained; this containment causes CO to increase into more hazardous levels. If a fire breaks out inside a closed building, the incomplete combustion creates extremely high levels. Those levels can present a hazard to both the public and emergency responders trying to aid the public.

The toxic hazards are well-defined in the body. CO enters the body through the lungs and proceeds into the blood stream creating carboxyheamoglobin. This then causes a number of health problems ranging from hypoxia to heart irregularities to neurological problems. Many of these problems can cause long-term damage to the body. The standard treatment for the toxic effects is hypobaric oxygen treatment, though the effectiveness of this is still disputed.

The U.S. Federal Government has set standards regulating the levels of CO a worker can be exposed to while on duty. Though these standards do not apply to EMS-FF workers, they are typically followed. The exposure of emergency responders has been documented in the past. With possible exposure levels well above OSHA standards, emergency responders need to be cautious about the situations they encounter and protect themselves when necessary.

Sources of CO are possible in all of the areas where an emergency responder operates. When responding to emergency calls, emergency responders need to be cautious and identify patients' complaints as possibly related to CO poisoning. While the literature does identify some exposure studies in controlled emergency situations, a complete study of the full working cycle of the responders is necessary. As the research shows, even minor duties on the jobs (e.g., backing a vehicle into a parking spot, checking equipment, and idling waiting for a call) can expose workers to dangerous situations. This can include confusion and dizziness. If exposed, workers can be rendered ineffective at treating and aiding the community, or exposure can even result in death.

CHAPTER 3: METHODOLOGY

Sample

A total of 56 direct readings of carbon monoxide are going to be taken during the course of this study. At each of the two training sites, four people will be selected for monitoring each day. They will be monitored for their 24 hour shift. There will be a total of 7 days of study done at each site, totaling 28 samples from each site. All testing was done with approval and oversight of the Human Subjects Review Committee, which is administered through the Human Subjects Protection Program Office with the University of Central Missouri. All participants will be explained the hazards of the study and have signed the participant waver (Appendix A). People who identified themselves as pregnant, under the age of 18, or wished not to participate will be excluded from the study.

Data Collection Tools

One instrument that will be used is the Industrial Scientific GasBadge Pro Personal Single Gas Monitor. Each of these monitors will be outfitted with electrochemical sensors for carbon monoxide. They will be span gas calibration checked prior to the field use. Each of these monitors is equipped with data logging capabilities that will sample and record at a rate of one reading per minute.

Data Collection

After signing the Participant Waivers, each participant will be given a Participant Number. This number will be used to help identify survey results with testing results. Each participant will be given a survey (Appendix B). This survey identified the type of department they worked for, age, sex, and other questions related to the survey.

After completion of the survey, participants will be fitted with the CO monitor that has been marked with their identification number. The monitor will be placed in the person's breathing zone, near the neck. The participant will be instructed to wear this on the outer layer of their clothing throughout the testing period and allowed to place it on the nightstand near breathing level while sleeping.

During the testing period, an observer will be present and he or she will monitor the participants. The observer is tasked with monitoring the participant's actions and tasks. Those observations will be recorded on the participant activity log (Appendix C). The observer identifies the time and action of the participants through the 24-hour monitoring period. When it is not feasible to have an observer present, the participants will be tasked with filling out the participant logs.

Data analysis

After each testing is performed with the CO monitors, data will be downloaded to the computer using the data download program supplied with the Industrial Scientific GasBadge Pro Personal Single Gas Monitor. This data will then be matched to the information obtained on the activity log. Once all the samples have been taken and matched together, the data will then be entered into a Microsoft Excel spreadsheet.

CHAPTER 4: RESULTS

Introduction

The testing for this study was performed at two different sites. One of the sites, Site A, was obtained between June 9, 2013 and June 16, 2013. This site was comprised of ambulance personnel exclusively. There were 28 testing points for this site. Each testing period was 24 hours long.

The data collected at the other site, Site B, was obtained between July 3, 2013 and July 10 2013. This site was comprised of both ambulance personnel and firefighter personnel. A total of 28 samples were taken at this site, as well. Each testing period was over their 24-hour shift, as well.

The total sampling time was 1,344 hours. Each monitor took a sample every two seconds, totaling 43,200 data points per participant. The total sampling data points were 2,419,200. Each sample included the current carbon monoxide reading and the ambient air temperature during the reading.

Sites

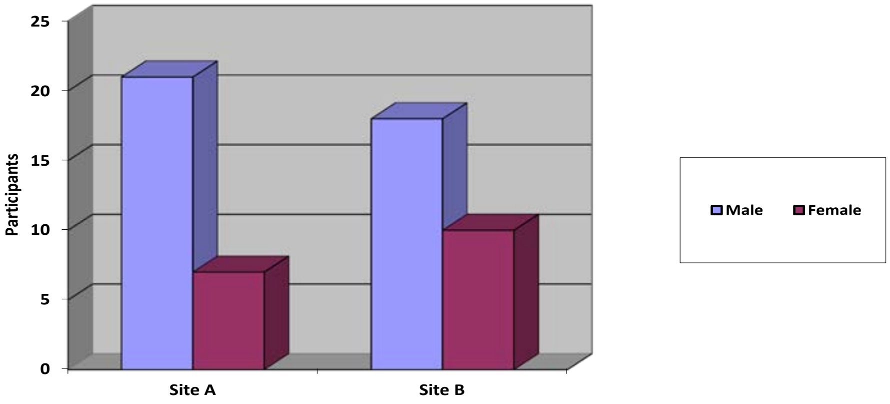
Site A was a rural emergency medical service, which provides pre-hospital emergency medical care to the sick and injured. This agency covers a total of 590 square miles (Miami, 2013). The total population of the county is comprised of 32,787 people. The largest city includes 5,600 people. Two cities include 4,000 people. Six other cities have a population of at least 1,000 people. The remaining six cities have a population below 1,000.

Site B was a service comprised of both emergency medical personnel and firefighting personnel. This agency covers a total of 474 square miles (Douglas, 2013). The total population of the response area is 112,864 people. The largest of those cities is comprised of 87,643 people. Four other large communities are between 6,500 and 5,000 people. The remaining eight communities are below 2,000 people.

