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A CASE-BASED COMPARISON OF INDUSTRIAL, OCCUPATIONAL, AND SUICIDAL DEATHS VIA HYDROGEN SULFIDE INHALATION IN THE UNITED STATES

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A CASE-BASED COMPARISON OF INDUSTRIAL, OCCUPATIONAL, AND SUICIDAL DEATHS VIA HYDROGEN SULFIDE INHALATION IN THE UNITED STATES

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Acknowledgments

This project was motivated by my experience in working one of two hydrogen sulfide suicide cases during my time as a Medicolegal Death Investigator for the Office of the Chief Medical Examiner in Oklahoma. My passion for death scene investigations and forensic pathology inspired me to shed light on an unsuspecting, and dangerous gas.

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Life is precious and should be treated as such. Sadly, this research would not have been possible had it not been for the unfortunate loss of life and those that have been affected. I hope to do my due diligence in bringing more awareness, education, and understanding to a topic that could potentially help prevent future tragedies.

THESIS ABSTRACT

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ABSTRACT:

Deaths due to accidental and intentional inhalation of chemically generated gases are not an uncommon occurrence in the field of forensic pathology and death investigations. Gases such as carbon monoxide, helium, nitrogen, nitrous oxide, and propane are the most encountered in these types of incidences (Azrael et al., 2016). And yet, an unsuspecting gas, hydrogen sulfide (H_2S), has recently emerged as a significant cause of inhalation mortality in the United States, but not in an anticipated manner. Previously, hydrogen sulfide-related deaths have been associated with fatalities and accidents in industrial and occupational settings such as oil and gas operations, agricultural settings, confined spaces, power plants, and utility industries (Morii et al., 2010). Post 2007-2008, in the United States, H_2S has been utilized as a means of suicide by individuals that intentionally generate the gas, usually, in small, confined spaces.

The first documented H_2S-mediated suicides emerged in Japan in 2007-2008, following a social media dissemination of an online “how-to” guide (Sams et al., 2013). Subsequently, H_2S-

related suicidal deaths have also increased in the United States, more specifically, suicides by the intentional generation of the toxic gas.

Despite the increase in H_2S-mediated suicides within the United States, limited research has been conducted regarding the potential hazards encountered during H_2S death scene response, incident investigation, victim recovery operations, and autopsy examinations. This colorless, odorless gas can pose serious health risks to unsuspecting first responders and other medicolegal personnel attempting to save, remove, or process victims on scene and in other investigatory venues.

To better elucidate the risk factors and pathology novel to H_2S deaths, a survey was deployed using Survey Monkey to members of the ABMDI (American Board of Medicolegal Death Investigators). Autopsy and investigative reports were obtained via email from various Coroner and Medical Examiners' Offices across the United States. Demographic data, incident characteristics, and pathology findings were compared with a previous study wherein preliminary data (n=30 cases) were collected from the National Vital Statistics System (NVSS), NAME (National Association of Medical Examiner's), and public source document searches (Reedy et al., 2011).

Our study demonstrated a definitive increase in reported H_2S fatalities, post-2008, within the United States. Additionally, our data revealed an increase in suicidal deaths via intentional H_2S manufacture and inhalation, as well as the presence of a preponderance of novel, greenish-discolored brain, and central nervous system tissues, unrelated to postmortem decomposition.

To ensure the safe investigation and diagnosis of deaths due to H_2S inhalation, it is paramount to incorporate a comprehensive, timely combination of scene information, decedent history, as well as the safe collection of appropriate anatomical and toxicological postmortem specimens. Postmortem analyses should include the quantification of thiosulfate levels in blood and/or urine, a detailed history of circumstances surrounding H_2S exposure, and a central nervous system (CNS)-focused internal examination or complete autopsy. Additionally, brain and CNS tissue should be thoroughly examined to elucidate a unique and possibly pathognomonic appearance of a greenish discoloration informative to H_2S toxicity.

This research has implications for the enhanced understanding of personnel and environmental hazards, incident dynamics, asphyxia mechanisms, and postmortem findings associated with H_2S-related fatalities.

Table of Contents

Table of Figures

List of Tables

CHAPTER I

Introduction

Background

Deaths due to accidental and intentional inhalation of chemically or naturally generated gasses are familiar in medicolegal investigations and forensic pathology. Gases such as carbon monoxide, helium, nitrogen, nitrous oxide, and propane are the most familiar (Azrael et al., 2016). These types of deaths are violent, unusual, and unnatural and fall under the category of death due to asphyxia. Greek for "without a pulse", these cases have varying mechanisms in which death may occur. The mechanism of asphyxia involves the deprivation and/or interference with the uptake and utilization of oxygen within the human body.

Asphyxia deaths occur in many diverse types of instances such as, general accidents, industrial and occupational accidents, homicides, and suicides. However, deaths by these gases are familiar and have a multitude of research to follow. The most common incidences of death due to asphyxiation via chemicals and gasses occur primarily in certain professions and on industrial sites such as oil and gas wells, manure pits, manholes, power plants, and utility sites (Occupational Safety and Health Administration [OSHA]).

Deaths due to asphyxia, have increased from 2005-2014 in the United States. Asphyxia includes but is not limited to chemicals and/or gases; it also includes ligature hangings, suffocation, and smothering (Yau & Paschall, 2018). Within this increase, 134 cases between 2005-2014 were deemed suicides via inhalation of chemicals and/or gases (Yau & Paschall, 2018). More recently, a new mechanism of intentionally generating a toxic gas has become a popular suicide trend in Japan. Its infamous media attention and easily accessible "how-to" online instructional guide is believed to be the culprit for the massive surge of suicide incidents since its first appearance in 2007 (Reedy et al.,2011). Since then, hydrogen sulfide (H_2S) suicides have increased exponentially, not only in Japan, but have been appearing in the United States.

This colorless, flammable, low-laying gas has a "rotten egg" odor, at lower parts per million, ppm. It is water soluble and can cause mild symptoms in concentrations as low as 10ppm. H_2S gas inhibits mitochondrial enzymes during cellular respiration by binding with the Fe^{3+} of cytochrome C oxidase, which then interferes with the utilization of oxygen, frequently producing fatal asphyxia. Unlike more common suicidal and accidental chemical asphyxiants, such as helium, carbon monoxide, carbon dioxide, and cyanide, H_2S is not as frequently encountered by most first responders and medicolegal personnel.

Most individuals that choose this method of intentionally generating a gas to commit suicide, do not leave suicide notes or any indicators to warn responders of the hazardous substance they have used. Therefore, unsuspecting first responders, medical, and medicolegal personnel are at elevated risk of exposure to the gas and can suffer severe health complications when attempting to rescue or remove victims and decedents. Little information or recent literature exists demonstrating the warning signs of intentionally generated H_2S as a means of suicide and its associated risks.

Not only is this gas deadly in its immediate environment, but it can also cause secondary exposure during autopsies. This gas is notorious for remaining within the body cavity of the decedent and can result in the process of "off-gassing". Residual H_2S gas can remain in the body and cause secondary exposure and harm to forensic pathologists and personnel during the examination of the thoracic cavity at autopsy. More research is necessary to better educate responders of all types on scene response, personnel and environmental hazards, and incident dynamics.

This gas has been observed and speculated to produce a uniquely novel postmortem finding of a greenish-discolored brain that is not associated with other causes of death and can be differentiated from postmortem putrefactive changes. This greenish-discolored brain can only be visualized if a full autopsy is conducted on each case. No studies have been done with enough cases to demonstrate the prevalence of such a pathological finding. This could be helpful when diagnosing death due to H_2S when the scene findings and other postmortem specimens are found to be unremarkable.

Problem Statement

Gas and chemical suicides are common, but a rise in a new suicide technique presents safety concerns for all those involved. This understudied gas, H_2S, as an intentionally generated and inhaled mechanism has appeared within the United States since its emergence in Japan, circa 2007. These cases are increasing in number within the United States which demands more research to better educate respondents to take precautions when responding to such incidences. Information needs to be updated and made available for first responders and medicolegal personnel with regard to scene safety and procedures to follow when encountering potential cases involving intentionally generated H_2S. Without updated information and education, these scenes can cause minimal to very severe effects, including death, to those who are unaware of its presence.

Significance of the Study

The purpose of this study was to demonstrate the characteristics of H_2S cases and determine if there is an increasing presence of suicides via H_2S inhalation within the USA. This study also includes cases of the more common manner of death involving H_2S, via accidents. This study demonstrated trends in H_2S-related fatalities, as well as associated demographic characteristics, and the postmortem pathognomonic finding of a greenish-discolored brain and its potential to be a definitive and unique diagnostic marker of H_2S toxicity. This research has implications for the enhanced understanding of personnel and environmental hazards, incident dynamics, and postmortem findings associated with H_2S-related fatalities.

