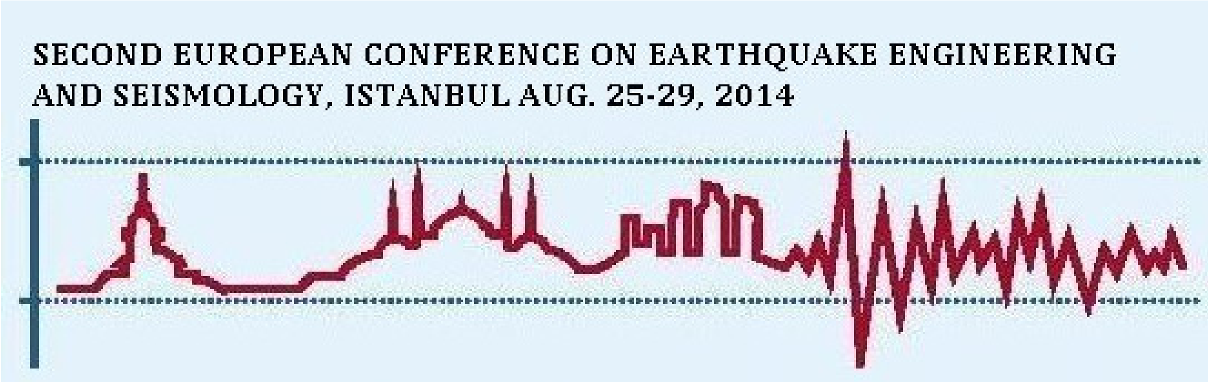

EARTHQUAKE NATECH RISK ASSESSMENT AND MAPPING USING RAPID-N

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Natural disasters, such as earthquakes, floods, and landslides, can impact industrial installations that process or store hazardous materials, potentially causing major accidents with fires, explosions or toxic releases. Accidents of this type are commonly referred to as Natech accidents (Showalter and Myers, 1994). Numerous Natech accidents in the wake of past natural events are testimony to the possibly major disaster potential of this type of accidents (Lindell and Perry, 1997; Steinberg and Cruz, 2004; Durukal and Erdik, 2008, Girgin, 2011, Krausmann and Cruz, 2013). A recent study on the status of Natech risk management in the EU and the OECD found an increase in Natech risk awareness but it also highlighted significant gaps in the development of methodologies for analysing and mapping Natech risk (Krausmann and Baranzini, 2012). However, for decisions relating to the siting of new or the retrofitting needs of existing hazardous installations, and for emergency planning, Natech-prone areas need to be identified and the associated risk adequately assessed. In order to fill this gap, a web-based rapid Natech risk assessment and mapping framework called RAPID-N was developed. It is available at http://rapidn.jrc.ec.europa.eu. While the framework is in principle applicable to any kind of natural disaster, it has currently been implemented for earthquake impact on industrial facilities.

RAPID-N features a modular structure in which four self-contained but interconnected subsystems focus on the individual aspects related to Natech risk assessment and mapping (Girgin and Krausmann, 2013). These modules are 1) a scientific module, 2) a natural hazards module, 3) an industrial plants and units module, and 4) the Natech risk assessment module.

The scientific module supports scientific tasks and computations but it also provides the property definition and estimation framework upon which RAPID-N’s risk assessment functionality is built. Due to the complexity of a multi-disciplinary problem like Natech risk assessment, the property definition and estimation framework was created to reduce the amount of data to be entered by the users, to provide default values for missing data, to estimate required damage and consequence parameters, and to guarantee a higher flexibility of the risk assessment by allowing the definition of alternative calculation methods by the users.

The natural hazard module provides the source and on-site natural hazard data required for the Natech risk assessment. Both historical and scenario natural hazards are supported. For earthquakes, it estimates the earthquake hazard parameters at the site of the hazardous installations of interest using location-specific attenuation relationships, which are subsequently needed for the risk assessment.

The industrial plants and units module collects physical data on industrial facilities and equipment found on site. This information includes data such as location, unit types and operating conditions, and stored substance properties. A special mapping tool is provided with RAPID-N to easily locate and delineate plant boundaries, and to identify their units using publicly available satellite imagery.

The Natech risk assessment module calculates the natural hazard damage to industrial units, performs the consequence analysis, and maps the results in a GIS environment. It includes:

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- Damage classifications to define the damage states of plant units due to natural hazard impact;
- Fragility curves to estimate the damage-state occurrence probabilities as a function of natural hazard severity;
- Risk states to define realistic Natech scenarios triggered by the damage states;
- A risk assessment functionality, the output of which is presented as risk summary reports and impact maps.

RAPID-N currently focuses on earthquakes and includes worldwide earthquake data with M > 5.5 since the 1970s. It also monitors the EMSC and USGS earthquake catalogues and automatically updates the RAPID-N database once changes are detected. A simple set of on-site ground motion parameter estimation equations, damage classifications and fragility curves for earthquakes for selected plant units is also provided. For consequence analysis, RAPID-N includes the complete set of parameters and equations of the Risk Management Programme (RMP) Guidance for Offsite Consequence Analysis methodology of US EPA.