Demographics

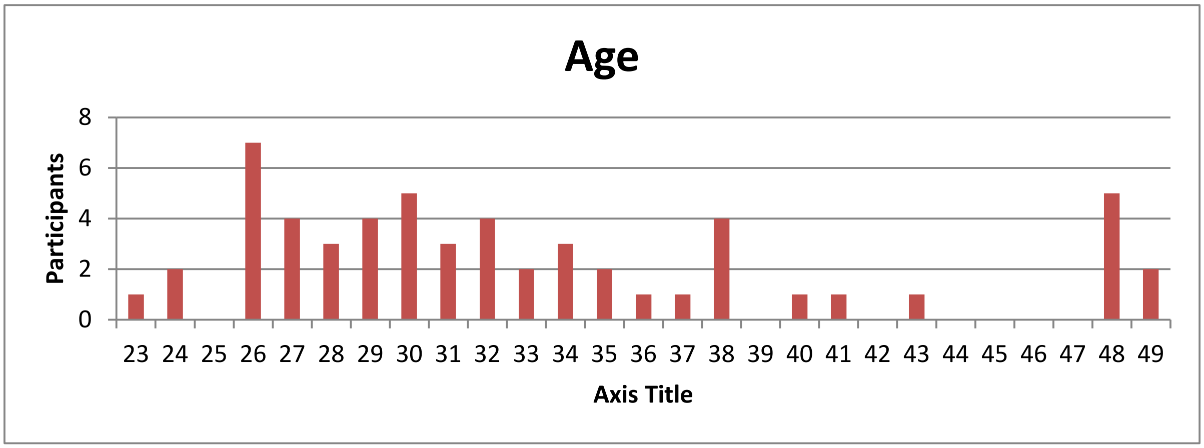
The demographics of the studied subjects were wide ranging for the field. Each site had similar demographics, which allowed for a good study group. Site A's 28 subjects tested consisted of 7 female samples and 21 males. Site B's 28 subjects consisted of 10 females and 18 males. The total site sample comprised of 17 females and 39 males (see Appendix D).

Graph 1: Site by Gender of Participant



The age of the subjects was a good sample set for the industry. At site A the highest age identified on the survey was 48 years old. The lowest aged participant was 26. The average age of the participants was 33.04 years old. At site B the highest age identified on the survey was 49 years old. The lowest age identified was 23 years old. The average age of the participants was 33.26 years of age.

Graph 2: Age of Participants



Survey results

Every participant who was involved in the study completed a participant survey. The survey included information on what agency they worked for, their demographic information (i.e., age and gender), and other questions needed to identify their non-work related Carbon Monoxide exposure that could alter the results of the study. Other questions focused around the symptoms they experienced in the past and if they believe they are exposed to carbon monoxide beyond healthy levels while working (see Appendix B).

One of the largest possible non-work related carbon monoxide exposures that the participants could have been exposed to was that of smoking tobacco products. (DeBruin, 2004) The participants were asked in the survey whether they smoked, and if yes how many packs a day. Fifty five of the participants stated that they did not smoke tobacco products. One person from site B stated that he did smoke tobacco products at a rate of half a pack a day. He did note on the side of the survey form that he did not smoke tobacco while at work. Looking at his corresponding monitor data, there was no significant differences between his data and the other participants' data, so it is believed that he did not smoke while working on his shift.

Participants were asked if they experienced any symptoms during their operational period that would suggest possible exposure to high levels of carbon monoxide. This included headache, dizziness, nausea, fatigue, confusion, agitation, drowsiness, vision changes, fainting, and memory or walking problems. At site A, 26 of the participants stated on the survey that they had none of these symptoms during their operational periods during the past. Two of the participants from site A identified that they do experience headaches while working. Those two people were both males in their late twenties.

At site B, 25 of the participants identified that they had none of the stated symptoms while working. Three of the participants did indeed identify that they had experienced headaches while on duty at work in the past. Those three people were comprised of two males and one female. Their ages varied more than site A with one person in their late twenties and the other two in their early and late thirties. No other symptoms were identified as being experienced in the past on the survey.

The participants were then asked if they believed that any of their symptoms got worse when they were at call scenes. As stated above, 26 of site A's participants and 25 of site B's participants identified no symptoms that could have been related to carbon monoxide while on duty. Of the two from site A that stated that they did have symptoms, they stated on the survey that the symptoms did not get worse while on any call scenes. Of the three from site B that stated that they had carbon monoxide related symptoms, only 1 stated that the symptoms did not get worse at call scenes. The other two stated on the survey that the symptoms, headaches, got worse when they were on call scenes. They identified those symptoms as getting worse on the scenes of motor vehicle accidents.

The final question on the survey requested them to indicate if they believe that they were exposed to high levels of carbon monoxide while working during their shift. At site A, 26 of the participants stated that they did not believe that they were exposed to high levels of carbon monoxide while working. Two of the participants at this site state that they did believe that they were exposed to high levels. Those two were both in their late 20s and were one male and one female.

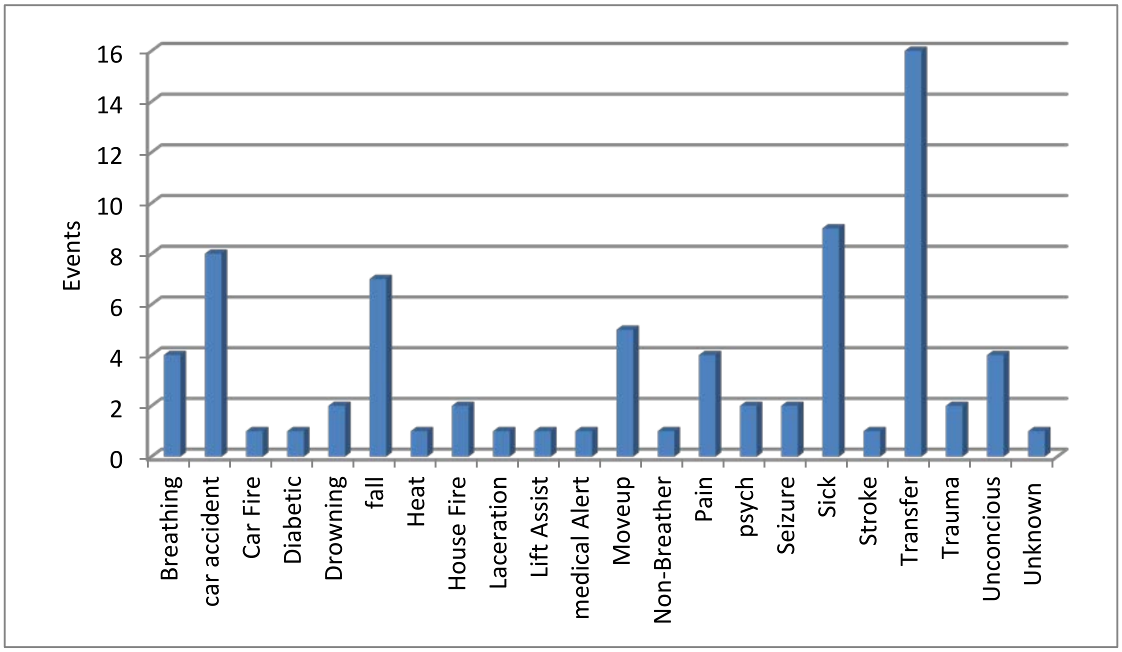
At site B this question showed one of the few differences between the two testing sites. Participants at site B stated in vast majority they believed that they were exposed to high levels of carbon monoxide. Only nine of the participants at site B stated that they did not believe that they were exposed to high levels of carbon monoxide. The remaining 19 participants at this site believed that they were exposed to high levels of carbon monoxide while on duty. The age ranges of those were between 23 and 43 with twelve males and seven females.

