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The classification of physical effects from natural hazards for Natech risk assessment based on a Japanese database

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A B S T R A C T

There has been considerable evidence that natural disasters can be threats to technological systems and when these threats are concomitant, they pose tremendous risks to countries and communities. Such risk (termed *Natech* risk) should be incorporated early in the design process, particularly in land-use planning of sites.

In this study, a descriptive classification of *Natech* risk sources was developed, mainly from analysis of a Japanese database, to contribute to preliminary analysis of *Natech* risk. Analysis of the information gathered, resulted in a classification including fifteen *physical effects* and six *physical impacts* that cause technical disorder. Here, the pertinent aspects of natural hazards were termed *physical effects*, and the phenomena caused by *physical effects* were termed *physical impacts*: the primary observable consequences and influences on the functions of technological systems. The classification is expected to be helpful for *Natech* risk identification, by providing guidewords useful for risk assessment and management.

1. Introduction

Disasters triggered by natural hazards can pose serious threats to people, facilities, and the natural environment, as well as economic and social systems. Humans have a long history of combating these threats by developing countermeasures to mitigate their impacts. Even now, the efforts are still being made to do so as natural hazards threaten our society with new types of risk accompanied by development of responsive human activities.

This growing concern has highlighted use of the term *Natech* to describe accidents triggered by natural hazards that create catastrophic technological calamity (Galderisi et al., 2008). In an industrial area, the power of a natural hazard can disrupt industrial operations or destroy industrial installations, leading to uncontrollable technological events and ending in serious disaster. In some cases, damage from the technical event might be greater than from the triggering natural disaster.

Natech risks can be found particularly at industrial sites storing hazardous materials because of concerns about the loss of containment after destructive natural events (Krausmann et al., 2011a). Natural hazards can even trigger multiple and simultaneous losses of containment because of their massive power to generate widespread impacts. Response to such widespread impacts requires simultaneous response efforts from multiple emergency responders, which makes it difficult to establish effective risk reduction within limited resources.

In recognition of the threats from natural disasters, international cooperation has led to collaboration in *Natech* risk identification, analysis, and risk assessment. An expert group established by the OECD analysed the problems of multi-hazard risk modelling (Organisation for Economic Cooperation and Development, 2012). Their survey revealed a strong demand for data mining and standards, a lack of matured multi-risk/multi-hazard assessment models, and rare consideration of the potential for domino or cascading impacts in natural-man-made systems. The Joint Research Centre of the European Union (JRC) researched the status of *Natech* awareness and preparedness in selected EU Member States and the United States (Cruz et al., 2004). They found that all of the countries in their study have disaster management systems in place for natural disasters and technological disasters. Nevertheless, the study found that none of the countries have specific *Natech* risk and emergency management programmes in place, and that few have considered the problems of cascading or domino

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effects in disaster management. A questionnaire survey in 2009 for EU member states about the state of *Natech* risk reduction revealed that a framework for *Natech* risk reduction exists in the responding countries but a strategic *Natech* risk-reduction initiative still appears to be lacking (Krausmann, 2010). The survey also showed that the responding countries have largely recognised natural hazards and disasters as a relevant source of risk to a chemical facility, with the potential to trigger a major incident. During such incidents, tanks, pipes, and reactors containing hazardous substances could be breached, fractured, torn, or displaced by natural hazards, after which they could release hazardous substances over a wide swath of territory. The distribution of hazardous substances often makes recovery from a disaster more difficult compared to the damage caused by a single natural disaster. Therefore, storing industrial chemicals, particularly for the chemical industry, requires an effective strategy for *Natech* risk reduction not only in safety management during production, but also during the design of plants and installations.

Under the currently available strategy of risk reduction, hazard control measures change as a plant design process advances from conceptual to basic; then to detailed design (Fig. 1). At the beginning of a design process, hazard reduction is considered according to steps comprising “elimination of hazards”, “reduction of the severity”, and “reduction of the likelihood” based on the information about the facility function and basic specifications (CCPS, 2009). Then, residual risk should be further reduced by separating people and important facilities from hazards by balanced combination of land-use planning and economic rationality. As the process design is determined, passive, active, and procedural safe guards are considered and implemented for the plant operation, while taking into consideration detailed design information and operation procedures.

