Safety Science xxx (2017) xxx–xxx

Contents lists available at ScienceDirect

Safety Science

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

A Total Safety Management framework in case of a major hazards plant producing pesticides

O.N. Aneziris [a,*], Z. Nivolianitou [a], M. Konstandinidou [a], G. Mavridis [b], E. Plot [c]

[a] National Center for Scientific Research "DEMOKRITOS", Aghia Paraskevi 15310, Greece
[b] K&N EFTHYMIADIS SA, 57022 Sindos, Greece
[c] INERIS, France

ARTICLE INFO

Article history:
Received 26 July 2016
Received in revised form 22 February 2017
Accepted 23 March 2017
Available online xxxx

Keywords:
Total Safety Management
Process safety
Common operation picture
Barrier management system
Risk assessment
Visualization tools

ABSTRACT

The aim of this paper is to present the framework for Total Safety Management through its application to a major hazards chemical plant, namely a pesticides producing unit. This framework was developed within the European Project entitled "Total Operation Management for Safety Critical Activities" (TOSCA) aiming at an innovative approach able to integrate and enhance safety, quality and productivity. The cornerstone of this framework is the "Common Operation Picture" notion, which involves a useful synthesis of the unit risk assessment, with the intention to provide understandable information to the relevant stakeholders and decision-makers. This framework has been applied to the storage area of a hazardous substance called dichloropropene, a flammable material used for pesticides production. The Fault Tree and the Bowtie methods have been used for the risk assessment of various accidental releases from the dichloropropene storage tanks. Production data, safety barrier information and results of risk analysis are stored in a database linked with accident sequences visualization tools.

1. Introduction

Over the last 30 years various methodologies and tools have been developed playing a significant role in the safety assessment of plants involving toxic, flammable and explosive substances. Several state of the art reviews for risk assessment methodologies have appeared in the literature by Khan and Abbasi (1998), Tixier et al. (2002) and Villa et al. (2016) for both qualitative and quantitative risk assessment methodologies. Qualitative methods include the HAZOP method, widely used in the chemical industry, which investigates deviations of all process variables in a plant together with their causes and consequences; the Failure modes and Effects analysis (FMEA), which can allow the evaluation of multiple failures, as reported by the Center of Process Safety (CCPS 2000); and the Master Logic method developed by Papazoglou and Aneziris (2003) which is a logic top down diagram and identifies initiating events leading to accidents. Quantitative probabilistic methods, include Fault Trees, Event Trees, Bowties and Bayesian networks, aiming at assessing risk and improving safety performance as proposed by several researchers (Villa et al., 2016; Ale et al., 2014; Khan and Abbasi, 1998; Tixier et al., 2002; Papazoglou et al., 1992). The Fault tree and Event tree methods are widespread for evaluating system reliability and plant safety. Fault tree analysis permits the top event frequency to be estimated from a logic model of the failure mechanisms of a system and has been applied in the chemical process industries (Khan and Abbasi 1998, 2000; Khakzad et al., 2011; Khan et al., 2000). Event Trees are logic models that quantify the possible outcomes following an initiating event and have been widely used for process safety such as for plants handling ammonia by Papazoglou et al. (1992), for LNG storage facilities by Aneziris et al. (2014), for distillation columns by Hashem et al. (2015), for LNG carriers by Vanem et al. (2008), and also for consequence estimation by Vílchez et al. (2011). The Bowtie method is based on a central event, and is composed of a fault tree that models the failures, which may lead to the central event and of an event tree on the right side modelling the events that may occur after the appearance of the central event. It has been used for assessing risk in the process industries by Dianous and Fiévez (2006) and Duijm (2009), for distillation columns by Markowski and Kotynia (2011), and as a risk management tool by Chevreau et al. (2006).

In addition to these, several approaches and associated tools have been developed for assessing safety management systems such as the Functional Resonance Accident Method (FRAM) proposed by Hollnagel (2012), and the Systemic – Theoretic Accident Model and Processes (STAMP), proposed by Leveson (2004). FRAM describes the functions that are necessary to make a system

* Corresponding author.
E-mail address: olga@ipta.demokritos.gr (O.N. Aneziris).

http://dx.doi.org/10.1016/j.ssci.2017.03.021
0925-7535/© 2017 Elsevier Ltd. All rights reserved.

operate, assesses the variability of each function and of multiple functions and identifies countermeasures required. STAMP specifies accidents, hazards and functional requirements by creating the functional control structure of the system and by identifying unsafe control actions. Both FRAM and STAMP have been used in the process industry by Rodríguez and Díaz (2016).

In the recent years standards for risk management, risk communication and risk mitigation have been developed, namely the ISO 31000:3009 and the NORSOK Z-013, 2010. The basic elements of risk management, as have been reported in these standards, are the following: (a) establishing the internal context of the organization (such as internal stakeholders, information flows, policies, resources and knowledge) and external parameters relevant to the environment in which the organization operates; (b) risk identification, analysis and evaluation; (c) risk treatment; (d) monitoring and reviewing of risk assessment; (e) application of risk; (f) communication and consultation with stakeholders; (g) monitoring and reviewing risk assessment so as to ensure continuous improvement in safety of the work environment and the personnel. The major steps for risk assessment as have been presented in these standards but also by Papazoglou et al. (1992) are hazard identification, accident sequence modelling and quantification, consequence assessment and finally integration of results in order to estimate the risk level.