Emergency Call Data

The incidents that each participant responded to was collected through both reports from the sites dispatch center as well as an activity log that each participant kept during the study. The calls that were monitored during the study totaled 121. Site A accounted for 76 of those calls. Site B accounted for 45 calls total. Each of those calls were broken down by date of call, time and call type (see Appendix E).

Site A is exclusively an emergency medical service provider. This site does no firefighting tasks except to act as medical support on a fire scene. That being said, all the calls from this department were related EMS calls. The most frequent call type experienced was transfers from one hospital to another. This accounted for 20.05% of all calls experienced by the participants. Other frequented call types included sick patients (11.84%), car accidents (10.53%), and falls (9.21%). Graph 3 shows the breakdown of call types.

Graph 3: Site A Call Type



Site B was comprised of half emergency medical personnel and half firefighters. Those firefighters also responded to EMS calls but have additional firefighting responsibilities, as well. Of the sites 45 total calls, twelve of them were firefighting specific, 26.67% of all calls at site. Of those twelve calls, three of them were related to power lines arcing, seven fire alarms were responded to with no active fires found, one fire was responded to with no fire found, and one active dumpster fire was responded to.

At site B there was a total of 33 emergency medical calls responded to. The largest percentage of calls responded to by the participants was motor vehicle accidents. This totaled six responses accounting for 18.18% of all the medical calls and 13.33% of all calls at site B. Other frequent call types include sick patients (15.15% medical, 11.11% overall), falls (9.09% medical, 6.67% overall), and breathing difficulty (9.09% medical, 6.67 overall).

Monitor results

Each monitor took a reading every two seconds during the study. The vast majority of those readings were in a range between zero parts per million (ppm) and five ppm. Of the 2,419,200 data points collected, 2,395,182 data points were within the 0 to 5 ppm ranges. That range accounted for 99.01% of the total data points. 6 to 10 ppm totaled only 5,550 data points, accounting for 0.23% of the total data. 11 to 15 ppm accounted for 0.61%, with its total of 14,853 readings. All the other readings taken totaled only 3,615 data points, only 0.14% of the whole group. Table 2 shows the specific breakdown of the total data points in each range.

TABLE 2: Total Data Points for Each Reading Range

0-5 ppm	6-10 ppm	11-15 ppm	16-20 ppm	21-25 ppm	26-30 ppm	31-35 ppm	36-45 ppm	46-60 ppm	61+ ppm
2395182	5550	14853	608	1562	1087	73	93	71	121

Looking at the specific time spent in each data set gives a better identification of the total exposure of the participants. The largest group spent a total of 1,330.66 hours in the range of 0 to 5 ppm. The participants spent only 185 minutes in the 6 to 10 ppm ranges, and 495.1 minutes in the 11 to 15 ppm range. They totaled only 120.5 minutes inside a range greater than 15 ppm. Table 3 shows the breakdown of the total time spent at each range.

TABLE 3: Time in Minutes for Each Reading Range

0-5 ppm	6-10 ppm	11-15 ppm	16-20 ppm	21-25 ppm	26-30 ppm	31-35 ppm	36-45 ppm	46-60 ppm	61+ ppm
79839.4	185	495.1	20.27	52.07	36.23	2.43	3.1	2.37	4.03

Even though the vast majority of the readings taken were at a very low range, the monitors did read occasional elevated readings. The highest readings, or peaks, that each monitor obtained varied between not only the sites, but between the participants, as well. At site A the highest peak that was measured was at 77 ppm. The average peak though for the 28 samples taken was only 17.35 ppm.

At site B the peaks varied extensively more than at site A. Site B had a peak reading of 499 ppm. This amount was the highest reading measured during any part of the study. The next highest peak measured by another monitor at site B was only 58 ppm. Even with the extremely high peak that was read, the average peak of site B was still only 41.86 ppm.

OSHA has set a Time Weighted Average (TWA) for Permissible Exposure Limits (PEL) in relations to carbon monoxide. OSHA set those limits at 50 ppm. During the testing period the monitors evaluated not only the current carbon monoxide readings but also the Time Weighted Average readings. At site A, the highest TWA that was recorded was 31.49 ppm. This figure is above established OSHA Action Limits. There were only six other TWA recorded at this site over 10 ppm. The average TWA recoded at Site A was only 6.31 ppm.

Site B had a much lower average TWA then site B even though it did have the highest reading of the whole study. The average TWA at site B was 3.05 ppm. The highest TWA measurement taken was 10.98. Only one other TWA measurement at site B broke the 10 ppm level. The average of all the TWA at site A and B was 4.68 ppm.

Though no Short Term Exposure Limit (STEL) is set for carbon monoxide, the STEL data gives important peak information when evaluating the data at hand. At site A the highest STEL recorded was 27.53 ppm. Only two other STEL measurements broke the 10 ppm level. The remaining 25 readings were below 10 ppm. The average STEL measured at site A was 3.84 ppm.

