3.14 Technological risk: Natech

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3.14.1 Introduction

The past few years have seen a number of natural disasters accompanied by major damage to industrial facilities and other infrastructures. In March 2011, a tsunami struck a Japanese NPP, causing a nuclear meltdown, and raging fires and explosions at oil refineries in the wake of the massive earthquake that triggered the tsunami also made the global headlines. Other recent examples of major disasters include Hurricane Sandy in 2012, which caused multiple hydrocarbon spills and releases of raw sewage, the damage to industrial parks during the Thai floods in 2011, or Hurricanes Katrina and Rita in 2005, which wreaked havoc on the offshore oil and gas infrastructure in the Gulf of Mexico (Krausmann and Cruz, 2013; Cruz and Krausmann, 2008, 2009).

These events clearly demonstrated the potential for natural hazards to trigger fires, explosions and toxic or radioactive releases at hazardous installations and other infrastructures that process, store or transport dangerous substances. These technological 'secondary effects' caused by natural hazards are known as 'Natech' (Natural-hazard-triggered technological) accidents (Krausmann et al., 2017a). They are a recurring but often overlooked feature of many natural-disaster situations and have repeatedly had significant and long-term social, environmental and economic impacts, including supply-chain disruptions (Figure 3.57). It is important to note that natural-hazard impacts on commercial districts or residential areas where lower quantities of hazardous materials are present are also a safety concern.

Natural hazards can cause multiple and simultaneous releases of hazardous materials over extended areas, damage or destroy safety barriers and systems, and down lifelines often needed for accident prevention and mitigation. These are also the ingredients for cascading disasters. For this reason, successfully controlling a Natech accident has often turned out to be a major challenge, if not impossible, where no prior preparedness planning had taken place.

> *Natech accidents can have serious consequences, including cascading events. While their risk is increasing, they are not adequately addressed in DRM.*

Unfortunately, disaster risk-reduction frameworks do not fully address technological hazards in general or Natech hazards in particular. In addition, chemical accident prevention and preparedness programmes often overlook the specific aspects of Natech risk, which has caused a lack of dedicated risk-assessment methodologies and guidance for industry and

authorities on how to manage these risks both onsite and offsite.

This is aggravated by the expected increase of future Natech risk due to worldwide industrialisation, climate change, population growth and community encroachment in areas subject to natural hazards (Krausmann and Baranzini, 2012).

This subchapter gives an overview of the state of play in Natech risk reduction in the EU and globally; it highlights existing gaps in Natech risk reduction and makes recommendations on how to close these gaps.

While natural-hazard triggered nuclear accidents also qualify as Natech events (see Chapter 3.13), this subchapter focuses on Natech risk in terms of non-nuclear hazardous industrial activities.

3.14.2 Forensic analysis of Natech accidents and lessons learned

Post-accident analysis is a valuable tool to recreate the dynamics of accidents and to draw conclusions on the most prominent damage mechanisms and hazardous materials release paths, particularly vulnerable storage and process equipment types, as well as on the hazardous materials most commonly involved in these types of accidents. For this reason, efforts have been made to systematically collect and analyse information on the causes and dynamics of Natech accidents to support scenario development and the design of better protection options. In order to facilitate this process and to overcome the deficiencies of conventional industrial accident databases with respect to Natech accidents, the European Commission has set up the eNATECH database for the systematic collection and analysis of Natech accident data and near misses. The database exhibits the more sophisticated accident representation required to capture the characteristics of Natech events and is publicly accessible (eNATECH, 2015).

Lessons can be learned in all phases of risk and accident management, from prevention and preparedness to response and recovery. Analyses of single accidents produce immediate lessons specific to the event, while analyses of a set of similar accidents from a broader data pool yields lessons learned that are more widely applicable. The latter type of study facilitates, for example, the identification of commonly occurring causes of accidents involving specific substances or industries, which may not be easily recognisable within a single occurrence. This analysis also lends itself to identifying technical and organisational risk-reduction measures that require improvement or that are missing.