CHAPTER II

Review of the Literature

Asphyxia Overview

Death via chemical and gaseous asphyxiants occurs in both suicides and industrial/ occupationally related accidents. Some of the most frequently encountered deaths involve chemical and gaseous asphyxiants such as cyanide, chlorine, carbon dioxide, helium, and carbon monoxide. Death by gas inhalation accounts for 5-15% of suicides in the world (Azrael et al., 2016). Carbon monoxide is the most utilized, fatal, chemical asphyxiant in the United States (Henn et al., 2013). Although, trends in intentionally generating gases like H_2S, lack abundant and current, research.

The trend of intentionally generating H_2S as a means of suicide has increased in the United States since its first appearance in Japan between 2007 and 2008. This method of suicide has limited research and information for first responders as well as medicolegal personnel regarding the safety precautions necessary for safely approaching scenes. Information on these types of cases could help in working these scenes as they are not always the typical industrial-occupational settings that responders are accustomed to. H_2S-related deaths are mostly accidental, commonly occurring at industrial and occupational job sites, but are now becoming an increasing method of suicide. This increase in cases of H_2S-related suicides within the United States should be alarming and necessitate more research on the topic. Current research is also limited concerning the postmortem finding of a greenish discolored brain. Such an association in H_2S deaths may further substantiate a novel, definitive diagnosis of death when a complete autopsy cannot be conducted, or when other findings are unremarkable. Other means of diagnosing death via H_2S include a combination of scene investigation and history, postmortem toxicological findings of elevated levels of thiosulfate, and greenish-discolored organs, not related to postmortem decomposition.

Knowing more about this new method of intentionally generating this toxic gas could help gain a better understanding of the up-and-coming technique of suicide via H_2S inhalation. Furthermore, its postmortem effects on the brain could prove useful as a differentiative and unique postmortem finding in diagnosing deaths due to H_2S.

This literature review will address several areas of research starting with an overview of chemical and gaseous asphyxiants. Followed by the origination of the H_2S suicide trend and the increase of suicidal deaths via H_2S inhalation within the United States. It will also cover how this method has increased exponentially since its origination in Japan in 2007. The preceding section will cover the most familiar type of death via H_2S poisonings at industrial/occupational-related job sites. The concluding section will cover postmortem observations and physiological changes of cases where H_2S was intentionally generated and/ or accidentally inhaled by the decedents and their associated toxicological findings. This section will also cover the etiology and postmortem observation of a greenish-discolored brain as a pathognomonic finding in postmortem examinations of decedents who have died via inhalation of H_2S.

Chemical and Gaseous Asphyxiants

Chemical and gaseous asphyxiants are common in medicolegal death investigations, and industrial, and occupational settings. Death due to inhalation, whether accidental or intentional, has been the focus of many industrial, occupational and safety researchers, but also in the field of medicine and forensic pathology. Chemical and gaseous-related suicides have become more frequently encountered but the source and mechanism in which gas or chemicals are used have only focused on a few primary asphyxiants. The most notable gas is carbon monoxide. From 2005-2012, the most used asphyxiant in suicides was carbon monoxide (Azrael et al., 2016), followed by helium and hydrogen sulfide. Carbon monoxide suicides are usually accomplished by burning charcoal in an enclosed area or hooking a hose from the exhaust pipe of a running car in through the window where the person inhales it. The article by Azrael et al., 2016, discusses the difficulty in tracking sources and means of methods of gas and chemical suicides due to the lack of mortality data available. This lack of data does not adequately address the source or type of the chemical or gaseous asphyxiants (car exhaust, charcoal, helium tank, etc.). The authors describe that the U.S. National Center for Health Statistics mortality data uses a coding system that does not include such information so that cases can be distinguished by source and/or type. Azrael et al., 2016, use The National Violent Death Reporting System (NVDRS) and describe the data to be inefficient at capturing the relevant information through a coding system, but were able to locate within the text of these case reports, the type and source of asphyxiants used. Information was gathered using text variables and coded variables to locate cases and identify sources and types. The result shows that "Of the 80,715 suicides in the data set, 3,242 (4%) were suicides due to gas" (Azrael et al., 2016). Most of these cases were death by CO poisoning, with 13% being by charcoal burning and the remaining majority were by motor vehicle exhaust as the source (Azrael et al., 2016). The remaining suicides used nitrogen (4%), nitrous oxide (3%), propane (3%), helium (77%), hydrogen sulfide (5%) and unspecified gases (2%) (Azrael et al., 2016). This study further substantiates that most gaseous suicides are carried out using carbon monoxide. Azrael et al., 2016, mention that other types of gaseous suicides are too infrequent to identify trends.

Hydrogen Sulfide Gas

H_2S is a colorless, low-lying, flammable gas. "It is recognized by its distinctive "rotten egg" odor and is found in natural gas wells, sulfur springs, coal pits, and other areas where organic, decaying matter is present" (Ballerino-Regan & Longmire, 2010). At higher levels, this odor dissipates, making the presence of the gas even deadlier to unsuspecting victims. It is heavier than air which is why it easily accumulates in confined areas with little to no ventilation (Centers for Disease Control and Prevention, 2014). It is water soluble and can cause mild symptoms at concentrations as low as 10ppm. Primary exposure is due to inhalation and can affect the respiratory and digestive systems and is also an ocular irritant. H_2S interferes with cellular respiration by inhibiting cytochrome oxidase, preventing the utilization and uptake of oxygen. It wreaks havoc on the systemic system which includes organs such as the brain, liver, kidneys, small intestines, and pancreas (Mesrati et al., 2019). In short, exposure to lethal levels leads to asphyxiation.

The Origination of Suicide via Hydrogen Sulfide Inhalation in Japan

Previous deaths by H_2S inhalation have most commonly been associated with industrial/ occupational-related incidents. Morii et al., 2010, note that the first appearance of suicide via H_2S inhalation occurred in 2007. In 2008, Japan experienced a surge in deaths and attempted suicides via intentional hydrogen sulfide inhalation. All in part, to what Morii et al. attributed this to a popular online message board that gave specific instructions on how to create the toxic gas at home using easily accessible and common household products. These products consisted of a toilet cleaning product, an oxidative ingredient, and a bath additive, (a lime-sulfur reagent). Bathing is a popular custom in Japan and products like bath additives are common to have in the household. MUTOHAP was a popular bath additive that was forced to cease production after the online message board coined the product as a key ingredient in creating H_2S for the purpose of suicidal inhalation. The Japanese Cabinet Office claimed that in 2008, within 80 days, 220 people were reported to have attempted suicide via H_2S. 208 of those cases were fatalities. It was noted that in 2008 several deaths occurred secondarily to family members when they attempted to save their loved ones during the commission of their suicide attempts.

Characteristics and Increase in Hydrogen Sulfide Suicides within the United States

Since its emergence in Japan between 2007-2008, suicide via H_2S inhalation has increased exponentially and made its way to the United States. H_2S gas is ubiquitous in oil, gas, industrial, and mechanical industries. As an intentionally generated gas, H_2S poses a threat to unsuspecting first responders, medical personnel, last responders, and forensic pathologists. Reedy et al., 2011, discusses the underestimated increase and characteristics of H_2S suicide cases within the United States in recent years. The study was intended to be informative for future first responders and health officials to become aware of this increasingly dangerous suicide method. The authors determined that instructions were posted on an online "how-to" message board discovered by Japanese law enforcement officials. Subsequently, there has been an upward trend in suicide by hydrogen sulfide in the USA. Prior to these events, hydrogen sulfide deaths were commonly associated with industrial-occupational accidents. There is a detailed list within the article of common acid/ sulfur sources used in these cases also known as detergent suicides. The authors believe the website with this information contributed to the increase in suicide cases by H_2S by making this information easily accessible for consumers.

The purpose of the study was to examine the increase in frequency and individual characteristics of H_2S suicide deaths in the U.S. by collecting data from the National Vital

Statistics System (NVSS) from the Center for Disease Control's website. The authors also collected data via listserv, contacting Medical Examiners through the NAME system (the National Association of Medical Examiners) and Google. The information, reports, and details obtained were voluntarily given by these sources. All cases were required to have H_2S, and suicide listed as cause and manners of deaths for the purpose of this study. Responses by Medical Examiners were not mandatory. The results from NVSS and NCHS showed "...there were 45 deaths from hydrogen sulfide from 1999 to 2007, but all were deemed unintentional." (Reedy et al.,2011). Data from the listserv responses yielded eleven cases from 2008-2010 and Google search showed nineteen more cases in the U.S. (30 cases total). Demographics included primarily Caucasian males between the ages of 20-44 years old.