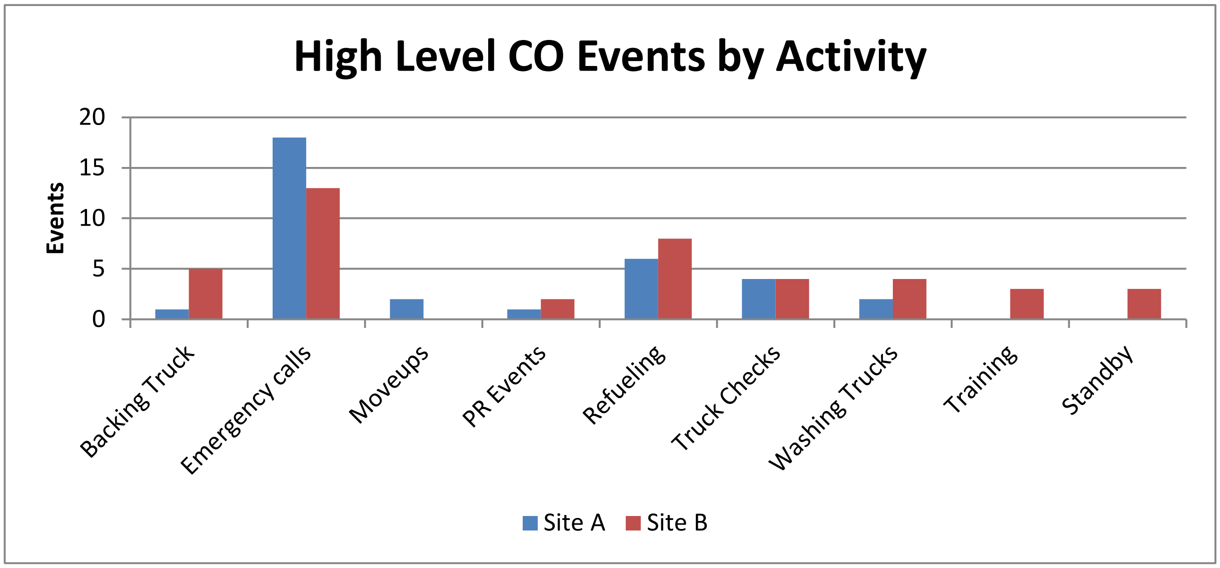
At site B the measurements of STEL were higher, based on the fact that one of the readings was at high levels for a short period of time. The highest STEL reading measured showed at 85.98 ppm. This was during the period of time that the monitor recorded at reading of 499 ppm. The next highest STEL for site B was only 13.18 ppm. The average STEL reading for Site B was 5.82 ppm. The average STEL in the study was 4.83 ppm.

Activity vs. Readings

The participants of the study did many other activities besides running emergency calls that could have subjected them to carbon monoxide. Trainings, checking trucks for readiness, and refueling are just a few of the activities that the participants experienced during the study. When the call data, activity logs, and readings were matched up, important information presented itself. As stated above, there were 121 emergency calls ran by the participants. The total high carbon monoxide events, meaning times when the carbon monoxide levels increased to 10 ppm more, was 76 events.

Of those 76 events, site A accounted for 34 of the total events. The event with the highest carbon monoxide reading of 77 ppm was while a crew was refueling their vehicle. There were six total high level events involving refueling of vehicles. Their average exposure measurement was 26.33 ppm. There were numerous other events involving high carbon monoxide events. Those included emergency calls, which accounted for the majority of the high level events at 18 events. Those had an average carbon monoxide peak reading of 25.28 ppm. Graph 4 shows the breakdown of high level events.

Graph 4: High Level Carbon Monoxide Events by Activity



Site B’s high level events consisted of 42 events in total. Of those events, the one with the highest peak reading, 499 ppm, was the only actual firefighting event monitored in the study. The high reading was caused by a dumpster fire that the firefighter was fighting. During this activity the participant was wearing a self-contained breathing apparatus (SCBA). This prevented the participant from being exposed to the high level of carbon monoxide. Just like with site A, the majority of the high level incidents were measured while the participants were on emergency calls, 13 events in total. The average peak level for those events was 61.62 ppm. The average peak exposure overall was 37.26 ppm.

Symptoms Experienced

The participants were asked to log any symptoms they experienced during the study to evaluate if there is potential that they are experiencing the effects of exposure to high levels of carbon monoxide. Of the 56 participants that were in the study, only three reported any of the symptoms of carbon monoxide exposure. At Site A there were two people who reported symptoms. One of those subjects, a 28 year old male, reported a headache after a transfer. There were no high levels of exposure measured during that transfer or previously in that shift. The other participant that experienced symptoms was a 26-year-old male who stated he had symptoms of fatigue, confusion, and drowsiness at 0730 hours. He noted that they were likely due to being sleepy. The most recent high level that the participant was exposed to was around 8:00 P.M. the day before. Site B had only one participant report experiencing CO related symptoms. The participant complained of a headache. There was a previous event of high levels, 15 ppm, within an hour of the complaint but by the next activity log entry, no report of any symptoms was made.

CHAPTER 5: DISCUSSION

Hypothesis evaluation

At the start of this study, three hypotheses were defined.

Hypothesis 1: EMS and Fire personnel are exposed to high levels of carbon monoxide while on duty.

Hypothesis 2: The primary sources of carbon monoxide that EMS and Fire personnel are exposed to are from their emergency vehicles.

Hypothesis 3: Call and training volume will directly correspond with carbon monoxide exposure levels.

Each of those hypotheses were evaluated against the results of the study. The results were found to be rationally correct in thinking but some unexpected or unforeseen results presented itself from the data.

The first hypothesis stated that EMS and Fire personnel are exposed to high levels of carbon monoxide while on duty. Through the obtained data, it was evident that the majority of times working on their shift, the participants were not exposed to any dangerous or even moderately dangerous levels of carbon monoxide. Over 99% of the time, the air had a concentration of 5 ppm or less of CO. There were however, events that showed exposure to high levels of carbon monoxide. This hypothesis was proven correct through the research and data obtained through the study, but the vast majority of the time, no excess exposure was seen.

The next hypothesis stated that the primary sources of CO that EMS and Fire personnel are exposed to are from their emergency vehicles. The data showed that the vast majority of the time, vehicle exhaust was the source of carbon monoxide in the environments the participants were working in. This result was to be expected due to the fact that the nature of the job requires the participants to be mobile and frequently work in the vicinity of their vehicles. The data showed that the majority of the time the source of the CO could be traced back to their vehicle's exhaust. Rarely was there an event that indicated the source was from other sources. This hypothesis was proven correct through the data obtained during the study.

The final hypothesis for the study stated that the call and training volume will directly correspond with CO levels. This is a partially true statement based on the data presented in the study. Indeed, the call volume did increase the events of CO readings. What was not hypothesized was the fact that the exposure often did not occur directly at the call scene. Rather the exposure came from support activities, required after the call. These activities included backing vehicles into the station, cleaning and restocking the vehicle with materials and supplies, and refueling the vehicles. It was found that these activities either require or are generally done with a participant working inside the vehicle with the doors open or were outside the vehicle but still in close proximity. Further research is needed to identify if call volume does increase the required support activities. In addition, further research should be done to identify if differences in equipment, maintenance procedures and operational procedures affect exposure to personnel.

