Words into Action Guidelines:
National Disaster Risk Assessment
Hazard Specific Risk Assessment

9. Natech Hazard and Risk Assessment

Key words:
Natech, technological risk, chemical accident, industrial safety, loss of containment, cascading effect, Natech risk assessment

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The impacts of natural hazard events on chemical installations, pipelines, offshore platforms and other infrastructure that process, store or transport dangerous substances can cause fires, explosions and toxic or radioactive releases.[1] Although these "Natech" accidents are a recurring feature in many natural disasters, they are often overlooked, despite the fact that they can have major social, environmental and economic impacts.

They may cause multiple and simultaneous releases of hazardous substances over extended areas, damaging or destroying safety barriers or systems, and downing lifelines often needed for accident prevention and mitigation.

In addition, emergency responders are usually neither equipped nor trained to handle several substance releases at the same time, in particular as they also have to respond to the natural hazard event consequences in parallel.[2,3,4]

Because of the inherent multi-hazard nature, Natech risk assessment concerns industry operators and authorities in charge of chemical accident prevention and civil protection. Natech risk assessment and management therefore requires a comprehensive understanding of the interdependencies of human, natural and technological systems. Successfully controlling a Natech accident has often turned out to be a major challenge – if not impossible – where no prior risk assessment and proper preparedness planning had taken place.

Sources and setting

Examples of recent major events that highlight the importance of the serious consequences of Natech accidents include the 2002 river floods in Europe, which resulted in significant hazardous substance releases, including chlorine[5] and dioxins, the 2011 Tōhoku earthquake and tsunami, which caused a meltdown at a nuclear power plant and raging fires and explosions at oil refineries,[6] and Hurricane Sandy in 2012, which triggered multiple hydrocarbon spills.

The Tōhoku earthquake, in particular, is a textbook example of a cascading

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1 Showalter, P.S. and M.F. Myers (1994). Natural disasters in the United States as release agents of oil, chemicals, or radiological materials between 1980-1989: analysis and recommendations. *Risk Analysis,* vol. 14, issue 2, pp. 169-182.

2 Krausmann, E., A.M. Cruz and E. Salzano (2017). Natech Risk Assessment and Management - *Reducing the Risk of Natural-Hazard Impact on Hazardous Installations.* Amsterdam: Elsevier.

3 Girgin, S. (2011). The natech events during the 17 August 1999 Kocaeli earthquake: aftermath and lessons learned. *Natural Hazards and Earth System Sciences*, vol. 11, issue 4, pp. 1129-1140.)

4 Krausmann, E., A.M. Cruz and B. Affeltranger (2010). The impact of the 12 May 2008 Wenchuan earthquake on industrial facilities. *Journal of Loss Prevention in the Process Industries*, vol. 23, pp. 242-248.

5 Hudec, P. and O. Lukš (2004). Flood at Spolana a.s. in August 2002. *Loss Prevention Bulletin,* issue 180. Institution of Chemical Engineers, United Kingdom.

6 Krausmann, E. and A.M. Cruz (2013). Impact of the 11 March 2011, Great East Japan earthquake and tsunami on the chemical industry. *Natural Hazards*, vol. 67, issue 2, pp. 811-828.

risk, because the earthquake itself caused only limited damage owing to the stringent protection measures in place. However, the tsunami and its impact on a nuclear power plant resulted in the most severe technological disaster ever recorded in the region and whose adverse effects still persist.

It does not necessarily require a major natural hazard event, e.g. a strong earthquake or flood, to cause a Natech accident; it can be triggered by any kind and size of natural hazard event. Consequently, Natech risks exist both in developed and developing countries where hazardous industrial sites are located in natural hazard regions. Industrial growth, climate change and the increasing vulnerability of a society that is becoming more and more interconnected will increase the likelihood and impact of such events in the future.

Hazard assessment

Natech events are joint disasters that combine natural and technological hazards and that feature very complex consequences owing to amplifying effects between the two types of hazard. Adequate prevention, preparedness and response are specifically needed, therefore, to prevent them and mitigate their consequences.

Unfortunately, disaster risk reduction frameworks do not always consider technological hazards and chemical accident prevention and preparedness programmes often overlook the specific aspects of Natech risk. This results in a lack of dedicated methodologies and guidance for risk assessment and management for industry and authorities.

Adequate national-level Natech risk assessment is therefore important to see the overall picture and pinpoint potential risk hotspots that require detailed risk assessment. Many such potential hotspots, such as refineries, petrochemical complexes, and oil and gas pipelines, are also considered critical infrastructures. Consideration of Natech risk is required for their effective protection. In this context, it is important to consider all natural hazards that a hazardous installation can be subject to in a certain area.

Although the consequences of hazardous materials release are well known and industrial practices exist to cope with most scenarios, including major events, the cost of additional safety measures to reduce the Natech risk can result in reluctance to accept that such risks exist and to act to reduce them. This also means a limited amount of data from industry, which are required for national risk assessment. Adequate legislative frameworks and their enforcement should ensure that operators share information that is critical for Natech risk assessment.