3.14.2.1 General lessons learned

The analysis of Natech accidents across different types of natural hazards showed that there are certain commonalities regardless of the

FIGURE 3.57

Hydrocarbon releases at a refinery during floods in Coffeyville, USA, in 2007.
Source: photograph courtesy of the Kansas Wing of the Civil Air Patrol

natural-hazard trigger. Studies have indicated, for instance, that storage tanks at atmospheric pressure, and in particular those with floating roofs, appear to be particularly vulnerable to earthquake, flood and lightning impacts compared with other types of industrial equipment (Krausmann et al., 2011). While no systematic studies for other types of natural hazards are available, individual case histories seem to support this conclusion in the case of storms or heavy rain (Bailey and Levitan, 2008; Godoy, 2007).

From an industrial safety perspective, the high susceptibility of storage tanks to natural-hazard impacts is problematic, as these plant units often contain large quantities of crude oil, gasoline or other types of flammable liquid hydrocarbons. It is therefore unsurprising that many Natech accidents involve hydrocarbon releases that have ignited and escalated into major fires or explosions (Table 3.8). In addition, with hazardous materials releases possibly occurring from several sources at the same time, an increased ignition probability, coupled with simultaneous damage to safety barriers and systems including the frequent loss of lifelines needed for process control or firefighting, the likelihood of cascading disasters is also higher for Natech events than for conventional industrial accidents.

3.14.2.2 Lessons learned from Natech accidents due to earthquakes, floods and lightning

Most Natech accident analyses have focused on accidents triggered by earthquakes, floods or lightning. Priority was given to these hazards because of the generally greater severity of Natech events caused by earthquakes (Antonioni et al., 2009), and the high frequency of accidents initiated by floods and lightning in EU Member States and OECD Member Countries (Krausmann and Baranzini, 2012). Systematic analyses of the dynamics and consequences of Natech accidents caused by other natural hazards are scarce, although other natural hazards, such as tsunamis, extreme temperature, high winds or landslides have also caused Natech accidents.

Hydrocarbon storage tanks are found to be particularly vulnerable to natural-hazard impact, which increases the cascading risk. Safety barriers are usually also affected by natural hazards and are unavailable for accident mitigation.

The main damage and failure mechanisms of industrial structures and hazardous equipment during earthquakes are direct shaking impact, ground deformation and liquefaction (Figure 3.58). The impact ranges from structural damage without the release of hazardous materials, such as shell buckling, sloshing damage or anchor-bolt stretching, to damage with loss of containment, caused, for instance, by the failure of flanges or pipe connections, shell and roof failures or tank overturning and collapse (Krausmann et al., 2011). The analyses also showed that during earthquakes it is common that several loss-of-containment events occur simultaneously. This increases the likelihood of cascading accidents. The analyses also highlighted the vulnerability of safe-

TABLE 3.8

Substances mainly involved in flood-triggered Natech accidents according to an analysis by Cozzani et al. (2010)

Hazardous substance category	No. of accidents
Oil, diesel fuel, gasoline; liquid hydrocarbons	158
Propane, butane, LPG	12
Fertilisers	11
Acid products	7
Cyanides	5
Oxides	5
Ammonia	5
Chlorine	3
Explosives	3
Calcium carbide	3
Soap and detergents	1

ty barriers (e.g. catch basins around tanks or sprinkler systems) to seismic loading.

In the case of floods, the main damage and failure mechanisms are the displacement of equipment due to buoyancy and water drag, as well as the impact of floating objects. This can break connections between pipework and equipment, cause pipelines to rupture or lead to tank collapse or implosion (Krausmann et al., 2011). Once a hazardous material has been released, the presence of the floodwaters aggravates the accident by acting as a vector for spreading the released toxic or flammable materials over wide areas. This can also increase the likelihood of domino accidents while simultaneously creating further risks in the areas surrounding the damaged facility (Figure 3.57). The analysis of flood-triggered accidents also showed that released substances can react violently with the floodwaters, thereby creating secondary toxic or flammable gases from often less dangerous precursor chemicals (Cozzani et al., 2010).