The portion of this hypothesis that was proven incorrect was there are many other factors that corresponded with exposure of carbon monoxide. Other events showed high exposure rates. In the study there were three public relations events that the participants attended. At each of those events the vehicles are left on due to the large electrical demand of the equipment on board. At these events the participants work in or near the vehicle. In the study, at all three Public Relations events, there was at least one event of high carbon monoxide levels recorded on the participants. I would consider this hypothesis to be partly supported, because based on the obtained data, there are additional factors that affect carbon monoxide levels regularly than just the emergency calls and training.

Peaks

During the study, as stated in previous chapters, the Time Weighted Average was evaluated on a rolling scale by the monitors. OSHA has a TWA PEL of 50 ppm carbon monoxide in an eight-hour period. The highest TWA recorded during the study only reached 31.94 ppm. This level is well below federally required standards. There are other groups that set standards in regards to TWA exposure to carbon monoxide. The National Institute for Occupational Safety and Health (NIOSH) has an established TWA REL for carbon monoxide at 35 ppm in an eight-hour period. Again our data shows that all our test subjects were not exceeding this threshold. The American Conference of Governmental Industrial Hygienist (ACGIH) have published a TWA Threshold Limit Value for carbon monoxide at 25 ppm in an eight-hour period. Looking at our data, two of our participants exceeded these levels during the testing period. ACGIH’s TLVs are not enforceable but are considered a good benchmark to meet.

OSHA’s celling limit for carbon monoxide is set at 200 ppm. Only one event reached these levels during our study. That event was while a firefighter was actively fighting a dumpster fire. That participant had a potential exposure to elevated levels of carbon monoxide above this level for approximately two minutes. The appropriate personal protective equipment (PPE), SCBAs, were worn throughout, thus protecting the participant from the dangerous levels. PPE can range from SCBAs for high levels, to Air Purifying Respirators for low-level environments, with consideration given to the level of CO and other variables in regards to air quality.

As the data suggests, frequent extreme levels of carbon monoxide are not often experienced by emergency responders. Those who have a higher potential to experience those levels, firefighters engaged in active firefighting operations, are often equipped with PPE. A vast majority of firefighting apparatuses are equipped with self-contained breathing apparatuses (SCBA). This equipment is used in the firefighting operations and prevent exposure to high levels of carbon monoxide, as demonstrated through our results.

One area that did show frequent high levels of carbon monoxide exposure was during refueling operations. Refueling is often done with the vehicles running and the participants outside. This activity poses two key dangers to the participant. The first danger, which was not evaluated in this study, was that refueling a running vehicle gives the vapors of the fuel a close ignition source that could potentially ignite and cause a fire. The other danger, which was evaluated in this study, was the fact that the participants have to stand often near the rear of the vehicle, near the exhaust. This position exposes them to the exhaust.

Possible Flaws and Errors in Data

Due to the nature of the study, researchers were not allowed to observe the participants and record their activity. The participants themselves were responsible with the tracking of activities, locations, and symptoms they felt. This setup left room for errors in data entry and timing. To help ensure accuracy, call logs were obtained from each site's dispatch center so the data on times and events would be more accurate and could be used to complement the information provided by the participant's activity log. In the future, a researcher being able to independently observe and track the data may prove to have more accurate results.

There were no control measurements taken during this study. A control would be very difficult to place and track due to the large number of possible locations that the participants operate in. It should also be noted that the study was not designed to evaluate their exposure rates versus other industries or during non-working times. A future study could be created to evaluate if the participants are exposed to higher levels of carbon monoxide while on duty and then off duty.

Recommendations

Monitors

As with any hazard, recognizing the existence of the hazard is the first step to avoiding, mitigating, or eliminating it. The only true identification of carbon monoxide is through active or passive monitoring techniques. Monitors, like the ones used in this study, are low cost and require minimal upkeep. Agencies have already started to equip their personnel with personal monitors or placing fixed units at refueling stations or the bays of their stations. This is a good step but identification is not the only measure needed. Steps need to be taken to control the sources of carbon monoxide and minimize the situations that could exposure workers to dangerous levels.

Controls

Controlling hazards generally is done in one or more control steps. Those steps include avoidance, elimination, substitution, engineering controls, warnings, administrative controls and personal protective equipment. The most effective control is elimination. Unfortunately in this situation, removing the vehicle, the common source of the carbon monoxide, is not an option. Upkeep, though, is an option. Ensuring the vehicle is in good working order will help minimize the levels of carbon monoxide it produces.

Substitution of fuel sources and engine types are a possible solution to mitigate the hazards of the carbon monoxide. This step, however, is often very expensive and often not a suitable alternative. Electric vehicles are becoming more advanced, and the technology is moving in a positive direction; hydrogen fuel cells and compressed natural gas vehicles are, as well. This development in the future could become a suitable alternative to gasoline or diesel powered apparatuses. At this time there are no vehicles on the market that would be a suitable alternative for the current needs.

Engineering controls are the area that show promise to mitigate workers exposure to carbon monoxide. When crews are working in a station bay or hospital, the exhaust is often trapped in the small area they are working in. Local exhaust systems built into those building are effective at drawing the carbon monoxide contaminated air out of the area and pulling fresh air in. Points of source systems are also available that attach directly to the exhaust of the vehicle. This strategy can allow the vehicle to run and personnel to operate all around the vehicle with the exhaust being drawn directly up a tube and out of the building. This is the most effective engineering control found at this point in the study. Site B in the study had this type of system in place, but it was not used during truck checks or training when the vehicle was running.

The vehicles need a constant source of power to maintain the power demand of the vehicles. This requirement is why the vehicle is often running when not in the station. When the vehicle is parked in the station, it is plugged into the building power system. This set up is a possible engineering control that could be used to minimize exposure to personnel. If that same system was used with an extension cord when the truck is outside of the building, refueling, or at any area with a power source available, it would eliminate the need for the vehicle to be running, thus reducing exposure.

Proper administrative controls do need to be implemented to reduce the potential exposure to carbon monoxide. Crews need to be trained on the sources of carbon monoxide, control measures already in place, signs and symptoms of exposure, and how to mitigate exposure. Procedures should be written on proper refueling steps of vehicles, and when and how long it is appropriate to leave the vehicle running. These procedures will allow crews to be aware of the danger and take appropriate steps to minimize their exposure. Alarms can be placed in common areas of high exposure to warn if the levels are getting near dangerous levels.

Personal protective equipment is available to address the hazards of carbon monoxide. The most common form used is the SCBA. This gear provides the wearer with a constant, but limited, source of supplied air. The drawbacks to this gear are that it is very bulky and has only a small supply of stored air. Though the SCBA is common on firefighting apparatuses, it is rarely placed on ambulances. Due to the predictability of the locations and activities in which the hazard can manifest itself, the use of other control measures are more effective.