The study showed a significant increase in H_2S suicides in the U.S. between the years 2008 and 2010. According to Reedy et al., 2011, many first responders have been injured while attending to these decedents. It is vital for emergency, first, and last responders to be aware of these types of cases to prevent future injuries to themselves or others.

Characteristics of Hydrogen Sulfide Cases

Previous studies have demonstrated that intentionally generated H_2S cases have occurred in confined spaces such as small rooms and vehicles (Reedy et al.,2011). There are warning signs and indicators that help determine a H_2S-related scene such as, warning signs posted by the victim, suicide notes, buckets/pails, bottles household chemicals or pesticides, taped vents and windows, and chemical odors (LA-RTTAC, 2010). The study by Reedy et al., 2011, mentioned that just less than half of the thirty decedents in their study left warning notes with information regarding the utilization of H_2S gas and that 77% committed suicide in their vehicles.

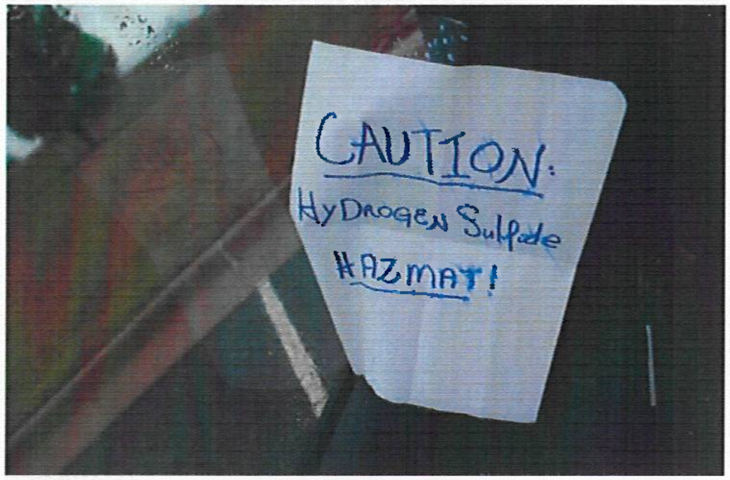

Figure 1: A warning note left at the scene of a H2S fatality scene taped inside the vehicle.

Figure 2: Buckets with remnants of chemicals used to intentionally generate H2S inside a vehicle.

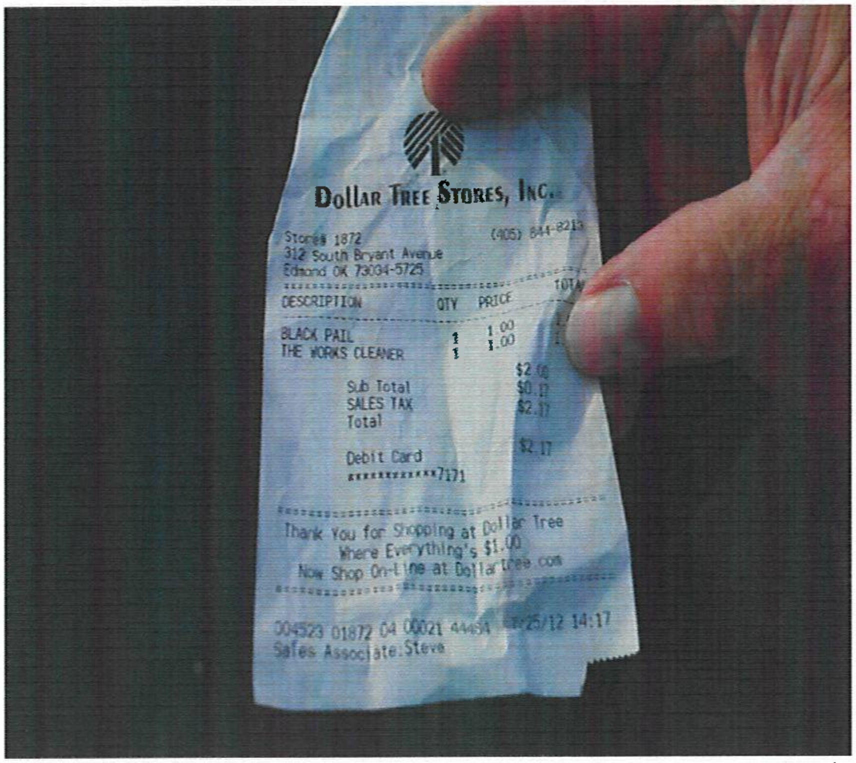

Figure 3: Evidence: receipt containing purchase information of a bucket and "The Works" toilet bowl cleaner utilized in an H2S case.

Case Reviews of Hydrogen Sulfide Suicide in the United States

A more recent article reiterates the dangers of H_2S and its increasing presence within the United States by discussing the origination of H_2S as a suicide method and a review of two cases of suicide by H_2S. Authors mention that Japan had 517 intentional H_2S suicides in 2008 (Sams et al., 2013). This article also mentions the popular, online how-to guides that were made available for the public to research and carry out this mode of suicide with hazard signs to be printed and placed at their location of suicide to warn others of the presence of the poisonous gas. Issues with these types of fatalities are that not all decedents use signs or notes warning first responders of what chemicals are present. "In 2008, The Japan Times reported that a 14-year-old girl's use of H_2S to commit suicide had forced an evacuation of her building, and 80 other occupants were sickened from exposure" (Sams et al., 2013).

Figure 4: Death scene of intentionally generated H2S. Decedent mixed household chemicals in a secure, sealed-off vehicle.

Sams et al. review two cases of decedents that committed suicide via H_2S inhalation while in their vehicles. Both decedents were found deceased in their vehicles, both left warning signs/ notes on their vehicle notifying first responders of the poisonous gas. Both were deemed death due to H_2S poisoning with the associated manner of deaths being suicides. This article sheds further light on the topic of suicides by H_2S making their way into the United States, but it is also, outdated. No current research has been done to prove or disprove an ongoing increase in its prevalence within the United States since this study was conducted. To date, this is the most recent case study with regards to this topic. Authors only used two cases which is too small of a sample size to demonstrate any significant trends in the United States.

Previous History of Occupational Hydrogen Sulfide Deaths

Although H_2S-related suicides seem to be increasing in the United States, it is not a new mechanism of death. As mentioned previously, H_2S has most commonly been associated with work work-related or industrial-type accidents (Morii et al., 2010). Thus, there is more research and safety protocols with regards to these types of deaths. They are mostly accidental in nature and occur on job sites and/or industrial settings.

According to the Occupational Safety and Health Administration (OSHA), there are parameters and limits of exposure to H_2S that they deem acceptable. "...The General Industry Permissible Exposure Limit is a ceiling of 20 ppm with a 50 ppm 10-minute peak allowed once during an 8-hour shift" (Ballerino-Regan & Longmire, 2010).

A study by Fuller et al., 2000, describes their findings of H_2S in occupationally related deaths that occurred within the United States between the years 1984 to 1994. The authors preface this article with the mechanism of action of the poisonous gas, H_2S, and its effects on the mitochondrial electron transport chain. The gas is heavy which means it displaces oxygen and even more so in confined spaces depending on the concentration. H_2S is a by-product of the chemical breakdown of organic materials and can be found in many different places such as sewers, power plants, oil producing wells, natural gas wells, wastewater treatment facilities, and sulfur springs, to name a few. "Crude oil is often saturated with H_2S, and natural gas may have levels of H_2S as high as 90% (900,000 ppm)." (Fuller et al., p. 940). Per the National Institute for Occupational Safety and Health, H_2S is present in at least seventy-three occupations, which means there are thousands of employees who could have anywhere from low to high rates of exposure. The authors list a table with differing amounts of H_2S concentrations and the corresponding effects on the body.

The authors further mention that no unique code was used for H_2S to classify deaths or injuries using vital statistics. Fuller et al., 2000, searched records through the U.S. Occupational Safety and Health Administration (OSHA) investigations using the fatality reports generated in the Integrated Management Information System (IMIS). The results showed 18,559 occupational-related deaths occurred that were reported to IMIS and OSHA. Of those deaths, eighty were due to H_2S poisoning that occurred in fifty-seven incidents. Of these incidents, thirty-six non-fatal injuries were documented as requiring hospitalization and treatments for H_2S exposure. Sixty-nine out of eighty fatalities were noted to be within confined spaces, as defined by OSHA, and nineteen fatalities were due to attempts to rescue other coworkers.