The analysis of lightning-triggered Natech accidents highlighted two different types of impact mechanisms: (1) direct impacts, causing structural damage to equipment, or the ignition of flammable vapours by the lightning strike (e.g. at the rim seal of atmospheric storage tanks); and (2) indirect impacts, which can trigger loss of containment, e.g. via process upsets due to power outage and power dips and impacts on electrical control and safety systems (Renni et al., 2010).

For a detailed discussion of lessons learned from Natech accidents due to a wide variety of natural hazards, the reader is referred to Krausmann and Salzano (2017).

FIGURE 3.58

Collapse of a dryer and severing of connected pipes at a fertiliser factory hit by the 2008 Wenchuan earthquake in China.
Source: photograph courtesy of E. Krausmann

3.14.3 Status of Natech risk management in European Union Member States and in OECD Member Countries

3.14.3.1 European Union

In the EU, major (chemical) accident risks are regulated by the provisions of the so-called Seveso Directive on the control of major-accident hazards and its amendments (European Union, 2012; see also Chapter 3.12). Following a series of Natech and other major chemical accidents (e.g. the spill of cyanide-laced tailings from a dam breach due to heavy rainfall and rapid snowmelt, or the release of chlorine from a flooded chemical facility), it was decided that an amendment of the Seveso Directive was needed to close remaining gaps. The latest amendment now explicitly addresses Natech risks and requires that environmental hazards, such as floods and earthquakes, be routinely identified and evaluated in an industrial es-

tablishment's safety report (European Union, 2012). Awareness of Natech risks in Europe has been growing ever since.

A recent survey among Seveso regulatory bodies aimed to assess the status of Natech risk management in the EU (Krausmann and Baranzini, 2012). The results of the survey showed an increasing awareness of the potentially disastrous impacts of natural hazards on chemical facilities. However, the survey also highlighted a number of gaps in Natech risk reduction, as well as related research and policy challenges.

Over half of the survey respondents indicated that their countries had experienced one or more Natech accidents in the period 1990-2009. The main accident triggers were lightning, low temperatures and floods. Considering the recurrence of Natech accidents, the survey results suggest that the legal frameworks for chemical-accident prevention have not always been effective. The survey participants expressed their belief that industries in many EU Member States may not consider Natech risks appropriately in their facility risk assessment, with potentially low preparedness levels as a result. The survey also revealed strong differences between the actual Natech accident triggers and the natural hazards perceived to be of concern, highlighting an incongruity between actual causes and risk perception.

The recurrence of Natech accidents has also raised doubts about the adequacy of design codes and standards for hazardous installations with respect to natural-hazard impact, as well as about the associated protection measures in place. The ultimate objective of these codes and standards is the preservation of life safety and, hence, the prevention of building collapse. While in itself an important goal, the preservation of a building's structural integrity is not necessarily sufficient to prevent the release of hazardous materials under natural-event loading.

The survey identified a number of key areas for future work for industry, regulators, and science and engineering. The majority of survey respondents called for the development of guidance on Natech risk assessment for industry with the highest priority, followed by the preparation of Natech risk maps to inform land-use and emergency planning by identifying a region's Natech hotspots.

3.14.3.2 The Organisation for Economic Co-operation and Development (OECD)

Parallel to the survey on the status of Natech risk management in the EU, OECD Member Countries were polled on the same subject. The OECD results showed a similar trend as in the EU and highlighted the same gaps (Krausmann and Baranzini, 2012). The majority of OECD survey respondents expressed their belief that there is a clear need to improve current regulations and fill existing gaps to fully address Natech risk reduction. Similar to the EU survey, they called for the development of natural-hazard and Natech risk maps, methodologies for and guidance on Natech risk assessment for industry and communities, as well as the training of authorities on Natech risk reduction.

Natech accidents continue to happen, which raises doubts about the effectiveness of existing safety legislation, as well as about the adequacy of design codes and standards for natural-hazard impact at hazardous installations.

One of the main international guidelines considering Natech risks are the OECD Guiding Principles for Chemical Accident Prevention, Preparedness and Response (OECD, 2003), the application of which is the subject of an OECD Council Recommendation. Given that the 2003 revision of the Guiding Principles considered only some aspects of Natech risk management, the OECD Working Group on Chemical Accidents decided to address the issue more comprehensively by including a Natech project into its 2009-12 work programme to identify existing gaps and develop targeted recommendations for Natech risk reduction.

