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An investigation into the rate and mechanism of incident of work-related confined space fatalities

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ABSTRACT

Confined spaces are defined by a particular set of hazards which include oxygen deficiency, toxic airborne contaminants, flammable atmospheres, the risk of engulfment in free-flowing solids and liquids, and physical hazards such as working at heights, electricity, and moving parts and machinery. This study conducted an analysis of work-related traumatic fatal injuries involving confined spaces and compared the rate of confined space fatalities in the working population between similar industrialised countries; the rate of confined space entrant to confined space rescuer deaths; and identified the difference in the mechanism of incident between entrant and rescuer deaths. The confined space fatality rate can be estimated to vary between 0.05 and 0.08 deaths per 100,000 workers, of which no more than 17% were found to be those undertaking rescue; with most of these deaths the result of hurried and ad hoc rescue attempts. While the major causes of death among entrants were toxic atmospheric hazards and physical hazards; confined space rescuer deaths were overwhelmingly as a result of toxic atmospheres. It is likely that these figures are an underestimate of all confined space fatalities, as government WHS authorities rarely identify such incidents as having occurred in a confined space. The inclusion of engulfment and other physical hazards of confined space work in safety legislation, and the separate identification of confined space incidents will permit better analysis and recommendations for confined space work safety improvements.

1. Introduction

Confined space fatalities continue to be a significant cause of workplace death in Australia and internationally. A detailed investigation into the aetiologies of confined space fatalities, including the rate and differences between confined space entrant and confined space rescuer fatalities, will assist in the reduction of these workplace deaths.

1.1. The dangers of confined spaces

The dangers of working in confined spaces have been known for many years. While Ramazzini (translated 1983) was the first to examine the relationship between employment and malady, Thackrah (1832) identified the atmospheric hazards present in confined spaces and the effect on those employed to enter such places. He noted that well sinkers were 'frequently obliged to respire carbonic acid, and other gases found in wells', and that sewer workers were 'often affected by the fetid gases', sometimes to the point of unconsciousness or death (Thackrah, 1832, pp. 117–118). Confined space incidents also result in multiple fatalities, often when rescue is attempted by workmates and untrained personnel. As early as 1812, it is recorded that three men lost their lives when one after another they climbed down into a well to recover some stolen beef and were overcome by the atmospheric conditions (Kletz, 1996). Sewer workers attempting rescue of workmates suffered the same fate in 1895 in an incident in which five were killed, one after another (Bond, 1996). Hamilton (1929) discussed the dangers of hydrogen sulphide in confined spaces and gave examples of resulting worker and rescuer fatalities.

It is unknown how many workers enter confined spaces on a daily, routine, or irregular basis. The United States Occupational Safety and Health Administration (OSHA) – the US national regulatory body for health and safety – estimated in 1993 that there were about 1.6 M workers who entered approximately 4.8 M confined spaces each year (Office of the Federal Register, 1993, p. 4542). Other estimates include over 658,000 confined space entries per year in Western Australia alone (Worksafe WA, as cited in MacCarron, 2006, p. 2); and an estimate of 2.1 M workers entering confined spaces annually (CSUF, 2012).

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Confined spaces include vats, tanks, silos, pits, pipes, shafts, pressure vessels and sewers. There is no universal definition of a confined space. The definition varies by country, jurisdiction, legislation, and in some cases industry group, however there are few differences overall. For the purposes of comparison between jurisdictions, a common definition of a confined space has been used in this study. A confined space is defined as an enclosed or partially enclosed space, which is not intended or designed primarily for human occupancy, and which has a risk of an unsafe level of oxygen, toxic airborne contaminants, flammable airborne contaminants, or a risk of engulfment by a free-flowing solid or liquid (Government of Singapore, 2009; Government of the United Kingdom, 1997; Safe Work Australia, 2016; Standards Australia, 2009; Standards Singapore, 2005). It should be noted that some jurisdictions such as the US and Canada also define a confined space as having limited or restricted means for entry or exit (ANSI/ASSE, 2009; Canadian Standards Association, 2016; OSHA, 2011). The US also divides confined spaces into those which do not have substantial risks; and those which have a risk of a hazardous atmosphere or risk of engulfment as *Permit Required Confined Spaces* (PRCS) (OSHA, 2011). A summary of the definitions of a confined space by jurisdiction is provided in Table 1 (Government of Victoria, 2017; Government of Western Australia, 1996; OSHA, 2016).

Underground mines are not defined as confined spaces, as they are intended to be places of work. Vessels and equipment located at a mine such as vats, hoppers, and tanks which may be located either above ground or underground, would be considered to be confined spaces. Ceiling cavities do not generally have a risk of containing an unsafe atmosphere or a risk of engulfment, so are not normally considered to be confined spaces. In an Australian study which examined 15 fatalities that occurred in the state of Western Australia during the period 1980–2004, six of the eight electrocution deaths took place in ceiling cavities, which are not ordinarily considered to be confined spaces (MacCarron, 2006). Ceiling spaces are also not usually considered confined spaces in the UK (Government of the United Kingdom, 2014), and are usually regarded as non-permit confined spaces in the US (OSHA, 2011). Likewise, although trenches have a substantial risk of engulfment, trenches would not, under all but the most exceptional circumstances, have the risk of containing an unsafe atmosphere. The Australian model Code of Practice for confined spaces states 'Trenches are not considered confined spaces based on the risk of structural collapse alone, but will be confined spaces if they potentially contain concentrations of airborne contaminants that may cause impairment, loss of consciousness or asphyxiation.' (Safe Work Australia, 2016, p. 5). Trenches are not considered confined spaces in the UK unless 'there is also the presence of or a reasonably foreseeable risk of one of the specified risks to the health and safety of those working in the space' (Government of the United Kingdom, 2014, p. 10). The 'specified risks' are defined as fire or explosion; heat injury; asphyxiation from a gas, fume or vapour; or engulfment. Likewise, in the US, OSHA confined space regulations apply only when excavation or trenching work is related to sewerage construction (OSHA, 2015).