A simplified case-study was carried out to demonstrate RAPID-Ns capability to assess the potential impact of the Istanbul earthquake on a facility. The earthquake scenario was kindly provided by the Disaster and Emergency Management Presidency (AFAD) of the Turkish Prime Ministry. More specifically, we used the parameters of a Mw = 7.5 earthquake, that causes the fracture of a 119 km strike-slip fault from west of the 1999 Kocaeli earthquake fault to Silivri. As industrial target a facility in the Izmit Bay area was selected as this region is expected to be subject to strong shaking in the scenario earthquake selected. The facility includes 17 storage tanks, 9 of which atmospheric tanks storing acrylonitrile, which is the most vulnerable equipment type with respect to earthquake impact. Since very little data on the facility was available, assumptions were made based on satellite imagery on tank dimensions, roof and base types, and dike areas. Storage conditions were derived from these parameters. Substance information was available only for the acrylonitrile tanks. In order to demonstrate also the assessment for flammable substances, we assumed one of the remaining tanks, called T2, to contain kerosene.

Calculating the distance of T2 from the epicentre and interpolating the hazard parameters from the selected shakemap, RAPID-N subjected the tank to a PGA of 0.79 g. It then selected the most appropriate fragility curve and related damage classification for T2 to calculate the likelihood of suffering a specific level of damage. A fragility curve from O'Rourke and So (2000) was selected in which DS1 corresponds to no damage and DS5 to total failure or tank collapse. The analysis shows that pool fire is the most likely outcome of the earthquake although the probabilities are low. The associated end-point distances, which designate the point up to which second degree burns are expected, range from ca. 70-300 m (Table 1). The result of the case study is plotted in Figure 1 which clearly demonstrates that all other tanks would come to lie within T2's effective end-point distance. Damaging effects due to heat impingement, in particular for adjacent tanks, would therefore be possible. A similar study was carried out for the tanks containing acrylonitrile. Worst-case end-point distances of 12 km were found for toxic dispersion effects.

Table 1. Summary of risk assessment results for Tank T2

Damage state	Release [t]	Consequence	End-point distance	Natech probability
≥ DS2	20	Pool fire	69 m	4.8%
≥ DS3	20	Pool fire	69 m	4.1%
≥ DS4	492	Pool fire	90 m	3.1%
= DS5	985	Pool fire	296 m	0.6%

The application of RAPID-N to case-study sites showed that the framework is a useful decision-support tool to identify Natech-prone areas. It can, however, also be used for preliminary damage assessment immediately after an earthquake to provide first responders with information on potential chemical releases or oil spills to be aware of. The study highlighted a rather pronounced absence of industry-specific data without which many assumptions have to be made that can introduce significant uncertainty into the results of the risk assessment.

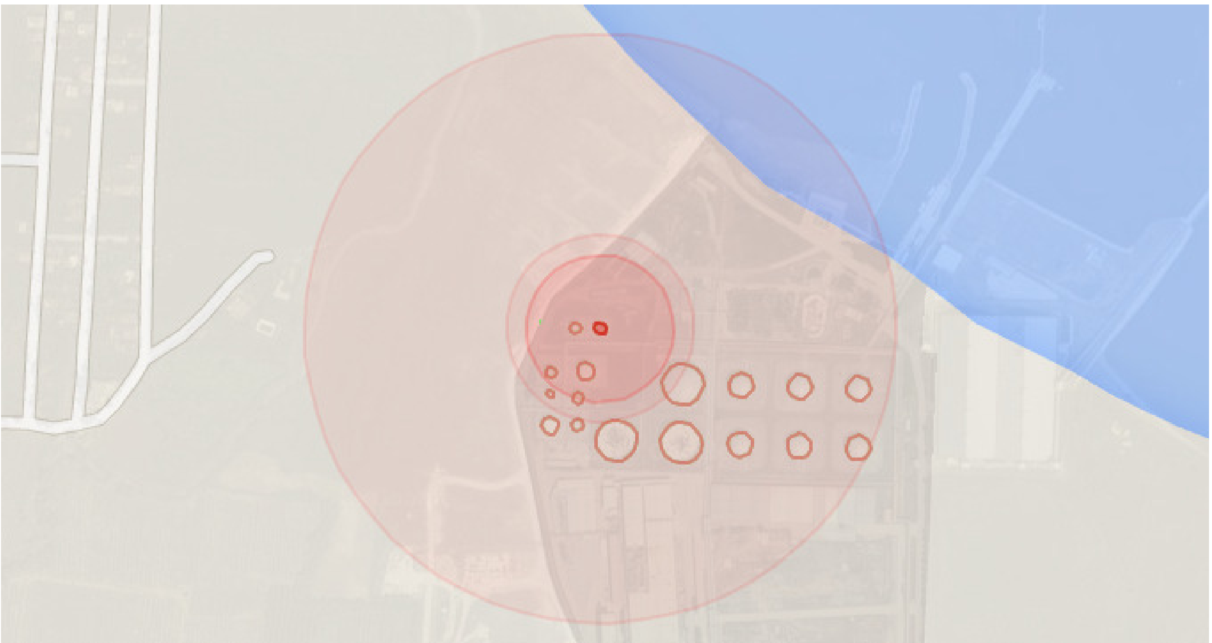

Figure 1. End-point distances for an earthquake-triggered pool fire at storage tank T2.

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