The authors demonstrated that occupational H_2S-related deaths had decreased over the years but recommended that employers must modify safety policies and procedures to further keep these incidents from happening in the workplace. They explained the importance of personal protective equipment and proper training/ education for employees working in these types of spaces. Fuller et al., 2000, express the importance of also training and informing first responders on how to safely handle and respond to these types of scenes.

Case Review: Hydrogen Sulfide Deaths in Unconfined Spaces

Aside from being intentionally generated by mixing chemicals, H_2S is commonly found in sewers, confined spaces, industrial power plants, volcanoes, water wells, oil, and gas wells (OSHA, 2000). It is easily produced when three factors are present. The first one being a sulphate source, this can come via byproduct of bacteria or chemicals; anaerobic conditions such as small, confined spaces or spaces with inadequate ventilation or air flow, and the third, being temperatures of greater than or equal to 68° F (Nogue et al., 2011). Nogue et al., 2011, elaborate on two incidents involving four fatalities due to H_2S poisoning that occurred at job sites. The first case involved three workers that entered an unconfined, interior room that contained wastewater byproducts, at the same time, a truck containing sludge from water purification stations began unloading into the silo next to the interior room. One of the workers began climbing out of the room when he lost consciousness due to the accumulated H_2S that had spilled out of the silo into the interior room where the workers were. The other workers rushed to the first workers' aid and met their demise. The second incident included one worker that was a foreman at a wastewater facility. As he was checking a wastewater substation, he lost consciousness then was later rescued and transported to a nearby hospital. During transport to a secondary hospital, he died from inhalation of the poisonous gas "… due to an 'embolism effect' produced by the displacement of wastewater when the substation pumps were turned on." (Nogue et al., 2011). This further substantiates the need for further education in the occupational field as well as for people responding to these types of scenes.

Diagnosing Death by Hydrogen Sulfide

Suspected deaths due to H_2S almost always warrant an autopsy. Cause of death due to H_2S can be diagnosed by multiple factors during the investigation. Current literature and research utilize the presence of thiosulfate and sulfide levels within the blood, thiosulfate in the urine, as well as scene investigation reports to confirm death by H_2S. According to Ballerino-Regan and Longmire, 2010, postmortem findings can include but are not limited to petechial hemorrhaging, hemorrhagic pulmonary edema, visceral congestion, myocarditis, a greenish color of the brain, viscera, and bronchial secretions. They further explain that these findings are highly variable. When it comes to testing blood thiosulfate, "Levels ranging from 8 to 77 times the normal level of 0.3 μg/mL have been documented in fatalities…" (Ballerino-Regan & Longmire, 2010). According to Ballerino-Regan and Longmire, 2010, blood sulfide levels are not useful if not taken within two hours of exposure. The article also mentions that thiosulfate may not be detectable in urine samples in cases of rapid exposure. The authors also mention the usefulness of obtaining brain and lung tissues to test for thiosulfate levels.

An article by Mesrati et al., 2019, discusses two autopsy cases and the complications associated with diagnosing death via hydrogen sulfide. In the body, the sulfide metabolizes to form thiosulfate. Issues can arise from testing for thiosulfate levels postmortem because, as the body decomposes, it produces more naturally occurring H_2S, thus making the test in other fluids and tissues less reliable (Mesrati et al., 2019).

Postmortem Findings Case Study of 6 Successional Deaths via Hydrogen Sulfide

Regardless of the manner of exposure, postmortem findings in cases of H_2S prove to have common pathological findings. The study by Barbera et al., 2016, examined not only occupational-related deaths but more specifically, their associated postmortem findings.

Barbera et al., 2016, preface this article with information about H_2S and associated physical/ neurological symptoms in relation to different concentration levels. The authors studied six fatalities that occurred because of H_2S exposure while working to unblock a wastewater cistern. All six were autopsied and femoral blood samples collected for toxicological analysis. The results showed all six decedents had H_2S in their femoral blood "…concentrations ranged from 8.7 to 28.6 mg/L." (Barbera et al., p. e8). The authors emphasize that H_2S "… is absorbed rapidly through the lungs in animals and humans, it is then distributed to the blood, brain, lungs, heart, liver, spleen, and kidneys." (Barbera et al., p. e9).

Toxicological analysis was key to identifying the amounts of H_2S in the femoral blood of all six decedents. Five out of six died because of poisoning and the sixth died because of drowning in fluid after the gas caused him to become unconscious. Barbera et al., 2016, stress the importance of toxicological analyses in these types of cases and how the different concentrations of this gas can cause immediate and rapid fatal decline.

This article was interesting because it was one event that resulted in six consecutive fatalities. The ranges in H_2S concentrations were interesting to see the levels in the first decedent to the sixth (levels slowly declined due to the decedents' proximity to the leak). These cases shed light that concentration levels of inhaled H_2S could have associated postmortem findings depending on the initial concentration of the gas at the time of the incident. This article gives insight to one of the ways H_2S fatalities can be diagnosed and how postmortem thiosulfate can be correlated with concentration levels of H_2S.

Postmortem Findings of a Greenish-Discolored Brain

One of the remarkable findings in current literature with regards to H_2S poisonings is the discovery of a greenish discolored brain. As mentioned previously, levels of thiosulfate might not be obtainable if certain parameters are not met. According to Ballerino-Regan and Longmire, 2010, blood sulfide levels are not useful if not taken within two hours of exposure; they also mention that thiosulfate is not detectable in urine in cases of rapid exposure.

Ballerino-Regan and Longmire, 2010, aimed to prove the finding of a greenish-discolored brain is a definitive marker in diagnosing death by H_2S poisoning. Park et al., 2009, discuss discoloration of the brain as being the only remarkable postmortem autopsy finding in cases involving H_2S gas. The authors describe this greenish discoloration to be rare, but it has been observed in several postmortem autopsies. The authors describe a case study involving a 35-year-old male who was found unresponsive at a chemical manufacturing factory. The decedent was said to be mixing chemicals for a new product when a noxious gas was created. The decedent was pronounced at the emergency room shortly after arrival. An autopsy was performed, and the intracranial exam showed a greenish-discolored brain. "A blood gas analysis revealed that the sulphide ion (S^2) concentration was 1.1 ppm (parts per million), about 36-fold higher than the reference value (0.03 ppm[1])." (Park et al., p. e19). No other remarkable findings were noted in the white matter of the brain or histological samples.

Park et al., 2009, demonstrate in a table the findings from the case study and compared them with those of three other cases (n=4). Three out of four cases had a greenish discolored brain and two out of four had other greenish discolored internal organs. The authors note that the mechanism of how this discoloration occurs is unknown. The authors stress the importance of requesting a blood gas analysis if H_2S is suspected in a death if the internal exam during autopsy is unremarkable for other definitive findings.

This was an informative article as it discussed one of the potentially distinctive postmortem findings of H_2S cases. Green central nervous tissue discoloration seems to be a unique identifier of these types of cases, but this report showed that it is not always present. The weakness is that this was not a large enough sample size to draw any major, definitive conclusions on the association between greenish-discolored brains and H_2S. Therefore, a larger sample size may prove that a greenish-discolored brain can be used to diagnose death due to H_2S.

Etiologies and Mechanisms of Postmortem Brain Discoloration

Part of the postmortem internal examination in autopsy cases is the examination of the cranium, which houses the brain. The normal human brain, which consists of differing regions and tissues, should be light with colors ranging from a pink to white and tan, depending on the tissue and region (Ahrendsen & Varma, 2021). Any discoloration or deviation from the norm of brain tissue is considered remarkable and can help diagnose certain diseases or etiological agents that could help with pathognomonic origin. A study conducted by Ahrendsen and Varma, 2021, examined differing discolorations by examining human brains, postmortem. Three cases were examined with separate etiological agents including methylene blue treatment (MB), hyperbilirubinemia hemorrhagic infarction, and H_2S poisoning. The study showed that each etiological agent affected specific and different regions of the brain. For example, MB treatment showed a blue-green discoloration in the cerebral gray, periventricular matter, cerebellum, and brainstem regions; the H_2S poisoning showed a dusky gray-green discoloration only in the cerebral gray matter and in the deep gray basal ganglia regions, and hyperbilirubinemia hemorrhagic infarction yielded a bright green discoloration in all regions of the cerebrum, the deep gray basal ganglia, and the dentate nucleus of the cerebellum (Ahrendsen & Varma, 2021).

This further elucidates that death due to H_2S produces a regionally, unique greenish discoloration in human brain tissues. Although H_2S is a natural byproduct of decomposition, it can be differentiated from acute/toxic H_2S exposure in the brain by examining the presence or absence of associated putrefactive changes caused by decomposition (Ahrendsen & Varma, 2021). As with other decomposed organs, if the brain exhibits advanced decomposition, it might be hard to confirm or negate the presence of a pre-putrefactive discoloration related to external

H_2S exposure. To observe this, cases need to have an autopsy conducted. The caveat to this is that this finding has yet to prove its appearance occurs in most cases involving H_2S.