1.2. Confined space fatalities

There have been a few studies of confined space deaths in Australia and North America. Selman et al. (2017) identified 59 confined space fatalities Australia-wide over the period 2000–2012, with a mean rate of 0.05 deaths per 100,000 workers in the working population. Two of the 59 fatalities (3.4%) were persons attempting rescue. A study of confined space fatalities in the US using the National Traumatic Occupational Fatalities (NTOF) data for 1980 through 1989 was undertaken by Pettit et al. (1996) which found 670 fatalities from 585 incidents over the ten year period, with a rate of 0.08 fatalities per 100,000 workers. 72 (12%) of the incidents involved multiple fatalities, although the study could not differentiate between entrants and rescuers in these incidents. A later study using Census of Fatal Occupational Injuries (CFOI) data produced by the US Bureau of Labor Statistics found 458 confined space-related fatalities over the five year period 1997–2001 with a rate of 0.07 fatalities per 100,000 workers in which 25 (5.5%) were persons attempting rescue - most of whom were not professional rescuers. It was noted that engulfment was the most common mechanism of incident (Meyer, 2003). CFOI data was examined for the period 1992–2005 by Wilson et al. (2012) in which only atmosphere-related confined space incidents were included, and revealed 530 fatalities in 431 incidents with 47 (9%) of the fatalities identified as would-be rescuers. A recent study conducted into confined space fatalities in the Canadian province of Quebec identified 41 fatalities over the period 1998–2011 with a fatality rate of 0.07 per 100,000 workers in which 6 (15%) of the deaths were attributed to rescuers (Burlet-Vienney et al., 2015b; Statistics Canada, 2014).

Further published studies which considered confined space fatalities in the total workforce either in the US or in other similar industrialised countries were not found; however a number of studies from the US restricted by geographical area, industry sector, or other criteria were identified. An examination of confined space fatalities in the US state of Virginia between 1979 and 1986 identified 50 deaths, including 3 (6%) of whom were rescuers (Sahli and Armstrong, 1992). Worker deaths in the US as a result of asphyxiation and poisoning over the period 1984–1986 were investigated by Suruda and Agnew (1989) and it was found that of the 233 deaths recorded, 146 occurred in confined spaces – 17 (12%) of whom were rescuers. Also noted were 42 deaths from mechanical asphyxiation as a result of engulfment. A study of livestock manure handling and storage facility confined space-related fatalities in the US between 1975 and 2005 identified 17 rescuer fatalities out of 77 total fatalities (22%) in 56 incidents (Beaver and Field, 2007). The United States National Institute for Occupational Safety and Health (NIOSH) – a division of the Centers for Disease Control (CDC) – conducts investigations of fatal occupational injuries as a part of the FACE (Fatal Accident Circumstances and Epidemiology) program, which targets particular causes of death and publishes the investigations into selected incidents (Higgins et al., 2001; Manwaring and Conroy, 1990). Analysis of confined space FACE data between 1982 and 1991 was undertaken in which 62 incidents resulted in 97 fatalities, including 35 (36%) attempting rescue (Suruda et al., 1994). It must be noted, however, that the FACE dataset is a selected subset of all confined space incidents, and while useful for aetiology analysis, it is not representative of the rate of confined space deaths or of the division between entrant and rescuer deaths as a whole. Confined space fatality data in the literature is generally weighted towards deaths from atmospheric hazards (toxic substances and oxygen deficiency).

The issue of multiple and rescuer fatalities in confined spaces was recognised as a growing problem in modern industry and in 1986 NIOSH issued an alert based on a number of fatal confined space incidents in which NIOSH concluded 'More than 60% of confined space fatalities occur among would-be rescuers; therefore a well-designed and properly executed rescue plan is a must.' (NIOSH, 1986). While much of the advice provided in the alert was pertinent and remains relevant today, the proportion of rescuer deaths attributed in the alert is very high and subsequent studies have identified much lower ratios (Beaver and Field, 2007; Burlet-Vienney et al., 2014; Meyer, 2003; Pettit et al., 1996; Suruda et al., 1994; Wilson et al., 2012).

1.3. Confined space hazards

The causes of confined space incidents, which may lead to injury and death, can generally be divided into four categories of mechanism of incident – defined as 'The action, exposure or event that best describes the circumstances that resulted in the most serious injury or disease' (Austalian Safety and Compensation Council, 2008). The first three of those mechanisms are toxic atmospheres, flammable atmospheres, and engulfment in free-flowing substances; which are the general causes for caution with confined space entry and work. The