As a final outcome of the OECD Natech project, a Natech Addendum to the Guiding Principles was issued (OECD, 2015). This addendum includes numerous recommendations for government and industry that address the inclusion of Natech risks in the drafting of regulations, rules and standards, their enforcement and implementation, and other activities in support of effective Natech risk man-

agement. With pipelines being at risk owing to natural hazards, the Natech Addendum also advocates the consideration of Natech risks in pipeline safety.

As a follow-up to the first Natech project, the OECD included a second Natech project in its 2017-20 work programme, which focuses on the implementation of recommendations from the first project and on improving international cooperation in Natech risk management.

3.14.4 Natech risk assessment

Risk analysis is an important tool by which to estimate the risk level of a hazardous activity. Quantitative risk assessment (QRA) in particular allows the identification of system weaknesses, the prioritisation of safety measures in terms of their importance for risk reduction, or the estimation of a facility's overall risk level, summarised in a risk figure. This risk figure can then be compared with prescribed risk acceptance target levels, where existing, to show that risks are adequately controlled in fulfilment of regulatory requirements (see Chapter 2.1).

3.14.4.1 General methodology

The identification of potentially Natech-prone areas and the determination of the associated risks are the first steps towards managing Natech risks. As Krausmann and Baranzini (2012) note, hardly any Natech risk maps exist in EU Member States and OECD Member Countries, and the development of a Natech risk analysis and mapping capability is considered a high-priority need by authorities to effectively reduce Natech risks.

There is a lack of consolidated Natech risk assessment tools, and extensions to traditional risk analysis need to be made to take into account the characteristics of Natech events.

Regardless of the risk-analysis approach chosen, extensions to both qualitative and quantitative risk analysis need to be made to take into account the characteristics of Natech events. Hence, specific damage models to assess the severity and probability of equipment damage due to a natural event, and a procedure to account for the possibility of simultaneous hazardous materials releases from more than one process or storage unit are needed. Simple damage models are available for a limited number of equipment categories (storage tanks, some types of process equipment) and in particular for earthquake impact. The inclusion of these damage models in QRA case studies has demonstrated the importance of considering earthquake-triggered accident scenarios for ensuring the safety of the facility itself and the surrounding population and environment (Antonioni et al., 2007; Campedel et al., 2008). Therefore, natural hazards can be important risk contributors at hazardous facilities and must be adequately considered in the risk-analysis process.

An in-depth discussion of the individual steps in Natech risk assessment, including the treatment of cascading events, can be found in Krausmann (2017).

3.14.4.2 Methods and tools for Natech risk assessment

The surveys discussed in Chapter 3.14.3 highlighted a lack of methodologies and tools for Natech risk analysis and mapping, which has so far hampered the appropriate inclusion of this type of risk into industrial risk assessment. Following calls by government to close this gap, the European Commission (JRC) developed the RAPID-N framework for rapid Natech risk assessment and mapping, which can be used to quickly identify Natech risk hotspots (Girgin and Krausmann, 2017, 2013). RAPID-N is a unique, semi-quantitative tool that allows the rapid analysis of Natech risks at local (single installation) or regional (multiple installations) level. This web-based tool is freely available via prior user registration and authorisation (RAPID-N, 2017). Figure 3.59 shows an example output of RAPID-N.

RAPID-N supports different natural hazards and industrial equipment types by design. It estimates and maps Natech risk in a web-based environment and can support land use and emergency planning, as well as Natech damage and consequence analysis immediately after a natural event. The latter in particular is fundamental for