CHAPTER 6: CONCLUSIONS

In conclusion, carbon monoxide is an ever-present danger to emergency medical services personnel and firefighters. Whether the danger is caused by the exposure of employees to vehicle exhaust or by active fires, the possible risk is always present. Through this study, it was found that the most common cause of elevated carbon monoxide readings was due to the emergency responder's vehicles. The vast majority of those exposures were not caused by direct emergency call scene operations but rather by support operations like refueling, training, and vehicle upkeep. Using engineering controls and administrative controls, exposure to carbon monoxide can be effectively mitigated, thus reducing the risk to personnel. This change will increase the safety and health of personnel on the job, increase readiness to respond to emergencies and care for the sick, injured, and those in danger.

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APPENDICES

Appendix A

CONSENT FORM

Identification of Researchers: This research is being done by Adam Grace, a graduate student, and Dr. Georgi Popov, a professor. We are with the Safety Sciences department at University of Central Missouri.

Purpose of the Study: The purpose of this study is to find out whether Emergency Medical Services personnel and Fire fighters are exposed to excessive levels of Carbon Monoxide through your duty cycle (shift).

Request for Participation: We are inviting you to participate in a study on Carbon Monoxide exposure to you while working. It is up to you whether you would like to participate. If you decide not to participate, you will not be penalized in any way. You can also decide to stop at any time without penalty. If you do not wish to answer any of the questions, you may simply skip them. You may also choose to stop monitoring at any time. You may withdraw your data at the end of the study. If you wish to do this, please tell us before you turn in your materials. Once you turn in the materials, we will not know which survey and/or sample is yours.

Exclusions: You must be at least 18 years of age to participate in this study and not pregnant.

Description of Research Method: This study will evaluate your exposure to Carbon Monoxide while working on duty. You will be asked to wear a monitor while participating in the test. You will also be asked to fill out a short survey that includes information on your age, if you are a smoker and other basic medical information. The survey will take about 5 minutes and the sampling will be for 24 hours. You will also have a chance to ask questions. Please note that we cannot give you your individual results because the data are anonymous.

Privacy: All of the information we collect will be confidential. We will not record your name, social security number, or any information that could be used to identify you. We will also provide you with a blank sheet of paper so that you can cover your responses as you write them down. This will prevent other research participants from seeing your answers.

Explanation of Risks: The risks associated with participating in this study are similar to the risks of everyday life and those experienced while working. All the monitors are approved for working in hazardous atmospheres and contain no dangerous substances.

Explanation of Benefits: The benefit of this study is that it will show the levels of Carbon Monoxide that emergency responders are exposed to during their study. Often while working, emergency responders are unable to properly test for Carbon Monoxide unlike in other industries. This can cause them to possibly be placed into hazardous environments. This study will provide quantitative results of EMS and Fire fighter exposures in both rural and urban areas to identify if further protective measures are needed to protect responders.

Questions: If you have any questions about this study, please contact Adam Grace. He can be reached at amg98550@ucmo.edu or at (913) 709-6989. If you have any questions about your rights as a research participant, please contact the Human Subjects Protection Program at (660) 543-4621.

If you would like to participate, please sign a copy of this letter and return it to me. A copy is available at any time for participants.

I have read this letter and agree to participate.
Signature: ____
Date: ____

Appendix B

Participant Survey

CO Exposure to EMS/Fire personnel during operational period
Department of Safety Sciences
University of Central Missouri

*** NOTE: please only fill out survey AFTER you have signed the participant consent form ***

1. Please identify department/agency you are working for during the study.
   ____
2. Age: ______
3. Sex: ______
4. Do you smoke? __ NO __ YES, if so then how many packs a day? ____
5. Do you ever experience any of the following symptoms while working? (Check all that apply)
   - __ Headache
   - __ Dizziness
   - __ Nausea
   - __ Flu-like symptoms, fatigue
   - __ Confusion
   - __ Agitation
   - __ Drowsiness
   - __ Visual changes
   - __ Fainting
   - __ Memory and walking problems
6. Do those symptoms get worse when on call scenes? __ NO __ Yes, If so what types of calls? (Check all that apply)
   - __ Motor Vehicle Accidents
   - __ Inside a home
   - __ Inside a residential garage
   - __ Inside an apartment/multi occupant dwelling
   - __ Inside a commercial building
   - __ Inside a commercial garage
7. Do you believe you are exposed to high levels of carbon monoxide while working on the job?
   __ Yes __ NO

