Specific Risk Assessment: Technological

1 - Natech Hazard and Risk Assessment

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

The impacts of natural hazard events on chemical installations, pipelines, offshore platforms and other infrastructures that process, store or transport dangerous substances can cause fires, explosions and toxic or radioactive releases[1]. These so-called Natech accidents are a recurring but often overlooked feature in many natural disasters and have often had significant social, environmental and economic impacts. They may involve multiple and simultaneous releases of hazardous substances over extended areas, damage or destroy safety barriers or systems, and down lifelines often needed for accident prevention and mitigation. In addition, emergency responders are usually neither equipped nor trained to handle a high number of 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].

Due to their inherent multi-hazard nature, the assessment of Natech risks concerns industry operators, and authorities in charge of chemical accident prevention and civil protection. Therefore, Natech risk assessment and management 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

The 2002 river floods in Europe that resulted in significant hazardous substance releases, including chlorine[5] and dioxins, the 2011 Tōhoku earthquake and tsunami that caused a meltdown at a nuclear power plant and raging fires and explosions at oil refineries[6], and Hurricane Sandy in 2012 that triggered multiple hydrocarbon spills are just a few examples of recent major events that highlight the importance of the possible consequences of Natech accidents. Especially the Tōhoku earthquake is a textbook example of a cascading risk, because the earthquake itself caused only limited damage due 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 are still persisting.

It does not necessarily require a major natural hazard event, e.g. a strong earthquake or flood, to cause a Natech accident; they 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 society

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that is becoming more and more interconnected increases the likelihood 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, due to amplifying effects between the two types of hazard. Therefore, adequate prevention, preparedness and response are specifically needed to prevent Natechs and mitigate their consequences. Unfortunately, disaster risk reduction frameworks do not always consider technological hazards and chemical accident prevention and preparedness programs often overlook the specific aspects of Natech risk, resulting in a lack of dedicated methodologies and guidance for risk assessment and management for industry and authorities. Adequate national Natech risk assessment by authorities is important in this respect to see the overall picture and pinpoint potential Natech risk hot spots where detailed risk assessment is required. 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 installations can be subject to in a certain area.

Although the consequences of hazardous materials releases are well known and there are industrial practices 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 take actions to reduce them. This also results in limited data availability from industry, which is required for the national risk assessment. Adequate legislative frameworks and their enforcement should ensure that operators share information which is critical for Natech risk assessment. The necessary steps in the risk assessment, including hazard assessment, will be discussed in more detail later.

TABLE 1 - Sources of natural and technological hazard data

description of input data	national entities that most commonly have this data	examples of existing open databases available from international sources
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

Exposure and vulnerability

National Natech risk assessments should consider that major natural hazards can impact large areas, affecting the population, the building stock, as well as industry and other infrastructures. 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 while 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].

Via the analyses of past Natech accidents conclusions were drawn on the most vulnerable types of industrial equipment per natural hazard, common damage and failure modes, and the hazardous substances mostly involved in 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 which may ignite and escalate into major fires or explosions during Natech accidents. In fact, the likelihood of ignition is found to be high in earthquake- or lightning triggered Natech events. Oil and gas pipelines which transport vast amounts of hazardous substances are also vulnerable to natural hazards, especially at certain locations such as river crossings. Because they are usually located in the countryside, detection of pipeline Natech accidents can be delayed leading to major spills and eventually significant economic damage[11].

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 kilometers through the river network. In case of earthquakes, cracks that occur on dike floors due to ground movement may leak hazardous liquid substances which can eventually lead to significant ground water pollution. In case of multiple simultaneous toxic releases, the overall extent of the toxic cloud can be significantly larger compared to a conventional chemical accident with a release from a single source.

The vulnerability of the population may also be significantly affected during Natech conditions. For example, in case of toxic atmospheric dispersion caused by an earthquake, shelter in place might not be possible at all due to structural damage of buildings by the natural hazard impact. In contrast, evacuation from the location of an industrial accident might not be feasible due to the blockage of escape routes by debris or flooding. It should be noted that residents might be reluctant to evacuate an area if relatives are still trapped under the debris. Such factors should be considered for exposure and vulnerability analysis.

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 natural hazard specific equipment damage models and to consider the possibility of multiple loss-of-containment events at several industrial units at the same time.

In contrast to 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 site would be[12]. This needs to be followed by an analysis of which parts of the installation would be affected and how, considering that not all equipment is equally vulnerable. Priority should be given to the most hazardous equipment on site. The natural hazard risks to these selected facilities should then be analyzed. This also has to 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 has been identified, dedicated protection measures should be implemented. This process requires a significant amount of input data. However, considering that a lot of this information (natural risk maps, industry information) is already gathered in the framework of the NRA, this 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. Also, a number of research and policy challenges and gaps exist that can prevent effective Natech risk reduction. This includes 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 maps are usually only overlays of natural hazards with industrial site locations, and are therefore only Natech hazard maps. Natech risk maps should also include an estimate of the potential consequences that may differ significantly from site to site. It is also important to pay attention to inherent limitations of existing equipment vulnerability models from non-Natech applications if they 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. In fact, the very natural event that damages or destroys industrial buildings and equipment, can also render unavailable instrumentation (e.g. sensors, alarms), engineered safety barriers (e.g. containment dikes, deluge systems) and 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 there is a need for additional Natech-specific safety measures to accommodate the characteristics of Natech accidents.

Due to the aforementioned reasons, the assessment of Natech risk can 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) which may involve multiple process units or installations at the same time, is considerably more difficult. Currently there are no assessment tools that can capture all aspects of Natech risks. However, recently, risk assessment tools and methodologies which can estimate regional and national Natech risk rapidly have become available, e.g. 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 currently limited to selected natural hazards and certain types of installations, the tools are in active development to cover additional hazards and industries, and they can significantly facilitate national risk assessment studies.

Being an emerging risk even in developed countries, Natech risk is hardly assessed by national authorities in a comprehensive manner. There are no risk assessments at country level, but there are several national and international programs and regulations that require the operators of hazardous installations to consider Natech risks in their safety documents.

BOX 1 - Good practices of addressing Natech risk

European Union - Directive 2012/18/EC on the control of major-accident hazards involving dangerous substances (Seveso III Directive) that 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[16]. Moreover, the amended Japanese High Pressure Gas Safety (HPGS) Law requires companies to take any additional measure necessary to reduce the risk of accidents, to protect its workers and the public from any accidental releases caused by earthquake and tsunami.

United States - The state of California released the Accidental Release Prevention (CalARP) program, which calls for a risk assessment of potential hazardous materials releases due to an earthquake[17].

Resources for further information

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 requirement. Available at http://rapidn.jrc.ec.europa.eu (Natech risk assessment requires prior authorization). Natech Addendum to the OECD Guiding Principles on Chemical Accident Prevention, Preparedness and Response contains amendments to the Guiding Principles for guidance on Natech prevention, preparedness and response. Available at http://www.oecd.org/chemicalsafety/guiding-principles-chemical-accident-prevention-preparedness-and-response.htm.

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