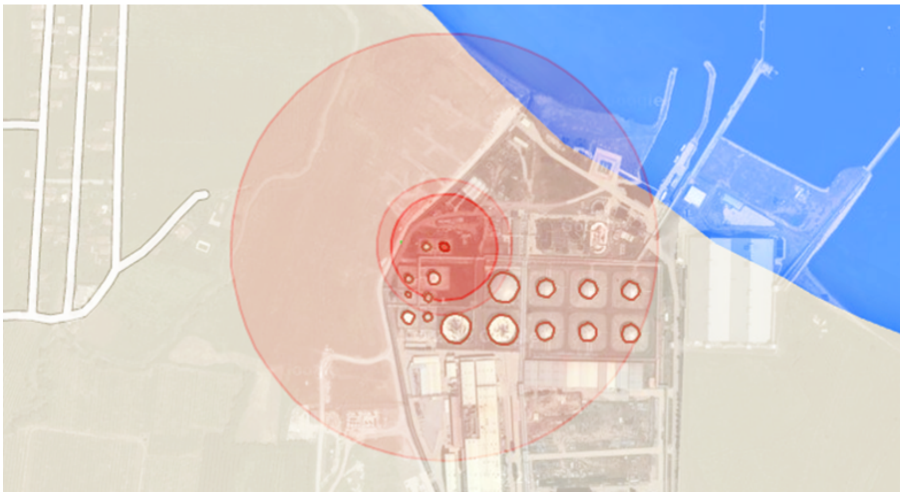
first responders who require an assessment of the dangers of secondary hazards from industrial plants following a natural disaster before dispatching rescue teams. It could also provide a means by which authorities may warn the population in the vicinity of an installation of imminent problems.

The current version of RAPID-N supports earthquake Natech risk analysis and mapping for fixed chemical installations, such as refineries or storage tank farms, and onshore pipeline networks. In the next release of the tool, floods will be included as additional Natech accident triggers. Additional short-term upgrades that are under way are (1) the inclusion of individual and societal risk calculations in addition to impact zones to move towards a more quantitative treatment of the problem, and (2) the implementation of an automated analysis function that will allow Natech risk analysis for facilities in the RAPID-N database immediately following the occurrence of a major natural event. Through this function, competent authorities, first responders and other interested parties can be quickly alerted to potential Natech accidents to ensure that fast protective action is taken if required.

While RAPID-N currently follows a semi-quantitative approach for analysing and mapping Natech risks to ensure a quick assessment with a minimum of data, the University of Bologna has developed a Natech module for its software package ARIPAR-GIS to characterise the Natech risks of single facilities in a quantitative way (Antonioni et al., 2017). This approach is more detailed than that of RAPID-N; however, it requires a significant number of data for the assessment process. The output of ARIPAR-GIS is individual risk and societal risk from Natech accidents caused by earthquakes and floods.

FIGURE 3.59

RAPID-N example output for the release and ignition of a flammable substance caused by a hypothetical Istanbul earthquake scenario. The circle endpoints indicate the point up to which second-degree burns would be received for different release scenarios.
Source: courtesy of European Commission (JRC)



3.14.5 Natech risk reduction

Past near misses have shown that Natech risk reduction generally pays off, and facilities that have benefited from natural-hazard specific design and the implementation of Natech risk-reduction measures have fared better during natural events (e.g. Cruz and Steinberg, 2005). Where these measures were inadequate or totally lacking, damage was more severe or even catastrophic.

Problem areas that stand out in most Natech accidents are related to insufficient prevention and preparedness, often caused by the grossly inadequate design bases of hazardous installations in natural-hazard prone areas due to a failure to acknowledge the specific requirements of process equipment under natural-hazard loads, the absence or weak enforcement of safety regulations, and a lack of guidance on how to address the problem of Natech risks in the industry. In addition, there is the misconception that engineering and organisational protection measures in place to prevent and mitigate conventional industrial accidents would also protect against Natech events. In fact, the very natural event that damages or destroys industrial buildings and equipment can also render inoperable engineered safety barriers (e.g. containment dikes, deluge systems) and lifelines (power, water for firefighting or cooling, communication) needed

to prevent an accident, mitigate its consequences and keep it from escalating. There is, therefore, a need for Natech-specific additional safety measures to accommodate the characteristics of Natech accidents, which require targeted prevention, preparedness and response.

