**Emergency Response Management in the Risk Assessment   
of Cascading Events caused by Natech Accidents**

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**1. Introduction**

Accidents triggered by natural events are becoming an increasing issue for industrial practitioners and policy-makers. These events are called Natech (Natural Hazards Triggering Technological Disasters), and their study has attracted attention due to their uncertain and complex nature, increasing occurrence, and severe consequences. Moreover, the increase in the number of natural events in the last decades has led to a growing number of Natech accidents [1]. In addition, the magnitude of the accident can escalate when it is triggered by a natural event. Natech accidents are characterized by the occurrence of cascading events [2], the possibility of multiple simultaneous failures [3], and the disruption of utilities, safety systems, and lifelines [4]. Besides active and passive barriers, human intervention plays a vital role in mitigating the effects of technological scenarios. The emergency response is widely considered a procedural safety barrier [5] and its role in risk assessment and management is paramount. Moreover, it is important in avoiding the occurrence of cascading events when considering fire-driven domino effects [6]. In fact, accidents that result in a fire are characterized by a time-lapse between the start of the primary fire and its spreading to neighbouring tanks [7]. This time-lapse represents the time available to perform an effective emergency response to avoid cascading events. Nevertheless, limited attention has been paid to date to the study of the emergency response, due to the complexity and the variety of actions and to the technical requirements needed to complete the procedures. Moreover, requirements differ when considering the aims of the intervention and the type of target considered. The three main targets of emergency response are human health, the environment, and assets [8]. Moreover, when considering the emergency response during Natech accidents, some actions can be delayed or unsuccessfully completed because of specific contingencies. In addition, technical elements can be unavailable or damaged due to the natural event. These elements should be considered to correctly actuate emergency response plans. Neglecting them could lead to a reduction of the effectiveness of the intervention, and to an underestimation of the overall risk in the framework of the quantitative risk assessment of Natech accidents and related domino effects.

**2. Methods**

Despite the criticality of the issue, scarce attention has been devoted to the study of emergency response in the case of natural events. To fill this gap, the present work aims to address the issue of emergency response in the case of natural events. In this framework, past accidents represent a source of detailed, complete and useful information considering the complexity of the phenomena involved. In the present study, accidents related to the Kocaeli earthquake (occurred on August 17th, 1999, in Turkey) [9] and the Great East Japan earthquake and tsunami (occurred on March 11th, 2011, off the Pacific Coast of Tohoku) [3] are considered. Through the analysis of these accidents, the actions of emergency response teams that can be hindered by natural events are highlighted, as well as the technical needs that resulted unavailable or damaged by the natural event.

**3. Results and discussion**

The accident dynamics that occurred in the events considered in the present study revealed that safety barriers alone cannot prevent the accident nor reduce the consequences, emphasizing that the role of emergency response is crucial to effectively counter Natech accidents. Nevertheless, past accidents also highlighted that the emergency response can be affected by natural events as well. According to the information available, shortcomings and lesson learned were derived and the main elements that should be improved to perform an effective emergency response are summarized as follow:

1. ***Design of mitigation safety systems***. Examples: length of hoses were not enough to reach industrial items; sprinkler systems were implemented in a limited number of tanks.
2. ***Capacity of fire-fighting materials****.* Examples: shortage of fire-fighting materials; possibility of multiple and simultaneous fires not accounted.
3. ***Utility systems***. Examples: lack of the main power supply; unavailability of the fire-fighting system; inadequate design of backup systems.
4. ***Size of the internal fire-fighting team***. Examples: emergency teams on site were not enough to counteract the accident; unavailability of additional and supporting teams.
5. ***Training for any emergency teams***. Examples: lack of proper training specifically for the case of Natech accidents; lack of proper training specifically for multiple and simultaneous accidents.
6. ***Emergency response plans***. Examples: lack of proper emergency response plans specifically for Natech accidents and related cascading events.
7. ***Accessibility of the site***. Examples: disruption of external infrastructure (roads and bridges); inaccessibility of the site.
8. ***Communications***. Examples: disruption of standard communication means; an incomplete set of information shared within the teams.

The factors identified above provide the starting point for the evaluation of the effects of natural events on emergency response. Accounting for these aspects allows the correct and complete assessment of the risk associated with Natech events and improves the emergency response plans of industrial sites.

**4. Conclusions**

Appropriate and effective emergency response is a crucial aspect in the risk assessment and management of Natech events. The present study evidenced several shortcomings related to the emergency response during and after natural events, highlighting criticalities that should be considered when evaluating the emergency response in these accidents. Eventually, the results of the study can guide an improvement of existing emergency response plans for natural events and Natech accidents.

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