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CHAPTER III

Methods

Purpose Statement

The purpose of this study was to determine if there has been an increase in frequency in H_2S-related cases within the United States, examine incident dynamics, as well as explore decedent demographics, asphyxia mechanisms, personnel and environmental hazards, and postmortem findings associated with H_2S-related fatalities.

Research Questions

1. Has there been an increase in the frequency of H_2S-related cases within the United States since 2008, more specifically, suicides?
2. What are the discernable patterns in decedent demographics and incident dynamics with regards to H_2S deaths?
3. Does the presence of a greenish-discolored brain indicate a pathognomonic, diagnostic marker for death via H_2S?

Null Hypothesis

There has been no increase in the frequency or continued prevalence of H_2S-related fatalities in the United States. There were no evident, discernable patterns in decedent demographics and incident dynamics. A greenish-discolored brain was not a pathognomonic marker for accurately diagnosing death via H_2S.

Research Design

This research followed a nonexperimental, explanatory qualitative case study design approach. Cases were that of pre-existing medical examiner reports and survey responses that were utilized to obtain information on H_2S-related fatalities from select agencies across the United States post 2008 to the beginning months of 2023 and combining them into one data set.

This study's investigative and autopsy case reports were selected upon the use or mention of the key words "Hydrogen Sulfide". Manners of death included in this study were suicide and accident.

Case Sample

The case sample for this study included investigative and autopsy reports that included H_2S in the cause of death section of each report. Medical Examiner and Coroner's Offices were in select cities/ counties in California, Florida, Illinois, Oklahoma, New Mexico, New York, and Texas. The data yielded fifty-five cases with a total of fifty-three cases that contained sufficient information for evaluation in this study.

Data Collection

A series of questions were deployed using Survey Monkey via email to members of the American Board of Medicolegal Death Investigators (ABMDI).[5] The survey contained questions regarding H_2S - related cases that have been worked by their agencies from 2008-2023. The questions included decedent demographics, location of incident (vehicle/residence/ job site/unknown), cause and manner of death, and with regards to each case, was a greenish-discolored brain present, and any other significant observations and/or information. Data was collected solely on participant responses via LISTSERV. Responses from the ABMDI were strictly voluntary and data was obtained from the number of responses received over the course of five months. Data was also collected by sending requests for investigative and autopsy reports to Medical Examiner and Coroner's offices in major cities/ counties across the United States. All cases requested had to mention H_2S as a cause of death. Incident characteristics, decedent demographics, and pathological findings were collected utilizing both methods of data collection.

Data Analysis

The respondents' entries and the data collected from evaluation of investigative and autopsy reports were categorized and charted to determine any changes in frequency and demonstrate any trends in H_2S fatalities within the U.S. The categorizations were as follows:

- Frequency of H_2S Fatalities
    - Suicides
- Demographics
    - Gender
    - Age
    - Ethnicity
- Location of Injury
    - Vehicles
    - Job Sites
    - Other
- Cause of Death
    - Different terminology utilized to diagnose death via H_2S
- Manner of Death
    - Accident
    - Suicide
- Postmortem Findings
    - Greenish-discolored brain

- Open-ended responses

Once all responses were collected and case data was reviewed the data was organized using the Microsoft Excel platform with one case per line including cause of death, manner of death, gender, age, ethnicity, postmortem findings, location of incident, and state. Responses were entered into R, a software program geared toward generating, statistical graphs and analyses. The table command of R was used to cross-tabulate the data and create contingency tables.

Data Confidentiality

The investigative and autopsy reports were kept in a secure location only accessible to the researcher. Identifying information for the individuals in these cases were not requested or utilized in this study. Personal information was redacted in most reports before retrieval. All electronic and paper copies of cases were destroyed upon the completion of this research.

Results

Frequency

In total, the data revealed fifty-three cases of deaths due to H_2S. When divided into manner of death being suicide or accident, the data contained forty-two suicides and eleven accidents. Suicide cases were absent in the data set (0 cases) in the years 2008, 2009, and 2015. The highest spike in suicides was in 2012 with seven cases. Despite having a total of forty-two suicides, this study revealed no significant, consistent increase in H_2S suicides within the United States status post 2008. The data demonstrated that suicides via H_2S were still occurring, and more frequently than cases involving accidental deaths, but there was again, no discernable increase in the number of cases, when examined by year (see Figure 5). When combining suicidal and accidental deaths by year, there were still no visible, discernable trends or increase in frequency in the number of cases. These cases mimicked the inconsistencies of suicide cases with the exemption of one accidental death that occurred in 2008, zero cases were reported in 2009 and 2015.

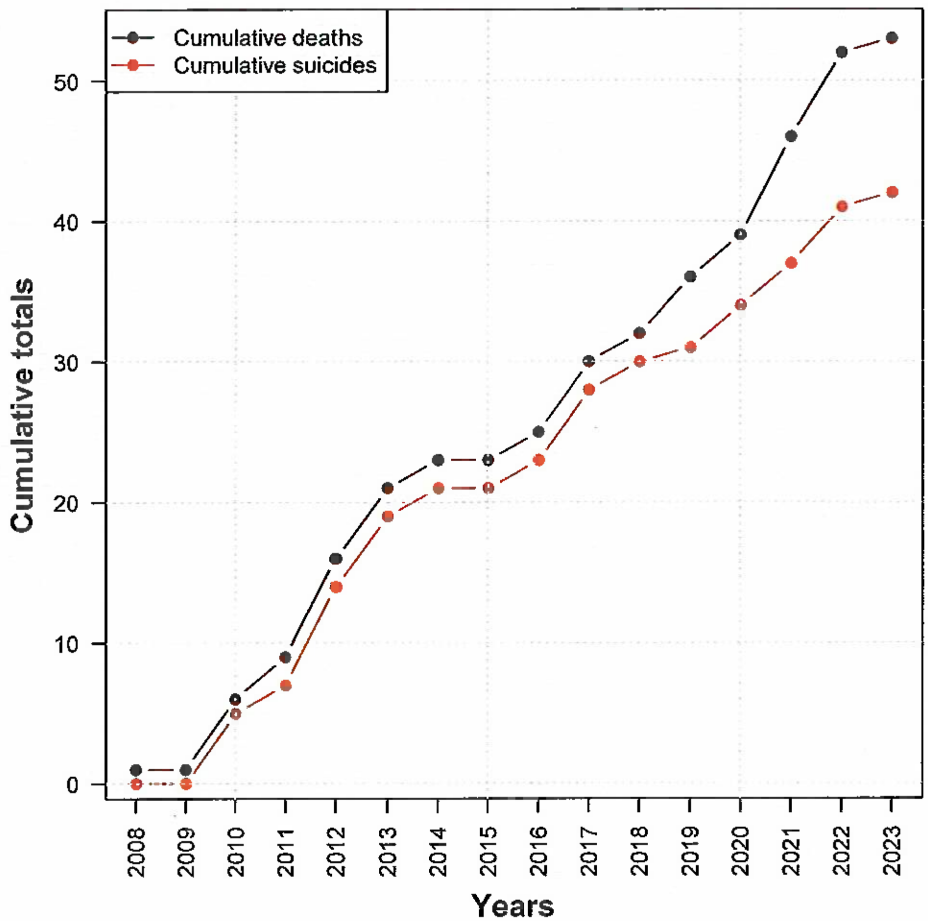

Figure 5: Comparison of total H2S cases and suicides, by year from 2008-2023

The data showed a larger number of cases in states with larger population sizes. California had the most H_2S fatalities (47%), followed by Texas (25%), Florida and New Mexico (9%), Oklahoma (6%), and New York and Illinois (2%) (see Figure 6). No distinctive patterns were observed between H_2S fatalities and the state in which they occurred, aside from the relativity of population sizes.

