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Review

Risk analysis of French chemical industry

Amine Dakkoune[a,b], Lamiae Vernières-Hassimi[a,*], Sébastien Leveneur[a,c], Dimitri Lefebvre[b], Lionel Estel[a]

[a] Normandie Univ, INSA Rouen, UNIROUEN, LSPC, EA4704, 76000 Rouen, France
[b] Université Le Havre – GREAH, 25 rue P. Lebon, 76063 Le Havre, France
[c] Laboratory of Industrial Chemistry and Reaction Engineering, Johan Gadolin Process Chemistry Centre, Åbo Akademi University, Biskopsgatan 8, FI-20500 Åbo/Turku, Finland

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ABSTRACT

Accidental events in chemical industry can cause damages to human health, environment and economy. To prevent such events in industries, it is essential to identify and analyze the past events. To the best of our knowledge, such an analysis has not been done for the French chemical industry sector, which is the second producer in Europe. To fill this gap, 169 events were selected and collected in the French database ARIA (Analysis, Research and Information on Accidents). These events occurred between 1974 and 2014. The causes and consequences of the events were analyzed. The study shows that the causes were mainly related to operator errors. Then, a semi-quantitative analysis of risk was also carried out, based on the frequencies and consequences of the events. This analysis confirms that chemical industry activities present a significant risk. Based on this analysis, national agencies can make some recommendations or rules in order to reduce the number of events in chemical industry.

1. Introduction

The chemical industry's activities are often controversial due to the high risks that they represent (Malich et al., 1998). Besides, the location of these industries, handling dangerous substances, are usually within densely populated areas (Reniers et al., 2006). Over the past decades, serious industrial accidents or incidents affecting lives, facilities and environment (Gomez et al., 2008) have heightened society's awareness of the negative effects of technology (Nivolianitou et al., 2004). These accidental events can be defined by five levels: Near miss, Mishap, Incident, Accident and Catastrophic accident according to Rathnayaka et al. (2011). Despite the improvement of safety, accidents still occur – but hopefully fewer and with less impact on human health and environment (EU, 2012).

Companies still wonder how these events can be reduced? Why did people make the same mistakes? Why the lessons have not been learnt from past accidental events?

Since the series of chemical disasters in recent decades, Flixborough (1974), Seveso (1976), Bhopal (1984), Basel (1986), Mexico (1988), Enschede (2000), AZF Toulouse (2001) (Sengupta et al., 2016), there was an impulse for the efforts in the area of process safety. Indeed, several articles, reports, books (Crowl and Louvar, 2001; Mannan, 2013; Sanders, 2015) or procedures on chemical accidents have been written to improve process safety. For example, the popular bow-tie approach used to identify the accident scenarios (de Dianous and Fiévez, 2006; Delvosalle et al., 2005, 2006; Gowland, 2006), or the Bayesian theory approach used in the work of Meel et al. (2007) and which is a complement of the previous bow-tie approach (Badreddine and Amor, 2010; Khakzad et al., 2013). Al-shanini et al. (2014) also proposed a systematic accident modeling based on precursor data. Edwards and Lawrence (1993) proposed the first method to quantify inherent safety, this proactive approach uses basic design measures to eliminate, prevent and reduce hazard. Khan and Amyotte (2004) used the same approach and proposed a new tool called Integrated Inherent Safety Index (I2SI) for inherent safety evaluation. In the same context, Tugnoli et al. (2007) proposed another tool based on the evaluation of Key Performance Indicators (KPIs). Different methodologies concerning the risk analyses have been published. Khan and Abbasi (1998a) suggest a new methodology for Hazard Identification and Ranking (HIRA) that indicates the severity of the likely accident. On the other hand, Khan and Abbasi (2001) developed a methodology of Optimal Risk Analysis (ORA) that allows a risk analysis with a few time, effort and cost. Another example is giving by Papazoglou et al. (1992) that presented a set of procedures and methodologies for Probabilistic Safety Assessment (PSA) in chemical plants. However, Rossing et al. (2010) proposed a methodology based on feed-back experiences from

* Corresponding author.
E-mail address: lamiae.vernieres@insa-rouen.fr (L. Vernières-Hassimi).

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traditional HAZOP studies. Other methodologies of risk analysis have been discussed and compared in several articles (Khan and Abbasi, 1998b; Rouvroye and van den Bliek, 2002; Tixier et al., 2002).

Some authors interested on domino hazard assessment such as the methodology proposed by Antonioni et al. (2009) and Cozzani et al. (2014) to include domino effects in Quantitative Risk Analysis (QRA). Recently, Alileche et al. (2016) have developed a specific model for the assessment of domino effect scenarios based on event tree analysis. By analyzing the events that have occurred, we can learn from them and prevent the same accidents from happening again (Grossel, 2002). However, the effectiveness of learning from accidents can often be questioned. In many cases, the learning process stops at the reporting stage (Zhao et al., 2014).

