Risk Analysis, Vol. 28, No. 5, 2008 DOI: 10.1111/j.1539-6924.2008.01092.x

Extending the Quantitative Assessment of Industrial Risks to Earthquake Effects

Michela Campedel,[1] Valerio Cozzani,[1]* Anita Garcia-Agreda,[2] and Ernesto Salzano[2]

In the general framework of quantitative methods for natural-technological (NaTech) risk analysis, a specific methodology was developed for assessing risks caused by hazardous substances released due to earthquakes. The contribution of accidental scenarios initiated by seismic events to the overall industrial risk was assessed in three case studies derived from the actual plant layout of existing oil refineries. Several specific vulnerability models for different equipment classes were compared and assessed. The effect of differing structural resistances for process equipment on the final risk results was also investigated. The main factors influencing the final risk values resulted from the models for equipment vulnerability and the assumptions for the reference damage states of the process equipment. The analysis of case studies showed that in seismic zones the additional risk deriving from damage caused by earthquakes may be up to more than one order of magnitude higher than that associated to internal failure causes. Critical equipment was determined to be mainly pressurized tanks, even though atmospheric tanks were more vulnerable to containment loss. Failure of minor process equipment having a limited hold-up of hazardous substances (such as pumps) was shown to have limited influence on the final values of the risk increase caused by earthquakes.

KEY WORDS: Equipment vulnerability models; industrial risk; major accident hazard; NaTech risk analysis; quantitative risk analysis; seismic vulnerability models

1. INTRODUCTION

Earthquakes may cause severe structural damages in industrial facilities, possibly resulting in loss of containment of hazardous substances stored or processed on the site. When the loss is particularly relevant, the seismic action may be the trigger of major industrial accidents, thus increasing the overall severity of the natural events either in terms of economical losses, or in terms of overload of emergency services, which are expected to face heterogeneous impacts on systems, or in terms of people safety if the installations are located in populated areas and keeping into account that population is possibly struggling with the effects of the catastrophic natural event (Lindell & Perry, 1996, 1997; Steinberg *et al*., 2001; Cruz *et al*., 2004; Cruz, 2005). As a consequence, quantitative risk assessment (QRA) of industrial installations should consider the probability of occurrence and intensity of possible seismic events, and the escalation of these natural events also in terms of industrial accidental scenarios, for proper prevention and emergency planning (DPC, 1993).

Despite these considerations, the European Community Directives for the prevention of major industrial accidents (e.g., Council Directive

[1] Dipartimento di Ingegneria Chimica, Mineraria e delle Tecnologie Ambientali, Alma Mater Studiorum, Università di Bologna, via Terracini 28, 40131 Bologna, Italy.
[2] Istituto di Ricerche sulla Combustione, Consiglio Nazionale delle Ricerche, via Diocleziano 328, 80125 Napoli, Italy.
* Address correspondence to Valerio Cozzani, Dipartimento di Ingegneria Chimica, Mineraria e delle Tecnologie Ambientali, Alma Mater Studiorum - Università di Bologna, via Terracini 28, 40131 Bologna (Italy); tel: (+39)-051-2090240; fax: (+39)-051-2090247; valerio.cozzani@unibo.it.