Natural hazard data	Ministries related to natural disasters; meteorological services	USGS; EMSC; GEM; NOAA; Blitzortung.org
Industrial process and unit data	Ministries related to industry and environment; industrial associations	Global Energy Observatory; EGIG; CONCAWE; PHMSA
Natural hazard industrial fragility data	Research institutions; standardization bodies; industrial associations	HAZUS, RAPID-N

Table 1- Sources of natural and technological hazard data

Exposure and vulnerability

National Natech risk assessments should consider that major natural hazards can impact large areas, affecting the population, the building stock, industry and infrastructure. Potential multiple and simultaneous releases from various installations and also from different parts of each installation, as well as the possibility of on- and off-site secondary cascading (domino) events, should be taken into account when assessing exposure.

Industrial facilities handling hazardous materials are inherent vulnerabilities for the social system in which they are nested. If not managed well, not only extreme events but also low-level hazards can generate broad chain effects if vulnerabilities are widespread in the system and the risks are not handled properly.[7]

By analysing past Natech accidents, conclusions were drawn concerning the most vulnerable types of industrial equipment per natural hazard, common damage and failure modes, and the hazardous substances mostly involved in

7 Pescaroli, G. and D. Alexander (2015). A definition of cascading disasters and cascading effects. Going beyond the "toppling dominos" metaphor. Global Risk Forum, Davos, Switzerland.

the accidents.[8,9,10,11]

Among the process and storage units commonly used by industry, atmospheric storage tanks, especially those with floating roofs, appear to be particularly vulnerable to natural hazards. This is critical from an industrial-safety point of view, as these units usually contain large amounts of flammable liquids that may ignite and escalate into major fires or explosions during Natech accidents. The likelihood of ignition is high in earthquake- or lightning-triggered Natech events.

Oil and gas pipelines transporting vast amounts of hazardous substances are also vulnerable to natural hazards, especially at river crossings. Because the pipelines are usually located in the countryside, detection of pipeline accidents can be late, leading to major spills and significant economic damage. 6

Natech accidents may result in exposed areas that are much greater than for ordinary industrial accidents. For example, if floods cause an overflow of containment dikes at a facility, any released substances that would normally be captured within the dikes can easily be dispersed by the flood waters and contaminate the environment up to hundreds of kilometres through the river network. In the case of earthquakes, cracks that occur on dike floors as a result of ground movement may leak hazardous liquid substances that can lead to significant ground water pollution.

The vulnerability of the population may also be significantly increased during Natech conditions. For instance, when there is toxic atmospheric dispersion caused by an earthquake, shelter might not be possible because of structural damage to buildings. Also, evacuation from the location of an industrial accident might not be feasible because of the blockage of escape routes by debris or flooding. And residents might be reluctant to evacuate an area if relatives are still trapped under the debris. Such factors should be considered in undertaking exposure and vulnerability analysis.

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8 Cozzani, V. and others (2010). Industrial accidents triggered by flood events: analysis of past accidents. *Journal of Hazardous Materials*, vol. 175, pp. 501-509.

9 Renni, E., E. Krausmann and V. Cozzani (2010). Industrial accidents triggered by lightning. *Journal of Hazardous Materials*, vol. 184, pp. 42-48.

10 Krausmann, E. and others (2011). Industrial accidents triggered by earthquakes, floods and lightning: lessons learned from a database analysis. *Natural Hazards*, vol. 59 (285).

11 Girgin, S. and E. Krausmann (2016). Historical analysis of U.S. onshore hazardous liquid pipeline accidents triggered by natural hazards. *Journal of Loss Prevention in the Process Industries*, vol. 40, pp. 578-590.

Natech risk assessment use in national DRR measures

Risk assessment is a powerful tool for identifying hazards and estimating the associated risk. Industrial risk assessment methodologies vary across countries, ranging from fully quantitative to qualitative approaches. For Natech risk assessment, existing methodologies need to be extended to include equipment damage models for natural-hazard impact and the possibility of multiple loss-of-containment events at several industrial units at the same time.

Unlike many natural hazards, technological hazards are usually localized – an aspect that needs to be considered in the national risk assessment. In order to assess the Natech risk to a hazardous installation, operators should determine if their site is located in a natural hazard zone and, if so, what the expected severity of the natural hazards on the site would be.[12]

This needs to be followed by an analysis of which parts of the installation would be affected and how, since not all equipment is equally vulnerable. Priority should be given to the most hazardous equipment. The natural hazard risks to these selected facilities should then be analysed. This analysis should also include an assessment of the impacts of the natural events on the prevention and mitigation measures in place. Once the potential consequences have been assessed and a need for further risk reduction identified, dedicated protection measures should be implemented. This process requires a significant amount of input data. However, as much of this information (natural risk maps, industry information) is already gathered in the framework of the national risk assessment, these data could also be used for the Natech risk assessment. Krausmann (2017)[13] provides a detailed discussion of the requirements and steps for Natech risk assessment. Risk assessment methodologies and tools have inherent uncertainties that need to be considered in the decision-making process.