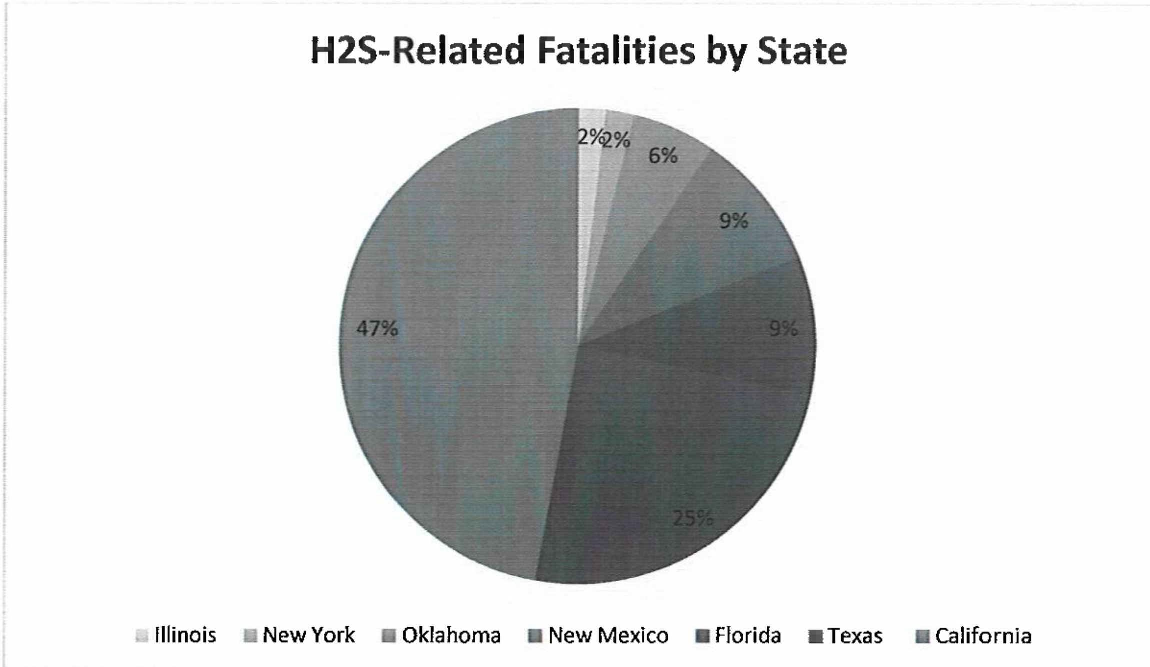

Figure 6: H2S-related fatalities in the U.S., status-post 2008. These include both suicides and accidental deaths.

Gender, Age, and Ethnicity

When analyzing the gender and manners of death, the data revealed that males were more likely than females to die from H_2S accidentally. There was a total of eleven accidental deaths, nine of the accidental cases involving males, occurred on job/ industrial sites (see Table 2). Males accounted for 81% of accidental manners whereas females only accounted for 18.2%. It was noted that the accidental, double fatality of the two female decedents took place in a vehicle due to a faulty car battery, per investigative reports. Thus, the two cases were separated from the data set of deaths occurring on job sites and in the industrial settings category (see Table 2). When filtering accidental deaths by location of injury, males predominated deaths on job sites or industrial settings (100%) when compared to that of females (0%).

Males were twice as likely to commit suicide via H_2S inhalation than females by 28-14 (see Table 1). Males were also twice as likely to commit suicide in a vehicle when compared to females (see Table 2). Upon observation of location of injury, seven males and four females were included in the category "other" which encompassed locations such as apartments, motels, and residences; all were deemed suicides.

Table 1: Gender and Manner of Death

	Male	Female	Total
Accident	9	2	11
Suicide	28	14	42
Total	37	16	53

Table 2- Gender and Location of Injury

	Job Site	Vehicle	Other	Total
Male	9	22	7	38
Female	0	11	4	15
Total	9	33	10	53

The mean age for the total data set was thirty-five years-old. With the average age of suicide victims being 33 years-of-age and accidents was 44 years-of-age. In accidents, the youngest decedent was 3 years-of-age and the oldest was 71 years-of-age. The most common age range for accidental deaths was between the ages of 40-49 (45%). The youngest decedent having committed suicide was 18 years-of-age and the oldest was 70 years-of-age. For suicides, the age range was 19-29 years-of-age (42%) (see Table 3).

Table 3- Age and Manner of Death

	0-18	19-29	30-39	40-49	50-59	60-69	70+
Accident	1	0	3	5	0	1	1
Suicide	3	18	8	6	6	0	1

Cross-tabulation of age and gender revealed in male fatalities, three between the ages of 0-18, eleven of the ages 19-29, seven of the ages 30-39, eight of the ages 40-49, six of ages 50-

59, one case between 60-69, and two cases were 70+. The most frequent age group was the 19-29 age group (see Table 4). Of the female-related fatalities, one was between 0-18, seven were of the ages 19-29, four were of the ages 30-39, three were of the ages 40-49. There were no documented female H_2S fatalities from ages 50+.

Table 4- Age and Gender

	0-18	19-29	30-39	40-49	50-59	60-69	70+	Total
Male	3	11	7	8	6	1	2	38
Female	1	7	4	3	0	0	0	15

When comparing ethnicity and gender, the data revealed that twenty-four cases were Caucasian males, followed by 7 Caucasian females, 7 Asian males. African American females comprised six cases, whereas African American males consisted of five cases. American Indian males comprised two cases and Hispanic females and Asian females occupied one case each.

Table 5- Ethnicity and Gender

	African American	American Indian	Asian	Caucasian	Hispanic	Total
Males	5	2	7	24	0	38
Females	6	0	1	7	1	15

Upon examination of ethnicity and manner of death, Caucasians were more likely to die in both accidental and suicidal manners. Caucasians comprised eight accidental cases and twenty-three suicides. Secondary to Caucasians in accidental deaths were that of Native American/ American Indians with two cases. Secondary in suicides were African Americans with ten cases. Native Americans were not represented in any suicide cases. Asians were not represented in cases involving accident as the manner. However, they comprised eight suicide cases. Hispanics were not represented in accidental deaths but were represented in one suicide case (see Table 6).

Table 6- Ethnicity and Manner of Death

	African American	American Indian	Asian	Caucasian	Hispanic	Total
Accident	1	2	0	8	0	11
Suicide	10	0	8	23	1	42
Total	11	2	8	31	1	53

Location of Injury/ Death

According to the data set, 74% of intentionally generated H_2S gas suicides occurred in vehicles and the remaining 26% of suicides took place in indoor locations that included residences, apartments, and motels (see Figure 7). Out of the forty-two suicide cases, eighteen left warning/ suicide notes indicating the presence of H_2S. Only 43% of suicides contained signs written by decedents warning responders of their utilization of H_2S in the commission of their suicides.

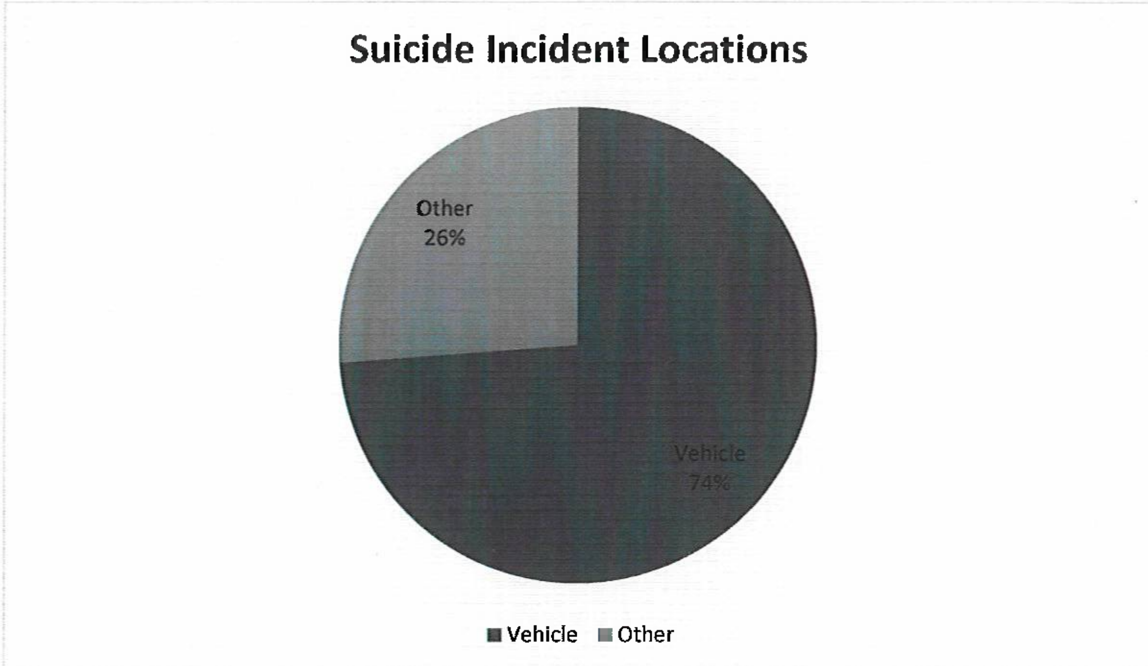

Figure 7: Locations of suicides via H2S. "Other" includes residences, motels, and apartments.

