Safety Science 82 (2016) 368–373

Contents lists available at ScienceDirect

Safety Science

journal homepage: www.elsevier.com/locate/ssci

A preliminary analysis of Key Issues in chemical industry accident reports

Lyndsey Fyffe [a,*], Steven Krahn [a], James Clarke [a], David Kosson [a], James Hutton [b]

[a] Vanderbilt University, United States
[b] United States Department of Energy, Office of Environmental Management, United States

ARTICLE INFO

Article history:
Received 29 September 2014
Received in revised form 13 October 2015
Accepted 23 October 2015
Available online 11 November 2015

Keywords:
Chemical industry
Accident investigation
Process safety
Semi-quantitative analysis

ABSTRACT

Chemical industry accident reports provide a wealth of information that can be used to develop lessons learned to improve safety and efficiency of operations at chemical industry facilities. The United States Chemical Safety Board (CSB) is one source of these accident reports. As a part of an investigation and causal analysis process, CSB investigators identify "Key Issues" for each chemical accident. This research evaluated trends in those Key Issues by applying two distinct analyses of these issues. The first analysis assessed the Key Issues naturalistically, as reported by the expert investigation team; however, this result was problematic, as about 2/3 of all Key Issues, as described in the chemical industry accident reports, occurred only once. In the second analysis, the Key Issues were sorted thematically to capture insights from the many single-occurrence issues. This thematic analysis, using categories drawn from the Occupational Safety and Health Administration's (OSHA's) Process Safety Management (PSM) guidance, allowed for a more comprehensive understanding and grouping of the issues behind the chemical accidents studied. The findings of this research identified several accident themes that can be used to develop a better understanding of chemical industry accidents and potentially improve safety and efficiency of operations at chemical facilities.

1. Introduction

Regardless of the industry of origin of hazardous chemicals, a lack of proper control can result in an accident with serious consequences to workers, the environment and the public. Maintaining worker and public safety, along with protecting the environment, is a key priority in the chemical industry. Even prior to the advent of groups such as the Occupational Safety and Health Administration (OSHA) and industry groups such as the Center for Chemical Process Safety (CCPS), unexpected releases of toxic, reactive or flammable liquids were reported, yet remained a recurring problem. The introduction of OSHA's Process Safety Management (PSM) Guidelines played a large role in helping to lower the incidence of unexpected releases and other accidents at chemical facilities (U.S. Federal Record, 2013). Meanwhile, industry groups, such as the CCPS and others, have also focused on improving safety internally, by sharing lessons learned from accidents and promoting safety management. Due to this focus on safety, the chemical industry is relatively safe compared to other high hazard industries, considering the materials handled by these facilities on a daily basis (U.S. Department of Labor Bureau of Labor Statistics, 2013).

However, the overall relative safety of the chemical industry does not preclude the occurrence of accidents. Review of the recent accident records reveals that there have been accidents in the chemical industry ranging from combustible dust explosions, plant explosions and fires to chemical releases and asphyxiation. The chemical industry accident report database used in this analysis contains 60 accident reports issued between 1998 and 2012. These accidents represent 120 fatalities and 895 injuries, including chemical workers, first responders, and the public at large. At first glance, 60 accidents in 14 years may appear to be an acceptable rate (about 4 per year in a $769 billion industry in the U.S.); however, not all accidents involving injury are investigated by external groups and, consistent with the concept of continuous improvement, this research attempted to derive new insights from looking at this group of accidents as a whole.

Studying accidents to determine their causes is fairly common in high hazard industries. There are several accident databases available for study, with varying degrees of information available. Studies have shown that analyzing these accidents and applying

* Corresponding author at: Vanderbilt University, 2301 Vanderbilt Place/PMB 351831, Nashville, TN 37235, United States. Tel.: +1 (615) 343 8634; fax: +1 (615) 322 3365.
E-mail address: Lyndsey.Fyffe@Vanderbilt.Edu (L. Fyffe).

http://dx.doi.org/10.1016/j.ssci.2015.10.008
0925-7535/

lessons learned from them helps to avoid future accidents and reduce risk (Meal et al., 2007). The Environmental Protection Agency has a Risk Management Program that requires each facility under their purview submit a five-year accident history when they submit a Risk Management Plan (Kleindorfer et al., 2003). This database has been studied to find trends in the accidents at these facilities, including plant demographics, chemical inventories, and others (Kleindorfer et al., 2003). Some studies, such as Kahn and Abbasi, use several accident databases, worldwide to analyze the common causes which led to accidents at fixed chemical facilities (Kahn and Abbasi, 1999). Khan and Abbasi performed a statistical survey of a selection of chemical industry accidents over a 70 year period (1928–1997); as part of that analysis they assessed what they called 'major factors' that led to accidents at fixed chemical installations, such as those reviewed by the CSB. They did not use the PSM categories to sort the data, but basically found that mechanical integrity issues, operating and maintenance process issues, design concerns and ineffective hazard evaluation were leading causes (Kahn and Abbasi, 1999).