Appendix C

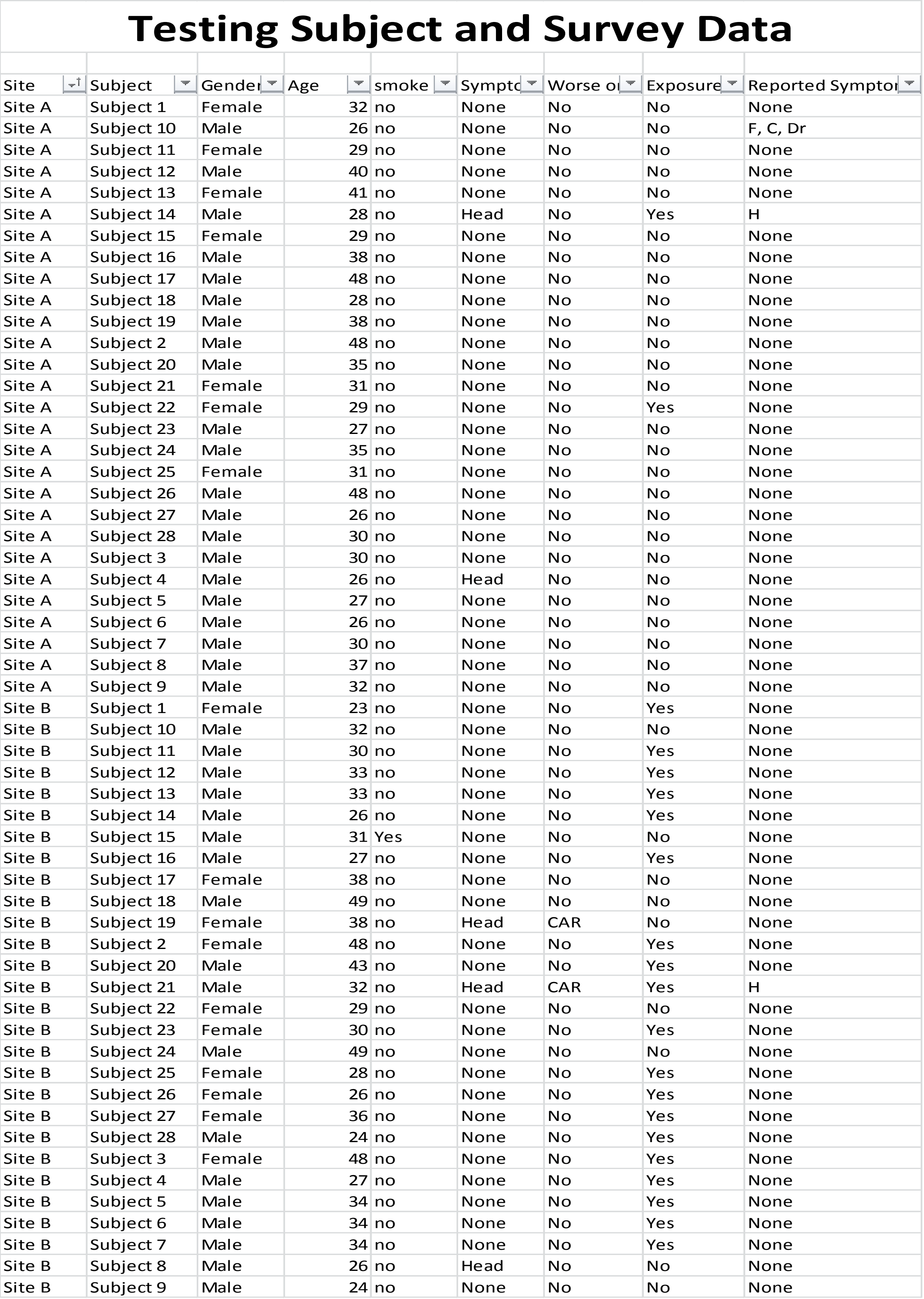
Participant Activity Log

CO Exposure to EMS/Fire Personnel During Operational Period
Department of Safety Sciences
University of Central Missouri

Participant ID:		Sample Date	/ /
Start Time	: AM PM	End Time	: AM PM
Sampling Tool	Electronic CO Monitor		Passive Detection Tube
Observer Type	Researcher	Researcher Representative	Participant

Time	**Activity Code**	**Symptoms**	**Notes**

Appendix D



Testing Subject and Survey Data

Site	Subject	Gender	Age	smoke	Sympto	Worse o	Exposure	Reported Sympto
Site A	Subject 1	Female	32	no	None	No	No	None
Site A	Subject 10	Male	26	no	None	No	No	F, C, Dr
Site A	Subject 11	Female	29	no	None	No	No	None
Site A	Subject 12	Male	40	no	None	No	No	None
Site A	Subject 13	Female	41	no	None	No	No	None
Site A	Subject 14	Male	28	no	Head	No	Yes	H
Site A	Subject 15	Female	29	no	None	No	No	None
Site A	Subject 16	Male	38	no	None	No	No	None
Site A	Subject 17	Male	48	no	None	No	No	None
Site A	Subject 18	Male	28	no	None	No	No	None
Site A	Subject 19	Male	38	no	None	No	No	None
Site A	Subject 2	Male	48	no	None	No	No	None
Site A	Subject 20	Male	35	no	None	No	No	None
Site A	Subject 21	Female	31	no	None	No	No	None
Site A	Subject 22	Female	29	no	None	No	Yes	None
Site A	Subject 23	Male	27	no	None	No	No	None
Site A	Subject 24	Male	35	no	None	No	No	None
Site A	Subject 25	Female	31	no	None	No	No	None
Site A	Subject 26	Male	48	no	None	No	No	None
Site A	Subject 27	Male	26	no	None	No	No	None
Site A	Subject 28	Male	30	no	None	No	No	None
Site A	Subject 3	Male	30	no	None	No	No	None
Site A	Subject 4	Male	26	no	Head	No	No	None
Site A	Subject 5	Male	27	no	None	No	No	None
Site A	Subject 6	Male	26	no	None	No	No	None
Site A	Subject 7	Male	30	no	None	No	No	None
Site A	Subject 8	Male	37	no	None	No	No	None
Site A	Subject 9	Male	32	no	None	No	No	None
Site B	Subject 1	Female	23	no	None	No	Yes	None
Site B	Subject 10	Male	32	no	None	No	No	None
Site B	Subject 11	Male	30	no	None	No	Yes	None
Site B	Subject 12	Male	33	no	None	No	Yes	None
Site B	Subject 13	Male	33	no	None	No	Yes	None
Site B	Subject 14	Male	26	no	None	No	Yes	None
Site B	Subject 15	Male	31	Yes	None	No	No	None
Site B	Subject 16	Male	27	no	None	No	Yes	None
Site B	Subject 17	Female	38	no	None	No	No	None
Site B	Subject 18	Male	49	no	None	No	No	None
Site B	Subject 19	Female	38	no	Head	CAR	No	None
Site B	Subject 2	Female	48	no	None	No	Yes	None
Site B	Subject 20	Male	43	no	None	No	Yes	None
Site B	Subject 21	Male	32	no	Head	CAR	Yes	H
Site B	Subject 22	Female	29	no	None	No	No	None
Site B	Subject 23	Female	30	no	None	No	Yes	None
Site B	Subject 24	Male	49	no	None	No	No	None
Site B	Subject 25	Female	28	no	None	No	Yes	None
Site B	Subject 26	Female	26	no	None	No	Yes	None
Site B	Subject 27	Female	36	no	None	No	Yes	None
Site B	Subject 28	Male	24	no	None	No	Yes	None
Site B	Subject 3	Female	48	no	None	No	Yes	None
Site B	Subject 4	Male	27	no	None	No	Yes	None
Site B	Subject 5	Male	34	no	None	No	Yes	None
Site B	Subject 6	Male	34	no	None	No	Yes	None
Site B	Subject 7	Male	34	no	None	No	Yes	None
Site B	Subject 8	Male	26	no	Head	No	No	None
Site B	Subject 9	Male	24	no	None	No	No	None

