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Design and application of a 5 step risk assessment tool for confined space entries

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ABSTRACT

Many serious accidents related to work in confined spaces still occur. Despite all the regulatory and standard-setting efforts that have been made, organizations seem to have difficulties with risk assessment for interventions in confined spaces. Risk identification and estimation were not carried out in most of fatal accidents. This paper proposes a 5 step risk assessment tool for confined spaces based on risk management standards. The tool was tested by 22 experts in managing entries in confined spaces, including experts during 10 visits in different organizations. Step 1 consists of a questionnaire to describe the configuration of the selected confined space, its environment and the work situations. The answers generate predefined types of risk such as mechanical, atmospheric, falling, chemical, and biological. Step 2 describes the components of risks (i.e., hazards, hazardous activity, hazardous event, harm). Step 3 estimates risk using adapted risk parameters and matrix. Step 4 categorizes the intervention by class and level of risk. Step 5 is a feedback loop for estimating residual risks after risk reduction measures have been taken. This tool enables to (i) carry out comprehensive risk identification by analyzing all the risk factors during an intervention in a confined space, (ii) categorize interventions and rescue conditions by using specific criteria, (iii) determine if two situations are indeed identical in terms of risks, (iv) decide if intervention planned meets the permit required confined spaces definition, (v) evaluate if external rescue is feasible, and (iv) decide if the residual risks are acceptable.

1. Introduction

Many industrial processes involve work in confined spaces. Reservoirs, silos, vats, manholes, pits, sewers, piping, crawl spaces and tanks are all common examples of confined spaces in industry (NIOSH, 1994). A confined space is defined in the United States Occupational Safety and Health Administration (OSHA) regulation as "a space that: (1) is large enough and so configured that an employee can bodily enter and perform work; (2) has limited means of entry or egress; and (3) is not designed for continuous employee occupancy" (29 C.F.R., 1910.146, 1993). A more or less similar definition can be found in regulations from different countries and from different provinces in Canada. For example, the Quebec Regulation on Occupational Health and Safety (ROHS) defines an enclosed area as "any area that is completely or partially enclosed, [. . .], which has the following inherent conditions: (1) is not designed for human occupation, nor intended to be, but may occasionally be occupied during work; (2) access to which can only be made by a restricted entrance/exit; (3) can represent a risk for the health and safety of anyone who enters, owing to any one of the following factors: (a) its design, construction or location, except for the entrance/exit provided for; (b) its atmosphere or insufficiency of natural or mechanical ventilation; (c) the materials or substances that it contains; (d) or other related hazards" (Quebec Government, 2014). Workers who enter these confined spaces are exposed to potentially high risks because of the confinement, inadequate natural ventilation, and access, rescue and communication problems (CSA, 2010). Studies have pointed out the risks of poisoning in the agricultural, construction and transportation sectors (Fuller and Suruda, 2000; Dorevitch et al., 2002; Svedberg et al., 2008; Riedel and Field, 2013). Between 1992 and 2005, an average of nearly 38 deaths occurred per year in the

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United States due to poisoning or asphyxiation in confined spaces. Twenty percent of these events resulted in several deaths (Wilson et al., 2012). An exhaustive analysis of the fatal accidents that have occurred in confined spaces in Quebec also illustrates the major role played by other hazards. For instance, moving parts of machinery count for 20% of the fatalities involving confined spaces, engulfment for 15%, fall from height for 12.5% and falling objects for 12.5% (Burlet-Vienney et al., 2014).

If there is a potential serious hazard in a confined space, then an employer in the United States must comply with the Permit-Required Confined Space (PRCS) regulations, which cover the implementation of a management program, employee qualifications, risk identification, atmospheric monitoring, mandatory supervision and rescue procedures (29 C.F.R., 1910.146, 1993). Serious hazards are defined in ANSI/ASSE Z117.1-2009 as conditions which may cause death, temporary impairment, functional disorder, or an inability to exit the space (e.g., hazardous atmosphere, engulfment, internal configuration such that an entrant could be trapped or asphyxiated, any other recognized serious safety or health hazard) (ANSI/ASSE, 2009). The information on the risks and the preventive measures must be available in writing at the work premises and explained to the worker(s) before entering a confined space. Canadian standard CSA Z1006-10 and the American ANSI/ASSE Z117.1-2009 on confined space risk management provide additional guidelines regarding roles and responsibilities of those involved, related planning (e.g. training, emergency response plan), program implementation (e.g., entry permits), and risk assessment (CSA, 2010; ANSI/ASSE, 2009). Risk management for confined space entries in other countries is described in a literature review by Burlet-Vienney et al. where 77 peer-review documents were analyzed (Burlet-Vienney et al., 2014). Several technical guides have been published in Europe and Australia (Health and Safety Executive, 2013; Guilleux and Werlé, 2014; Government of South Australia, 2011) and there is also one standard on confined space management from Australia (Standards Australia, 2001).