Figure 8: Scene of an individual that intentionally generated H2S inside a vehicle. Buckets containing the chemicals used to generate the gas were removed.

Upon combining total accident and suicide fatalities, the study showed that most deaths occurred inside vehicles (62%), indoor locations including residences, motels, and apartments (21%), followed by job sites/ industrial settings (17%) (see Figure 8). Of the suicides that occurred within "other" locations, 40% were noted to be in bathrooms.

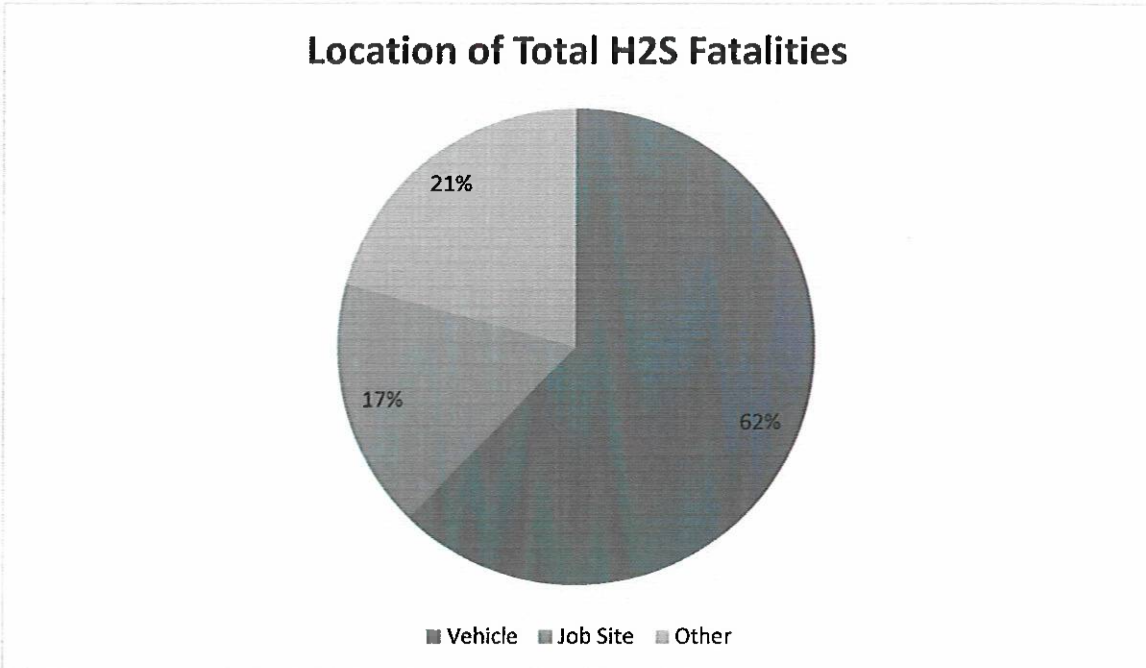

Figure 9: Total H2S fatalities by location of injury/ death.

In accidental deaths due to H_2S, 81.8% occurred at or on job sites and 18.2% occurred in a vehicle. Further examination of the investigative/autopsy reports in the accidental deaths (double fatality) in a vehicle revealed that they were due to a faulty car battery and were not industrially or job-related.

Cause of Death

Of the fifty-three cases utilized in this study, all contained different verbiage with regards to labeling cause of death. All cases involved death via some mechanism of death secondary to H_2S gas inhalation. The many ways in which cause of death was worded included the following: asphyxiation by H_2S, acute H_2S poisoning, H_2S inhalation, H_2S poisoning, H_2S exposure, H_2S intoxication, gaseous suffocation, toxic effects of H_2S gas, asphyxia by H_2S inhalation, toxicity of fertilizer mix including H_2S, asphyxia, and asphyxia due to H_2S intoxication.

Manner of Death

The only manners of death found in this study were that of accident and suicide. This study revealed that eleven cases were deemed accidents and forty-two were suicides. No cases were listed as undetermined, homicide, or natural.

Postmortem Findings

Reports of postmortem brain pathologies showed that twenty-eight out of forty-two suicides, 67%, were noted at autopsy to have greenish-discolored brains, unrelated to any other pathognomonic etiologies. When isolating vehicular suicides from suicides at "other" locations of injury, twenty-six out of thirty-one cases demonstrated the same pathological finding of a greenish-discolored brain (84%). The remaining ten suicides in the "other" category for location of injury did not demonstrate this postmortem finding (16%). Examination of accidental death brain pathologies revealed that all eleven cases were negative for the postmortem finding of a greenish-discolored brain (see Table 7).

Table 7- Greenish-Discoloration of the Brain and Method of H2S Exposure

	Greenish Discolored Brain Present	Absent or N/A	Total
Intentionally Generated H_2S	28	14	42
Unintentionally Generated H_2S	0	11	11
Total	28	25	53

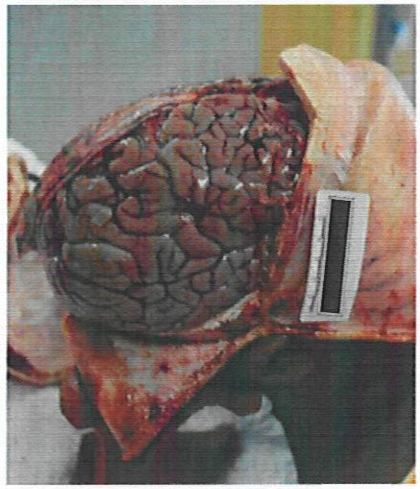

Figure 10: Intracranial examination of a decedent that intentionally generated H2S in a vehicle. Brain insitu displays a greenish discoloration.

Figure 11: Postmortem comparison of a H2S brain section; the decedent was in a vehicle upon pronouncement of death (left), and a normal postmortem brain tissue (right).

In addition to lethal, thiosulfate levels the data also revealed other significant observations at autopsy including the following: an odor of H_2S once the cranium was opened at autopsy, green-gray discoloration of the lips, tongue, palate, eyelids, larynx, and epiglottis, as well as a green-gray discoloration of, extremities, digits, eyelids, lips, skin, and abdomen (see Table 8).

Table 8- Postmortem Findings, Manner, and Location of Death

Postmortem Findings	Location	Manner of Death
Gray-green discoloration of face, neck, and epiglottis	Vehicle	Suicide
Odor of H_2S on internal examination of brain	Residence	Suicide
Green discoloration of face, forearms, and abdomen	Vehicle	Suicide
Green discoloration of eyelids, lips	Vehicle	Suicide
Green tongue and palate	Job Site	Accident
Green lips and digits (fingers)	Vehicle	Suicide
Green larynx	Job Site	Accident

CHAPTER IV

Discussion

The cases included in this study were investigated by Medical Examiner and Coroner's agencies across the U.S. The cases in this study fall under the jurisdictional category, as defined by NAME, as "A2.2 known or suspected non-natural deaths".[6] Due to the nature of H_2S deaths, they are considered a non-natural means of death and almost always warrant an autopsy or further investigation to determine cause and manner.

Frequencies could not be identified by examining cases by year, however, H_2S suicide cases have remained stable. Even when combined with accidental deaths, there were still no discernable patterns in frequency of H_2S-related fatalities as revealed on a graph generated by the R software platform. [3] This portion of the study was a second attempt of an earlier study to identify frequencies and increases in H_2S-mediated suicides.[4]

When examining gender in this study, males accounted for most total H_2S-related fatalities. In addition, male suicides were double that of females. Males also predominated the accidental manner of death category with all fatalities occurring on job sites or industrial settings.

The most prominent age range for suicide was between 19-29 years of age, this comprised nearly half of all suicide cases. The most prominent age range for accidents was between 40-49 years of age.

According to the U.S. Census Bureau, Caucasians account for 75.8% of the population, African Americans 13.6%, and Asians for 6.1%.[8] The suicide cases in this data set consisted of 55% Caucasian, 24% African American, 19% Asian, and 2% Hispanic. African American females represented a 54% majority of the African American suicides in this study. Thus, African American, and Asian victims were over-represented in the study findings.

Of the information listed in the reports, examination of the location of injury or location of death, is typically where the decedents were initially injured, pronounced, or found deceased. This data included vehicles, residences, job sites, motels, and apartments. This study revealed that most H_2S suicides occurred in vehicles. This has been demonstrated in a previous study where 77% of H_2S suicides took place in vehicles. [4] This study showed that 76% of suicides occurred inside of vehicles. However, ten suicides occurred in other locations such as apartments, residences, and motels, as listed by the reports. Most reports lacked specificity on the type of room within these "other" locations where suicides occurred, but 40% were noted to occur bathrooms. This portion of the research indicated that most H_2S suicides take place in one of the most confined and isolated (private) spaces decedents have access to, which is a vehicle.