The study of accidents and lessons learnt has been carried out by different authors (Ale et al., 2017; Balasubramanian and Louvar, 2002; Gomez et al., 2008; Khan and Abbasi, 1999; Makino, 2016; Nivolianitou et al., 2006; Planas-Cuchi et al., 1997; Saada et al., 2015; Sales et al., 2007; Sonnemans and Körvers, 2006; Uth, 1999). To perform such studies, the authors have to rely on reports, articles or databases including accident reports. There are several databases, usually managed by a governmental agency: Chemical Safety Board (CSB) in the United States, Relief Information System for Chemical Accidents Database (RISCAD) in Japan, Major Hazard Incident Data Service (MHIDAS) in the United Kingdom, Major Accident Reporting System (MARS) in the European Union, Zentrale Melde- und Auswertestelle für Störfälle und Störungen in verfahrenstechnischen Anlagen (ZEMA) in Germany, FACTS (Failure and ACcidents Technical information System) in the Netherlands or *Analyse, Recherche et Information sur les Accidents* (ARIA) in France.

Despite an extensive literature review on chemical events, we have not found any references that have dealt with data on chemical industrial events in France. This lack of study is relatively surprising because French chemical industry is important for its economy: sixth among chemical producers in the world and the second largest producer in Europe in 2014 (UIC, 2016). Furthermore, French chemical industries are often located near to populated areas (Zampa et al., 1996). Since the disaster of AZF in 2001, France has decided to modify its regulation concerning risk management by including the notion of frequency and probability in risk assessment (Lenoble and Durand, 2011; Taveau, 2010). Chemical industries account for 14% of industrial events reported in France in 2014 (ARIA, 2016).

In this study, we have gathered and studied the chemical industry events in France between 1974 and 2014 based on the ARIA database. In the first step, we have analyzed the causes and consequences of events in the different sectors of chemical industry in France. Then, a risk analysis was carried out based on the risk matrix proposed in ISO 17776 (International Organization for Standardization (ISO), 2000).

2. Methodology

2.1. Description of ARIA database

Chemical accident databases can serve as source of information for developing strategies for emergency responses (Gomez et al., 2008; Zhang et al., 2008). ARIA database can be considered as robust because it is one of the main European databases on technological accidents available with FACTS and MIHDAS (INERIS, 2016). ARIA was also exploited in several scientific studies (Casson Moreno and Cozzani, 2015; Cozzani et al., 2010; Hemmatian et al., 2014; Renni et al., 2010; Tauseef et al., 2011).

ARIA is a database managed by the French ministry of ecology, sustainable development and energy since 1992. This database inventories more than 43,000 accidental events occurred in France and in the world (INERIS, report DRA-12-124789-07543A).

The ARIA database gathers information on:

- Accidents and incidents involving dangerous chemicals in classified installation or assimilated (ca. 71% of the inventoried accidents).
- Transport of hazardous materials (15%) and other areas such as pressure equipment, mines and quarries, underground storage, as well as dams and dykes.

This database is intended to provide consequences, circumstances and causes of events, and lessons learnt.

The information listed in ARIA comes from government services (inspection of classified installations, fire and rescue services, etc.) from the press and from several professional organizations. The updating is performed as soon as new information is provided. It is also possible to access to accident summaries and detailed event data sheets.

2.2. Data selection

In ARIA database, events are integrated in two ways: summary and/or detailed fact sheets. The summary form provides the key information data. The detailed form (fact sheets) presents very precisely events in terms of feedback on: the course of events, their circumstances, consequences, measures taken in the short or medium term, proven or suspected causes, follow-up or lessons learned. For this reason, our study focuses on detailed fact sheets. Fig. 1 shows the procedure followed for selecting the events.

ARIA contains data for more than 43,000 events, which 42,000 events occurred in France, and 4000 events occurred in the French chemical sector. Among these 4000 events, 169 are sufficiently documented in terms of feedback on consequences, circumstances and causes. For the sake of accuracy, this study was based on these 169 events.

2.3. Definitions

In this work, the events were separated into five categories according to the definition provided by Rathnayaka et al. (2011):

- Catastrophic accident or disaster: an event that may cause multiple fatalities and massive damage to property, production and environmental, temporary or permanent plant shutdown, and that is mentioned in international media.
- Accident: an event that may cause one or more fatalities or permanent major disabilities, relevant financial loss, and that is mentioned in national media.
- Incident: an event that could cause major health effect or injury, localized damage to property and environment, considerable loss of production and affect company image.
- Mishap: an event that could cause minor health effects and/or minor damages to property and the environment, production loss or work

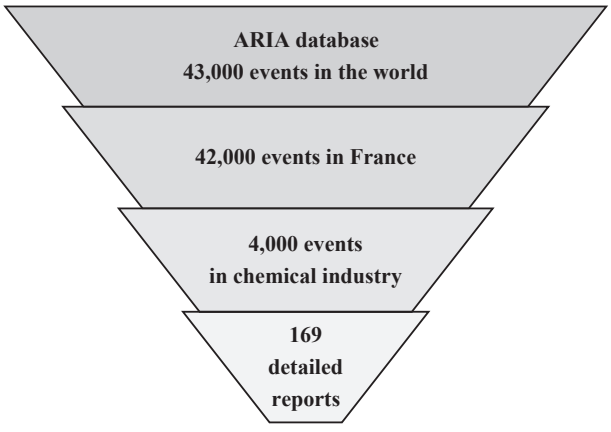

Fig. 1. Structure of events selection in ARIA database.