Over the last 10 years there has been a tendency to integrate management systems, such as quality and environmental management systems, or quality, environmental and occupational health and safety management systems. The most important benefits of this integration are: (a) reduction of documentation, (b) optimisation of internal and external audits, (c) communication and training activities, (d) improvement in efficiency of operations, (e) saving of resources, and (f) less bureaucracy as reported by Salmone (2008), Sanz-Calcedo et al. (2015), Santos et al. (2011), and Nunhes et al. (2017). A few attempts have been performed in order to achieve a Total safety management framework which may either integrate occupational Health and safety with operational process safety (Badri et al., 2012), or avoid risk on short and long term, by using a proactive approach and designing inherently safe processes (Zhi et al., 2012).

The aim of this paper is to present a framework for total safety management in the process industry that integrates safety and risk management approaches and is based on the principles of ISO 31000, CCPS 2000 and NORSOK Z-013, 2010 standard. Several issues of this framework are presented by Kontogiannis et al. (2017), a paper included in the same special issue of Safety Science for "Total Safety Management". The associated tool that has been developed to incorporate the total safety management framework is also presented and applied to a major hazards plant producing pesticides. This tool has incorporated risk assessment methods such as Bowties and Fault trees, several aspects of Safety management systems, visualization of various parts installations, as well as the safety equipment and risk zones in a 3D environment.

The paper is organized as follows: the introduction Section 1 is followed by Section 2 that presents briefly the Total Safety Framework and the associated tool in Section 3. Section 4 contains a brief description of the case study, which are the dichloropropene storage tanks of a pesticide plant, while the application of the Total Safety Management methodology in this plant is presented in Section 5. Finally, Section 6 discusses the developed methodology and tools and Section 7 concludes the paper.

2. Methodology for total safety management for industrial organisations

The Total Safety Management Framework is composed of several interrelated modules, as reported by Leva et al. (2014) and presented in Fig. 1 as follows:

(a) The Common Operational Picture.
(b) Risk Assessment for Design.
(c) Risk assessment for Operations.
(d) Risk Assessment for Critical Activities.

The different modules comprising this framework are illustrated in Fig. 1 and are briefly introduced below, while more details are presented by Kontogiannis et al. (2017).

2.1. Common Operational Picture

The Common Operational Picture (COP) is a 'mental model of how the system works' and guides the application of a safety management system in everyday practice. The COP has been implemented with success in the Defense Departments (Liu et al., 2011), where its aim was to collect, process and manage information of real-time battlefield situation information, but it can also be applied in emergency situations that may arise in the process industry. The COP "incorporates information which enables situational information to be produced, visualized and presented in such a way that all information is available to all the actors involved in the crisis response in real time", as reported by Luokkala et al. (2017). The COP could also incorporate risks that are significant in a particular area or uncertainties that exist in the risk evaluation and risk mitigation measures of a process industry, so as to present a compound risk picture of the installation. This picture may be represented in different ways but, nevertheless, it should be accessible by all stakeholders involved in either the prevention or the mitigation phase of accidents in order to analyse and communicate risk, but also support training and procedures design. It should provide a common understanding of various types of information required and visualized for accident

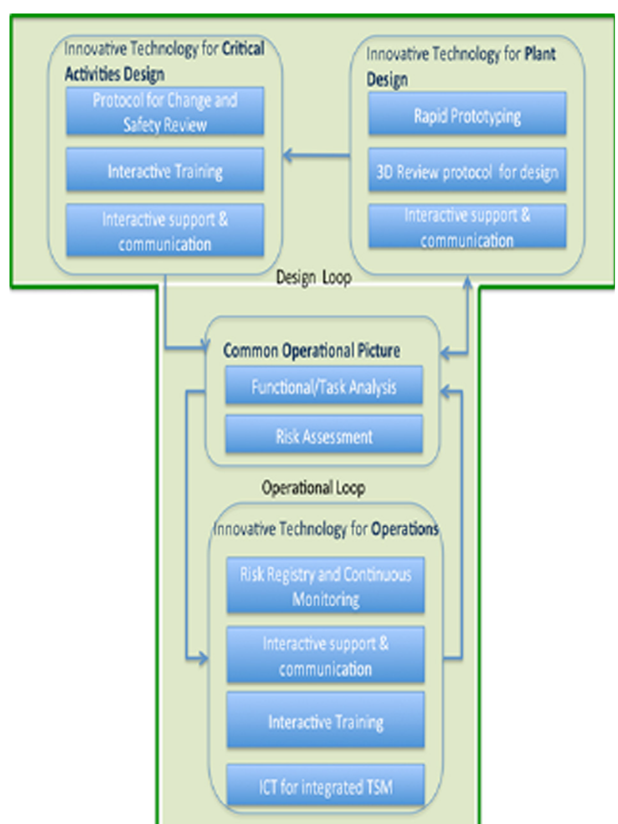

Fig. 1. TOSCA total safety management.

Please cite this article in press as: Aneziris, O.N., et al. A Total Safety Management framework in case of a major hazards plant producing pesticides. Safety Sci. (2017), http://dx.doi.org/10.1016/j.ssci.2017.03.021