CSA (2010) defines risk assessment as "a comprehensive evaluation of the probability and degree of possible injury or damage to health in a hazardous situation, undertaken to select appropriate controls." When confronted with the actual constraints and limited resources in the field, risk assessment (i.e., risk identification, risk estimation and risk evaluation) and procedures can prove difficult to implement. Chinniah (2015) reports the same issues with risk assessment for industrial machines. For example, in most of the fatal confined space accidents in Quebec between 1998 and 2011, the investigation report clearly mentioned a problem with identifying the hazards or underestimating the risks (Burlet-Vienney et al., 2014). Kletz (1998) also reports that many accidents have occurred when people were working inside confined spaces, either because the procedures for entering confined spaces were inadequate or were not enforced. Moreover, a study on 15 organizations that have implemented a confined space entry management policy reveals that over half of them did not conduct any preparatory analysis (e.g., risk fact sheets) before issuing an entry permit and relied solely on the experience of the permit issuer. In certain circumstances this approach can lead to poor risk assessment (e.g., omission or underestimation) and possibly to inadequate risk reduction measures. These field visits also revealed that most rescue procedures had neither been tested nor made available to the local fire department (Burlet-Vienney et al., 2015).

In addition, a literature review on confined space risk management reveals that some concepts present in regulations and standards are imprecise or difficult to use (Burlet-Vienney et al., 2014). For example, the concepts of serious risk (i.e., PRCS), similar confined space and classes of confined spaces lack precise and objective criteria to reach a decision. Besides, these concepts have not been studied. Risk estimation as referred in standards apart from atmospheric hazards was not carried out. None of the organizations quantified the identified risks. On the 77 peer-review documents retained, only 22 tackled overall risk estimation. Other documents are limited to risk identification or atmospheric risks. Of these 22 papers, 9 suggest practical tools for estimating risks. These tools are either matrices or risk scales (e.g., low, medium, high). The main problem of scales is that there is no criterion to choose the level of a risk (Government of South Australia, 2011). Moreover, if a list of risks is suggested, it is often incomplete (NIOSH, 1994; British Compressed Gases Association, 2009). Matrices suggested gives more guidance to estimate risks but remain generic (Rekus, 1994; UK Ministry of Defense, 2014; Standards Australia, 2001). Definitions used are vague and parameters are not adapted to the particular characteristics of confined spaces (e.g., multiple types of risks, real rescue conditions, interactions among hazards) and no list of hazard suggested. ISO 31010 (2009) recommends that a matrix should be designed to be appropriate for the circumstances. The architecture of these matrices also contains flaws (e.g., not even distribution of risk levels in the matrix) (Gauthier et al., 2012; Duijm, 2015).

The most essential roles in accident prevention are played by organizational factors, such as safety management and operations planning (Lind, 2008). A safety culture is required to make the administrative procedures really efficient and to minimize risks. For small and medium sized enterprises, Reinhold et al. (2015) suggest that using a supportive tool to assess the hazards and following the hierarchy of safety control measures could be an element for success. Caputo et al. (2013) and Blaise et al. (2014) are recent example of development of supportive approach for selecting safety devices of industrial machines and safe maintenance operation respectively. The objective of this study is therefore to design a risk assessment tool for confined spaces that addresses the deficiencies observed in the literature and on the field. This tool should allow carrying out multidisciplinary and comprehensive risk identification, estimating risks, categorizing interventions, predetermining rescue conditions and evaluating impact of risk reduction measures with objective criteria. This tool is based on five main stages prescribed in risk management standards: (i) characterization of the situation, (ii) hazard identification, (iii) risk estimation, (iv) risk evaluation and (v) risk reduction. It can be used as preparatory work done prior to the issuing of an entry permit.

2. Method

Risk management standard ISO 31010:2009 as well as ANSI/ASSE Z690.3 were used as guidelines during the development of the tool (ISO, 2009; ANSI/ASSE, 2011b). The standard on machine safety ISO 12100 (2010) and occupational hazards from the model developed by Aneziris et al. (2013) for managing risk owing to contact with moving parts of machinery were also used, as they include additional concepts related to mechanical and physical risks. To meet the identified requirements, a list of questions is needed to characterize the confined space work; an exhaustive list of hazards and related accident processes are required to identify hazards; an adapted method for estimating risks is required; and summary of the results of the risk estimation is needed.

Five experts in confined spaces from Quebec provided feedback during the development of the tool. They were in charge of managing confined space at their respective organizations, provide training on risks associated with confined spaces and entry permits, provide technical support to various organizations, validate permits and investigate accidents linked to confined spaces.