3.14.5.1 Structural prevention and mitigation measures

In general, structural risk-reduction measures for technological risks use engineering solutions, such as safety valves or containment dikes, for accident prevention and mitigation. In this context, prevention refers to passive and active actions or measures put in place to reduce the likelihood of damage and the occurrence of a hazardous materials release, while mitigation refers to actions or measures implemented to lower the impact of hazardous materials releases if they cannot be prevented.

Experience from past Natech accidents and the associated lessons learned have led to the development of recommendations for reducing Natech risks for accident scenarios from a wide variety of natural hazards. For example, in earthquake-prone areas, flexible tank-pipe connections should be used given that the breaking of rigid connections has often led to releases (Figure 3.60). Anchoring or restraining equipment could effectively avoid displacement and keep equipment containing hazardous materials intact. The vulnerability of safety barriers (e.g. catch basins around tanks or sprinkler systems) is particularly apparent during earthquakes. Critical active and passive safety barriers should, therefore, also be designed to withstand the forces of the expected earthquake.

Natech risk reduction requires targeted prevention, preparedness and response, including Natech-specific safety measures, the implementation of which was found to pay off.

FIGURE 3.60

Flexible steel pipe on a large oil tank in an earthquake-prone area. Source: photograph courtesy of A.M. Cruz

The risk of flood-triggered Natech accidents can be minimised, for example, if hazardous equipment is anchored or otherwise restrained to prevent floating and displacement by floodwaters. Indirect flood impacts via short-circuiting of electrical equipment that affects safety-critical systems can be reduced by protecting systems from wave loading and water intrusion. This can be achieved by waterproofing and appropriate design. The lifting of flammable waste oil in plant drainage systems due to flooding can be prevented by segregating the drainage systems for waste flammable substances and surface run-off water.

With respect to reducing the Natech risk from lightning strikes, the rim seal of atmospheric floating-roof tanks is the most likely point of ignition, and the seal should therefore be regularly checked and maintained. Furthermore, partial or total onsite power outage and power dips can lead to process upsets and thereby indirectly to hazardous materials releases. Internal backup systems should provide

emergency power to those processes from which dangerous conditions can result during power loss (Krausmann et al., 2011).

Many more structural Natech prevention and mitigation measures for different natural hazards and equipment types are discussed in detail in Cruz et al. (2017).

3.14.5.2 Organisational prevention and mitigation measures

In contrast to structural measures, which use engineered physical solutions for prevention and mitigation, organisational measures are administrative programmes and controls put in place to reduce risks. Organisational protection measures include staff training, the implementation of safety practices and procedures, including the monitoring of safety performance, educational and awareness-raising campaigns and the establishment of safety policies and laws. Since technical protection measures can never entirely eliminate hazards from a hazardous installation, organisational control is needed to support protection goals.

An in-depth discussion of organisational Natech risk-reduction measures and approaches is provided in Krausmann et al. (2017b). The following sections provide examples of such measures.

3.14.5.3 Natech risk governance

From a Natech point of view, risk governance is becoming exceedingly important in light of increasing industrialisation coupled with emerging hazards, such as climate change. Since natural hazards can impact large areas at the same time, an integrated risk-governance approach involving all stakeholders is needed that addresses the safety of individual industrial installations as well as the potential interactions with neighbouring installations, lifelines and nearby communities. The Great East Japan earthquake and the Thai floods in 2011, for example, highlighted the need to better understand infrastructure-failure interdependencies and the governance of the associated risks.

TABLE 3.9

**Effectiveness of Natech-specific early warning based on the warning time to warn and action time tact.
Source: Salzano et al. (2009)**

twarn/tact	Characteristics	Effectiveness
<< 1	Short warning time or slow preventive action	Low: little time to implement preventive action
≈ 1	Warning time similar to time needed for preventive action	Medium: some preventive action possible prior to natural-event impact
>> 1	Long warning time or fast preventive action	High: sufficient time for preventive action even if time-consuming

3.14.5.4 Emergency planning

Natech accidents caused by major natural events pose a tremendous challenge for emergency response owing to:

- possible multiple and simultaneous hazardous materials releases over extended areas, a scenario for which emergency responders are usually not trained and equipped;
- competition for scarce emergency response resources for providing aid in natural disaster areas and for combatting the Natech accident;
- hampering of search and rescue operations as a result of toxic releases, fires and explosions;
- inapplicability of standard civil-protection measures such as evacuation or shelter;
- reliance of industry on external lifelines and emergency-response resources for managing a Natech accident rather than preparing a 'standalone' emergency plan.