Meanwhile, the hazard control steps at the beginning of process development are focused on chemical substances and chemical production processes. For example, four inherent safety principles are intended to reduce risk of loss of containment: “minimisation”, “substitution”, “moderation”, and “simplification” (Amyotte et al., 2009). These four principles serve as guidewords that enable process engineers to consider a safer process by minimising hazardous substances in the process, substituting a safer substance for a more hazardous substance, moderating the process conditions (e.g. temperature) and simplifying the process to reduce opportunities to fail. The guidewords are applicable to chemical substances and to processes which constitute internal hazards. To date, there is no proper strategy or guidewords for external hazards (i.e. *Natech* risks) at this stage.

Because chemical risks should be better managed from earlier stages (Hassim and Edwards, 2006), management of *Natech* risks should start at earlier stages. Meanwhile, the earlier in the process design stage this occurs, the less of the design is already determined. Therefore, it is assumed that a tool for preliminary review would be helpful for *Natech* risk reduction during land-use planning, from the conceptual design stage to the basic design stage.

The aim of this study was to develop and propose a classification that could help incorporate consideration of *Natech* risk at earlier stages of process development by preliminary identification of *Natech* risk sources and their influences over a wide range of sites, facilities, and installations. To achieve this aim, the authors reviewed articles on natural disasters and *Natech* events to extract modes of natural hazards that were triggering phenomena for *Natech* events. Along with extracting such modes, classification of the impacts on a technological system was also conceptualized.

In this article, the data collection used to develop the classification is described. The phenomena that occurred due to natural hazards (and their consequences) were gathered mainly from a Japanese database, but additional information sources were found in the literature. Data from these were categorised to form a classification of *physical effects* and *physical impacts*. In this study, *physical effects* are the features of a natural hazard that influence the functions of a technological system; whereas *physical impacts* are visible, tangible, or recognisable consequences of natural hazards.

Although there is data from coverage of events that have occurred in various places in the world, this study particularly included events in Japan and described these in Japanese language. This is because Japan is one of the most natural-hazard prone countries in the world, and reasonable amount of records relating to natural disasters there are available (Kumasaki et al., 2016). The records gathered described not only *Natech* events, but also natural incidents that could have resulted in *Natech* events. Although conceptualization should work to widen the range of applicability, it should be noted that the findings in this study may be limited to regions with similar geographical, meteorological and technological settings because the occurrence of natural disasters and subsequent *Natech* events depend on local conditions. However, studying the features found in Japan should contribute to an initial understanding of the mechanism of how *Natech* events develop from natural hazards, and should help establish an effective system to alleviate the impacts and mitigate the consequences.

2. Literature survey

Based on a survey from the Web of Science, an online scientific database, the earliest article employing ‘*na-tech*’’ as a topic first appeared in 2004. In 2004, Young reviewed historic releases of hazardous materials (hazmat) caused by flood and wind-related

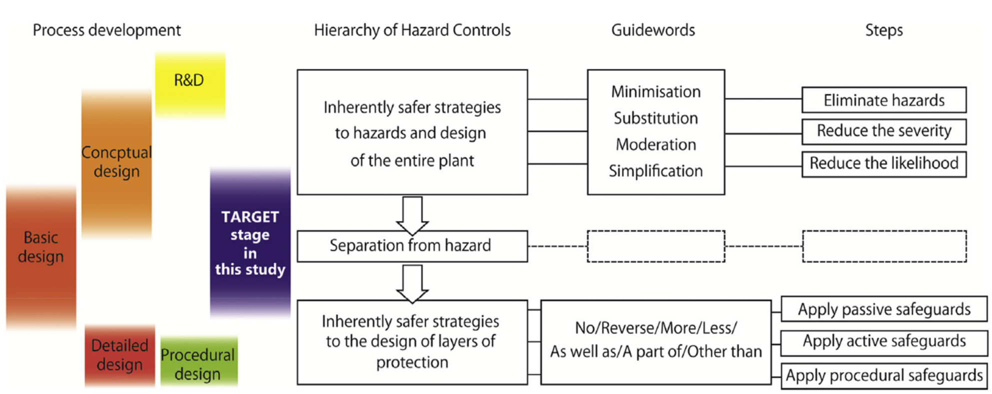

Fig. 1. Process development and related hazard control measures in the chemical industry.

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