According to OSHA, the most common industries where H_2S is present are petroleum production and refinement plants, sewer and wastewater treatment facilities, agricultural silos, textile manufacturing, pulp and paper processing, food processing, and mining.[1] Upon further review of the accidents in this study, there were only 2 fatality accidents that occurred in a vehicle, a mother and daughter were found inside the vehicle on the side of the road, deceased. This double fatality consisted of the youngest death in the study via H_2S, 3 years of age. The investigative reports had supplemental information that stated the incident was suspected to be due to a faulty car battery, not intentionally generated H_2S gas. For that reason, these two decedents were separated from the nine other accidental fatalities that occurred at classical job sites and industrial settings. One case report of an on-the-job fatality of H_2S exposure took place inside a railcar on a train, whereas other reports were lacking investigative narratives to be able to further expand upon more specific types of job sites or industrial settings in which deaths occurred. Due to the small sample size of accidental fatalities, and limited investigative reports, there were no discernable patterns or a specific type of on-the-job site that could be statistically defined.

With regards to cause and manner of death, all cases involved "H_2S" in the primary cause of death, with differing verbiage preceding or succeeding H_2S. Most cases examined in this study were suicides. Compared with statistics from OSHA, between 2011-2017 there were forty-six work-related H_2S fatalities as reported to the Bureau of Labor Statistics.[1] This indicates that suicide by H_2S could possibly generate higher numbers than accidental deaths.

Postmortem findings revealed that a majority of intentionally generated H_2S suicides carried out inside of vehicles showed an overwhelming prevalence of a greenish discolored brain. In total, more than half of the cases of intentionally generated H_2S revealed green brains, however, none of the accidental deaths due to H_2S exposure possessed this pathognomonic finding. This study demonstrated the likelihood of a green brain could be dependent on concentration, location, and proximity to the gas. Other pathological findings were present but the most referenced specimen for determining cause of death was the detection of lethal thiosulfate levels in blood and urine.

H_2S is an ever present and increasing problem that requires an enhanced understanding when responding and investigating these types of scenes. Whether it is intentionally generated or an accidental byproduct at a job site or industrial location, potential H_2S death cases should be approached with extreme precaution and appropriate personal protective equipment (PPE) should be utilized.

The Joint Regional Intelligence Center (LA-RTTAC) reviewed several cases involving intentionally generated H_2S. One of which mentioned law enforcement responding to an 18-year-old male that had attempted suicide. First responders discovered two pans with unknown chemicals on the bedroom table, the victim was found unresponsive in his apartment and transported to a nearby hospital where one-hundred people were secondarily exposed to the toxic gas which was later identified as H_2S. The hospital was shut down for five hours until decontamination procedures were completed. The patient subsequently succumbed to his injuries.[2]

A case in Oklahoma where a female committed suicide via H_2S in her vehicle resulted in secondary exposure at the Medical Examiner's Office during autopsy. Residual gas from the decedents' chest cavity was released (the process of off gassing), and due to poor ventilation, subsequently, caused minor ocular and respiratory effects to staff in the administration sector of the building (Office of the Chief Medical Examiner, Oklahoma).

These are just a few examples of incidences that stress the importance and necessity of safety protocols when approaching scenes involving unknown chemicals.

In fatality cases, it is essential to evaluate the scene by attempting to look for incident dynamics revealed in this study. However, they are not always present. However, there are often "signs" of the presence and/or utilization of H_2S gas. Things personnel can look for are location of the scene, is it in a confined space? Are there buckets near the deceased or empty bottles of lime sulfur spray, and cleaning chemicals? Did the decedent post warning notes outside of the location visible to others? Have ventilation (air vents or windows) been cut off or removed by tape or other items? Also, is there a chemical odor? All these have been mentioned as key indicators in assessing these types of scenes in a bulletin made public by LA-RTTAC for first responders, [2] and confirmed by our study findings.

It is important to photograph the scene in its entirety before moving or manipulating the decedent (s) or any evidence. It is essential to ensure the H_2S levels have been checked by HAZMAT personnel before approaching the scene. The victim (s) will need to undergo a decontamination process before being transported to any examination or remains storage facility (morgue, autopsy suite, funeral home, or hospital). Clothing items can contain residual gas that can be a threat to responders; these should be removed and placed into a bag or other sealed and well-marked container.[2]

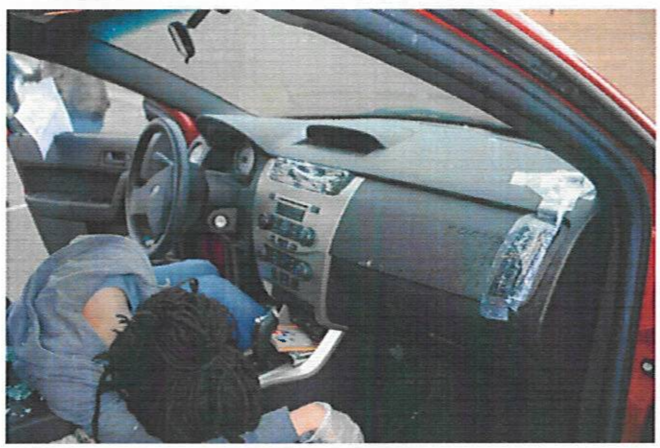

Figure 12: Air vents were sealed off to limit airflow inside the vehicle of an H2S suicide.

Figure 13: A bucket containing the remnants of chemicals used to generate H2S inside a vehicle (recovered from passenger floorboard)

Figure 14: Decontamination of an H2S victim, on-site at a death scene. Note, the clothing has been removed and the body is decontaminated by HAZMAT.

It is important to clearly and effectively warn others of the hazards associated with H_2S fatality incidents. Pronounced scene communication and visible signage indicators of hazardous materials are essential for scene and evidence packaging.

Limitations

The findings in this study are subject to several limitations including the inability to reach more agencies and in eliciting more responses via LISTSERV. Some agencies required payment for investigative and autopsy reports, resulting in a less than ideal sample size. To limit the cost of conducting this research, records were not requested from most of the agencies requiring fees, ultimately excluding additional potential cases. Each Medical Examiner/ Coroner's office is expected to uphold the National Association of Medical Examiner's (NAME) standards.[5] These standards are the foundation in which Medical Examiner/ Coroner's determine jurisdiction and decide if a case meets the criteria to be investigated. However, it is up to the individual Pathologists' discretion whether to conduct a full autopsy or not. In some of these cases, full autopsies were not conducted, thus limiting the potential for complete autopsy reports with more observable and remarkable brain pathologies. And finally, some reports were lacking or had incomplete data needed to equally include each case in individualized analyses. Although some cases were incomplete, this data set utilized all available and qualifying information from each case. This lack of information resulted in limitations in identifying statistically significant frequencies in cases but was sufficient for analyzing demographic data and common themes.

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CHAPTER V

Summary of Conclusions

The results show that there has been no definitive increase in the number of annual suicides via H_2S inhalation within the United States. This study demonstrated that forty-two out of fifty-two cases were suicidal, in manner, but inconsistencies were demonstrated upon examining the number of cases by year. However, suicide cases surpassed the number of accidental deaths, meaning first responders and medicolegal personnel should still be aware of the incident dynamics involved with H_2S scenes. The study findings rejected the null hypothesis but indicated that there are several discernable patterns in incident dynamics, decedent demographics, cause, and manner of death, and postmortem findings. The findings suggest most incidents occur in vehicles, the common demographics for suicides by H_2S are Caucasian males between 19-29 years-of-age. Caucasian males are also the most common demographic for accidental fatalities via H_2S. African Americans and Asians were overrepresented in this study in suicidal deaths. Postmortem findings are prominent green brains in intentionally generated cases that occurred in vehicles but were absent in occupational, accidental cases.

The major findings in this study demonstrate the importance of scene and incident dynamics when investigating suspected H_2S scenes, whether they are accidental or suicidal. This research shows common themes amongst intentionally generated cases, as well as important brain pathologies that with more data, could prove as a definitive diagnostic marker in diagnosing H_2S-related deaths. This research implicates the need for updating safety protocols, scene response, and informing responders of the associated risks when encountering H_2S.

Future Research

Future research could expand reaching more agencies to further substantiate what was found in this study. With sample size limitations within this study, the potential of a larger sample size may produce more statistically significant patterns and further elucidate postmortem commonalities amongst suicide cases. Further examination of H_2S concentration effects could help reveal a connection to green brain presentation. Investigation of histochemical and histopathological causation of the green brain phenomenon. And finally, the importance of continuing education could prove beneficial for first responders and medicolegal personnel.