In order to increase preparedness for Natech accidents, emergency plans for hazardous industry should consider natural-hazard risks. Plant-internal emergency plans for mitigating hazardous materials releases should assume that safety barriers are absent or non-functional and off-site response resources are not available, requiring backup lifelines to control the Natech accident. Off-site emergency plans need to take into account the eventuality of toxic releases, fires and explosions impacting the population and the rescue operations and the need for evacuation in a situation where transport routes might be com-

promised. An assessment of the vulnerability of the emergency response resources is also called for in the context of Natech risk reduction.

Emergency plans at both plant and community level should be periodically reviewed and tested to ensure that they remain up to date. This is of particular importance in times of climate change, which might require updates to the assumptions on which the emergency plan is based.

3.14.5.5 Early warning

Early warning is usually not available or practicable for reducing Natech risks, as warning times for some natural hazards are too short for preventive action at hazardous facilities. Salzano et al. (2009) contend that the effectiveness of Natech early warning systems is defined by the ratio of the available warning time and the time needed to implement preventive action (Table 3.9).

For earthquakes, for example, warning times range from fractions of seconds to only a few seconds, which makes early warning for earthquake Natech accidents rather impractical. In this case, the earthquake-resistant design of hazardous installations should be prioritised.

The situation is different for river floods, for which warning times can range from hours to days, leaving ample time and opportunity to mitigate the Natech risk, for example by implementing plant shut-down, depressurising equipment or transferring hazardous substances from predicted on-site inundation zones to safer locations. If tsunamis are generated in the far field, the warning lead time should permit the actuation of prevention actions, as for floods.

Interestingly, Bouquegneau (2007) also suggests that early protective actions, such as disconnecting sensitive equipment or stopping hazardous processes, are possible for lightning hazards by using information from meteorological lightning location systems.

3.14.6 Conclusions and key messages

Past Natech accidents have clearly shown the vulnerability of hazardous industrial activities to natural-hazard impact, with often major consequences on health, the natural environment, and the local, regional or global economy owing to asset damage and the associated business downtime. Some of these accidents have also dramatically demonstrated the increased risk of cascading effects and the challenges faced by emergency responders.
The good news is that awareness of Natech risks is increasing worldwide and first attempts to systematically assess and control this risk are being made. Nevertheless, a number of research and policy gaps related to Natech risk reduction remain that require addressing in a concerted effort of regulators, industry and the research community.

Partnership

In many countries, there is legislation that regulates hazardous industrial activities, and in some cases Natech risks are explicitly addressed. It is important that these regulations be enforced. Where missing, dedicated legislation for reducing Natech risks should be developed and implemented. At the same time, risk communication between industry and all levels of government should be improved to ensure that communication related to Natech risks flows freely and effectively to realistically estimate the risk. Public–private partnerships could facilitate the linking of science, practice and policy in support of Natech risk reduction.

Knowledge

Further awareness-raising efforts are needed to help stakeholders recognise the vulnerability of hazardous installations during natural-hazard impact. In this context, climate change must be a factor in the assessment, as it might change natural-hazard severities and frequencies and thus render the design basis of installations and equipment inadequate. In addition, plant workers, civil protection authorities and those in charge of chemical-accident prevention need to receive targeted training to be able to handle the challenges that are associated with Natech accidents.

Risk assessment is an important tool by which to identify safety gaps and prioritise safety-relevant interventions at a facility. There are no consolidated methodologies for Natech risk assessment, and research should focus on the development of Natech risk assessment methodologies and tools for different natural hazards, as well as related guidance at the industry and community levels. Data on

accidents and near misses crucial for learning lessons and scenario building are often closely guarded by industry for fear of negative repercussions on their activity. Authorities should promote and facilitate the sharing of Natech accident data by companies to support future risk reduction.

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3.12 Technological risk: chemical releases

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