One common form of analyzing individual accidents is a causal analysis, or the determination of the problem, without which the accident would not have occurred. The lessons learned through such causal analysis can be collected and shared through regulatory and industry groups to raise awareness of certain types of events with the hope of preventing similar events from occurring in the future. The U.S. Chemical Safety Board (CSB) is an advisory group that performs a causal analysis and drafts a thorough accident report, sharing recommendations with regulators and industry and tracking the implementation of these recommendations (U.S. Chemical Safety and Hazard Investigation Board, 2014a). These chemical industry accident reports compose the database that the present work evaluated.

As a part of each accident report, and consistent with the CSB's congressional tasking to "identify contributing causes," each investigation team defines "Key Issues" which contributed to the accident. As such, the identified Key Issues are an expert summary of the major factors contributing to the accident; they can include procedural issues ranging from the permitting of hot work to specific maintenance problems, or management issues such as a lack of organizational learning. These Key Issues are identified through a causal analysis (formal or informal), and represent factors that contributed significantly to the accident (Occupational Safety and Health Administration, 2012). The Key Issues act as a snapshot of the analysis from the investigation team concerning the contributing factors to each accident; as such, they provide information which can be used by chemical facilities to identify accident reports that may be applicable to their facilities, to help to improve process safety. The catalogue of Key Issues, or contributing factors, that has accumulated over the years 1998–2012 can be analyzed to identify areas of vulnerability and to develop improvement actions to enhance safety and efficiency of operations at chemical facilities.

2. Methodology

The objectives for this work were: to analyze the Key Issues based on their qualitative characteristics, quantify the number of occurrences of Key Issues, and search for common Key Issues in chemical industry accident reports in order to potentially identify lines of inquiry to improve safety and efficiency of operations at chemical facilities. In order to accomplish these objectives, this research involved two separate analyses of the Key Issues identified in chemical industry accident reports: naturalistic and thematic. The naturalistic analysis involved a qualitative categorization of the chemical industry accident report Key Issues, verbatim. In the present study, the naturalistic analysis served as a precursor to the thematic analysis, and only the results of the thematic analysis were carried forward. In the second analysis, a thematic analysis was performed to determine common themes that branch across several Key Issues and bring to bear more explanatory power than those developed during the first analysis.

The methodology for this study used a qualitative analysis technique to initially gain insight into the causes of accidents in the chemical industry. Similar qualitative analyses have been performed on accident documentation (i.e., Gephart, 1993; Roberts, 1990; Vaughan, 1990), and provided valuable insight. Gephart uses qualitative data analysis facilitated by a computer to develop key word lists for study, a similar methodology to the Key Issues analysis described herein (Gephart, 1993). Another study used qualitative data available through interviews from the chemical industry security field to provide recommendations to consider for security improvements (Genserik, 2011). The results of these studies provided trends that can be used to recommend improvements, similar to the analysis described herein.

2.1. The naturalistic analysis

In the naturalistic analysis, the Key Issues were studied as they occurred in the chemical industry accident reports; that is, exactly as they were described by the investigation team. The number of occurrences of each individual Key Issue was tallied in an attempt to identify Key Issues that were potentially common across several incident reports. It was anticipated that these commonly occurring Key Issues have the potential to offer clear and significant targets to address in working to prevent future accidents.

This first analysis involved using a naturalistic qualitative method in which the unit of analysis was one chemical industry accident report. Data collection consisted of the identification of Key Issues for each document, dividing the Key Issues into related concepts and then further subdividing the identified concepts into categories. For this approach, the words in the Key Issues were used verbatim, without making any changes or assumptions. This naturalistic approach to data analysis is further described in Patton (1987). The main objective was to refrain from manipulating the data in any way during this initial evaluation, but rather to allow the data to fall into natural groupings based on similarities in wording.

Performing the Key Issues analysis with a naturalistic approach was intended to capture slight differences in terminology and phrasing resulting from differences in accident circumstances. This naturalistic method is often used for the analysis of expert opinions (Glaser and Strauss, 1967).

A preliminary assessment of frequently occurring Key Issues was accomplished (see Table 1). Unfortunately, the Key Issues from the chemical industry accident reports contain inconsistent terminology and phrasing; the naturalistic approach to the Key Issues analysis yielded over 60 single occurrence Key Issues. In other

Table 1
Naturalistic Key Issue frequencies.

Key Issue	Number of occurrences in CSB reports	Percentage of reports containing Key Issue (%)
Emergency Planning, Response, and Notification	15	25.0
Equipment (or Process) Design and Scale Up	15	25.0
Regulatory Oversight	7	11.7
Process Hazards Analysis	7	11.7
Reactive Hazards and Safeguards	7	11.7
Operating Procedures	6	10.0
Accident Investigation and Lessons Learned	6	10.0