A number of research and policy challenges and gaps exist that can prevent effective Natech risk reduction. These include a lack of data on equipment vulnerability against natural hazards, and the unavailability of a consolidated methodology and guidance for Natech risk assessment, which has, for instance, resulted in a lack of Natech risk maps.

The few existing Natech risk maps are usually only overlays of natural hazards with industrial site locations and are therefore only Natech hazard maps. Natech risk maps must also include an estimate of the potential

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12 Krausmann, E. (2016). Natech accidents - an overlooked type of risk? *Loss Prevention Bulletin*, vol. 250. Institution of Chemical Engineers, United Kingdom.

13 ___________ (2017). Natech risk and its assessment. In: Krausmann, E., A.M. Cruz and E. Salzano. Natech Risk Assessment and Management - Reducing the Risk of Natural-Hazard Impact on Hazardous Installations. Amsterdam: Elsevier.

consequences, which may differ significantly from site to site. Attention should be paid to the inherent limitations of existing equipment vulnerability models from non-Natech applications if these are used to substitute for the missing Natech models.

There is the misconception that engineered and organizational protection measures in place to prevent and mitigate conventional industrial accidents would be sufficient to protect against Natech events. But the very natural event that damages or destroys industrial buildings and equipment can also render unavailable the instrumentation (e.g. sensors, alarms), the engineered safety barriers (e.g. containment dikes, deluge systems) and the lifelines (e.g. power, water for firefighting or cooling, communication) needed for preventing an accident, mitigating its consequences and keeping it from escalating. Therefore, for effective Natech risk reduction, additional Natech-specific safety measures need to be put in place to accommodate the characteristics of Natech accidents.

The assessment of Natech risk can therefore be challenging, even for the impact of a single natural hazard on a hazardous installation. Consideration of multiple natural hazards and cascading events (e.g. domino effects) that may involve multiple process units or installations at the same time is much more difficult.

Currently no assessment tools exist to capture all aspects of Natech risks. Recently, however, risk assessment tools and methodologies that can rapidly estimate regional and national Natech risk have become available. These include RAPID-N for semi-quantitative risk assessment[14] based on natural hazard information and the data on hazardous industrial installations entered by the user, ARIPAR for a quantitative treatment of the problem[15] and PANR for a qualitative assessment methodology.[16] Although still limited to selected natural hazards and certain types of installations, the tools are in active development to cover additional hazards and industries, and can significantly facilitate national risk assessment studies.

Being an emerging risk – even in developed countries – national authorities are still not assessing Natech risk comprehensively. Although there are no risk assessments at country level, several national and international programmes and regulations exist that require the operators of hazardous installations to include Natech risks in their safety plans.

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14 Girgin, S. and E. Krausmann (2013). RAPID-N: Rapid natech risk assessment and mapping framework. *Journal of Loss Prevention in the Process Industries,* vol. 26, issue 6, pp. 949-960.

15 Antonioni, G. and others (2009). Development of a framework for the risk assessment of Natech accidental events. *Reliability Engineering and System Safety*, vol. 94, issue 9, 1442-1450.

16 Cruz, A.M. and N. Okada (2008). Methodology for preliminary assessment of Natech risk in urban areas. *Natural Hazards,* vol. 46, issue 2, 199-220.

CASE STUDY

Box 1
Good practices for addressing Natech risk

European Union - Directive 2012/18/EC on the control of major-accident hazards involving dangerous substances (Seveso III Directive), which regulates chemical accident risks at fixed industrial installations, explicitly addresses Natech risks and requires the installations to routinely identify environmental hazards, such as floods and earthquakes, and to evaluate them in safety reports.
The inclusion of Natech risks in the Seveso Directive acknowledges that awareness of this risk has been growing steadily in Europe since the Natech accidents during the 2002 summer floods.

Japan - The Law on the Prevention of Disasters in Petroleum Industrial Complexes and Other Petroleum Facilities was updated after the Tokaichi-oki earthquake triggered several fires at a refinery in 2003. Moreover, the amended Japanese High Pressure Gas Safety Law requires companies to take any additional measure necessary to reduce the risk of accidents, and to protect their workers and the public from any accidental releases caused by earthquakes and tsunamis.

United States - The State of California released the California Accidental Release Prevention (CalARP) Program, which calls for a risk assessment of potential hazardous materials releases as the result of an earthquake.

The Natech database eNatech is specifically designed for the systematic collection and analysis of worldwide Natech accident data (available at http://enatech.jrc.ec.europa.eu).

Rapid Natech risk assessment and mapping tool RAPID-N allows quick regional and local Natech risk assessment, including natural hazard damage assessment and accident consequence analysis with minimum data requirements (available at http://rapidn.jrc.ec.europa.eu). (Requires prior authorization).

The Natech addendum to the OECD Guiding Principles for Chemical Accident Prevention, Preparedness and Response contains amendments to the original guiding principles (available at www.oecd.org/chemicalsafety/guiding-principles-chemical-accident-prevention-preparedness-and-response.htm).

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