Appendix E

Increased Carbon Monoxide Levels on Emergency Calls

Site	Date	Time	Call Type	Notes
Site A	6/9/2013	17:16	EMS	Car Accident
Site A	6/9/2013	12:52	EMS	fall
Site A	6/9/2013	17:23	EMS	Moveup
Site A	6/9/2013	12:32	EMS	Seizure
Site A	6/9/2013	9:06	EMS	Transfer
Site A	6/9/2013	15:05	EMS	Transfer
Site A	6/9/2013	16:37	EMS	Transfer
Site A	6/10/2013	11:07	EMS	Breathing
Site A	6/10/2013	8:37	EMS	Car Accident
Site A	6/10/2013	12:17	EMS	Car Accident
Site A	6/10/2013	23:34	EMS	Car Accident
Site A	6/10/2013	19:39	EMS	Diabetic
Site A	6/10/2013	3:35	EMS	fall
Site A	6/10/2013	10:22	EMS	House Fire
Site A	6/10/2013	14:00	EMS	Laceration
Site A	6/10/2013	12:34	EMS	Psych
Site A	6/10/2013	18:28	EMS	Sick
Site A	6/10/2013	23:58	EMS	Stroke
Site A	6/10/2013	7:43	EMS	Transfer
Site A	6/10/2013	23:04	EMS	Transfer
Site A	6/11/2013	18:36	EMS	Car Accident
Site A	6/11/2013	17:16	EMS	Lift Assist
Site A	6/11/2013	14:21	EMS	Moveup
Site A	6/11/2013	15:07	EMS	Moveup
Site A	6/11/2013	17:17	EMS	Moveup
Site A	6/11/2013	7:50	EMS	Psych
Site A	6/11/2013	8:28	EMS	Sick
Site A	6/11/2013	9:44	EMS	Sick
Site A	6/11/2013	13:53	EMS	Sick
Site A	6/11/2013	14:20	EMS	Sick
Site A	6/11/2013	16:30	EMS	Transfer
Site A	6/11/2013	17:00	EMS	Transfer
Site A	6/11/2013	15:06	EMS	Trauma

Site A	6/11/2013	14:08	EMS	Unconscious
Site A	6/11/2013	20:49	EMS	Unconscious
Site A	6/12/2013	4:31	EMS	Car Accident
Site A	6/12/2013	8:16	EMS	Heat
Site A	6/12/2013	4:44	EMS	Moveup
Site A	6/12/2013	9:02	EMS	Non-Breather
Site A	6/12/2013	10:46	EMS	Pain
Site A	6/12/2013	1:11	EMS	Sick
Site A	6/12/2013	4:37	EMS	Sick
Site A	6/12/2013	4:33	EMS	Transfer
Site A	6/12/2013	10:55	EMS	Trauma
Site A	6/13/2013	6:35	EMS	Car Accident
Site A	6/13/2013	13:57	EMS	Car Fire
Site A	6/13/2013	8:57	EMS	fall
Site A	6/13/2013	15:05	EMS	fall
Site A	6/13/2013	17:33	EMS	fall
Site A	6/13/2013	23:00	EMS	fall
Site A	6/13/2013	15:27	EMS	Seizure
Site A	6/13/2013	8:12	EMS	Sick
Site A	6/13/2013	10:12	EMS	Transfer
Site A	6/13/2013	15:59	EMS	Transfer
Site A	6/13/2013	23:19	EMS	Transfer
Site A	6/13/2013	10:58	EMS	Unconscious
Site A	6/13/2013	12:13	EMS	Unconscious
Site A	6/13/2013	19:06	EMS	Unknown
Site A	6/14/2013	15:53	EMS	Drowning
Site A	6/14/2013	17:30	EMS	fall
Site A	6/14/2013	0:55	EMS	Medical Alert
Site A	6/14/2013	1:56	EMS	Pain
Site A	6/14/2013	1:22	EMS	Sick
Site A	6/14/2013	21:51	EMS	Transfer
Site A	6/15/2013	12:26	EMS	Breathing
Site A	6/15/2013	20:32	EMS	Breathing
Site A	6/15/2013	15:17	EMS	Car Accident
Site A	6/15/2013	13:15	EMS	Drowning
Site A	6/15/2013	15:13	EMS	House Fire
Site A	6/15/2013	9:51	EMS	Pain
Site A	6/15/2013	12:32	EMS	Pain

Site A	6/15/2013	2:51	EMS	Transfer
Site A	6/15/2013	10:15	EMS	Transfer
Site A	6/15/2013	15:05	EMS	Transfer
Site A	6/15/2013	22:27	EMS	Transfer
Site A	6/16/2013	0:27	EMS	Breathing
Site B	7/3/2013	9:17	EMS	Breathing
Site B	7/3/2013	20:17	EMS	Breathing
Site B	7/3/2013	17:23	EMS	car
Site B	7/3/2013	20:52	EMS	car
Site B	7/3/2013	14:57	EMS	fall
Site B	7/3/2013	17:50	Fire	Power
Site B	7/3/2013	18:21	Fire	Power
Site B	7/3/2013	21:12	Fire	Alarm
Site B	7/3/2013	13:06	EMS	Transfer
Site B	7/3/2013	23:26	EMS	Trauma
Site B	7/4/2013	11:45	Fire	Alarm
Site B	7/4/2013	12:01	EMS	Pain
Site B	7/4/2013	22:26	EMS	Pain
Site B	7/4/2013	22:13	EMS	Psych
Site B	7/4/2013	2:14	EMS	Sick
Site B	7/4/2013	18:44	Fire	Alarm
Site B	7/4/2013	21:45	Fire	Fire
Site B	7/4/2013	8:00	EMS	Stroke
Site B	7/4/2013	22:02	Fire	Fire
Site B	7/4/2013	8:00	EMS	Trauma
Site B	7/5/2013	1:02	EMS	car
Site B	7/5/2013	12:05	EMS	car
Site B	7/5/2013	22:00	EMS	car
Site B	7/5/2013	10:45	EMS	fall
Site B	7/5/2013	12:05	EMS	Seizure
Site B	7/5/2013	9:15	EMS	Unconscious
Site B	7/6/2013	0:31	Fire	Alarm
Site B	7/6/2013	12:40	EMS	Breathing
Site B	7/6/2013	6:47	Fire	Alarm
Site B	7/6/2013	12:40	EMS	car
Site B	7/6/2013	16:01	EMS	Diabetic
Site B	7/6/2013	9:46	EMS	fall
Site B	7/6/2013	16:29	EMS	Laceration

Site B	7/6/2013	20:49	EMS	Psych
Site B	7/6/2013	0:04	EMS	Sick
Site B	7/6/2013	19:34	Fire	Alarm
Site B	7/6/2013	18:49	EMS	Sick
Site B	7/6/2013	16:29	EMS	Unconscious
Site B	7/8/2013	22:35	EMS	Laceration
Site B	7/8/2013	16:39	Fire	Alarm
Site B	7/8/2013	20:02	Fire	Power
Site B	7/8/2013	21:51	EMS	Sick
Site B	7/8/2013	23:16	EMS	Sick
Site B	7/9/2013	3:57	EMS	Pain
Site B	7/9/2013	3:56	EMS	Trauma