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RAPID-N: Rapid natech risk assessment and mapping framework

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ABSTRACT

Natech accidents at industrial plants are an emerging risk with possibly serious consequences. For the mitigation of natech risk, authorities need to identify natech prone areas in a systematic manner. In order to facilitate probabilistic natech risk mapping, a unified methodology was developed that is based on the estimation of on-site natural hazard parameters, determination of damage probabilities of plant units, and assessment of probability and severity of possibly triggered natech events. The methodology was implemented as an on-line, extensible risk assessment and mapping software framework called RAPID-N, which allows rapid local and regional natech risk assessment and mapping with minimal data input. RAPID-N features an innovative data estimation framework to complete missing input data, such as on-site natural hazard parameters and plant unit characteristics. The framework is also used for damage assessment and natech consequence analysis, and allows easy modification of input parameters, dynamic generation of consequence models according to data availability, and extension of models by adding new equations or substituting existing ones with alternatives. Results are presented as summary reports and interactive risk maps, which can be used for land-use and emergency planning purposes by using scenario hazards, or for rapid natech consequence assessment following actual disasters. As proof of concept, the framework provides a custom implementation of the U.S. EPA's RMP Guidance for Offsite Consequence Analysis methodology to perform natech consequence analysis and includes comprehensive data for earthquakes. It is readily extendible to other natural hazards and more comprehensive risk assessment methods.

1. Introduction

Major accidents at industrial plants, which are triggered by natural hazards and result in the release of hazardous materials, can have serious consequences on the population, the environment, and the economy (Girgin, 2011; Krausmann, Cozzani, Salzano, & Renni, 2011, Krausmann, Renni, Campedel, & Cozzani, 2011; Showalter & Myers, 1994; Steinberg & Cruz, 2004; Young, Balluz, & Malilay, 2004). Termed *natechs*, the risk of such accidents is expected to increase in the future due to growing industrialization, the predicted change of natural hazard occurrence patterns by climate change, and the increasing vulnerability of the society that is becoming more and more interconnected. Adequate preparedness and proper emergency planning are needed to prevent natechs and mitigate their consequences. For this reason, natech-prone areas should be identified and natech risks must be assessed in a methodical way by the competent authorities.

In the past, several authors developed natech risk assessment methodologies of varying levels of resolution. Cruz and Okada (2008) proposed a *qualitative* natech risk screening methodology at the district level while Sabatini et al. (2008) developed an index method aimed mainly at ranking natech hazards at the regional or national level. Busini, Marzo, Callioni, and Rota (2011) proposed a qualitative screening tool using a multi-criteria decision model. Antonioni, Spadoni, and Cozzani (2007) and Campedel, Cozzani, Garcia-Agreda, and Salzano (2008) described the development and application of a procedure for the *quantitative* assessment of natech risk due to earthquake impact. Antonioni, Bonvicini, Spadoni, and Cozzani (2009) generalised this procedure to other types of natural hazard impact. These studies also provided case-study natech risk maps displaying individual and societal risk around an industrial facility, which were obtained using an extended version of the ARIPAR software. However, a consolidated methodology for natech risk assessment and mapping is currently not available. Recent studies also showed that hardly any natech risk maps exist for the EU and OECD member states. Where available, natech risk maps are simple overlays of natural and technological hazards without considering site-specific features or the interaction of hazards (Krausmann & Baranzini, 2009, 2012). The

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need for a comprehensive and systematic natech risk assessment and mapping methodology is therefore evident.

In order to fill this gap, a natech risk assessment and mapping methodology was developed. The methodology is based on the calculation of on-site hazard parameters for natural hazard scenarios and the use of fragility curves to determine damage probabilities at plant units (e.g. storage tanks) for different damage states. Damage states are linked to risk states that define possible hazardous consequence scenarios resulting from the natural hazard triggered damage. Finally, the probability and severity of the potential consequences are calculated by using conventional industrial accident consequence models. The methodology does not claim to be a full-fledged quantitative risk assessment (QRA) as its purpose is the *rapid* assessment and mapping of natech risk mainly at regional, but to a limited extent also at local levels.

The methodology was implemented as an on-line risk assessment and mapping software framework that is called RAPID-N. The framework provides an integrated environment for natech risk assessment with advanced data management, analysis, and visualization tools. It provides means of easy data input including geographical features, complementary data estimation for missing information, rapid natural hazard damage estimation, and natech risk assessment by using an innovative modelling framework capable of generating case-specific dynamic models based on data availability. The results are presented as summary reports and interactive maps.

This paper describes RAPID-N and its modules in detail. General features of the framework are explained and the *property definition and estimation framework* which constitutes the basis of the data estimation and modelling framework of RAPID-N is described. Details on the industrial plant and natural hazard components are given. Key elements of the natech risk assessment methodology, such as fragility curves and risk states, are explained. Finally the flowchart of the risk assessment and mapping calculations is described step by step and an example natech risk assessment report is provided. More comprehensive technical and background information on the framework can be found in the RAPID-N user manual (Girgin, 2012).

2. RAPID-N

RAPID-N is an on-line, collaborative risk assessment framework available at http://rapidn.jrc.ec.europa.eu. The primary aim of the framework is rapid local or regional natech risk assessment and mapping with minimum data requirements. Competent authorities can use the framework for land-use and emergency planning, as well as first responders that require an assessment of the danger of secondary hazards arising from industrial plants following a natural disaster. In order to facilitate natech risk assessment, RAPID-N features a user-friendly interface with advanced data entry, visualization, and analysis tools. It does not depend on any commercial software libraries or third-party risk analysis applications.

In order to preserve confidentiality, the framework supports data protection and access restriction for critical information, such as industrial plant and plant unit data, and associated risk assessments. User registration is needed for data entry and further authorization is required for performing natech risk assessments. All other data supporting the risk assessment process is public. The users are allowed to enter their own data, such as on-site hazard parameter estimation, damage assessment, or consequence analysis parameters, and rules and equations to customize the calculations according to their needs. The data protection feature of the framework prevents user-specific modifications to affect other users and protects system integrity. This enables the users to experiment with different natural hazard damage assessment and natech risk analysis methods. Useful data or methods can be shared with other users following approval by the administrators.

By design, RAPID-N supports different natural hazards and plant unit (equipment) types. In order to demonstrate the applicability of the methodology, it includes earthquake-related data ready to be used for natech risk assessment. It incorporates long-term data from the European Mediterranean Seismological Centre (EMSC) and the U.S. Geological Survey (USGS), which is automatically updated once new information becomes available. A basic set of on-site natural hazard parameter estimation equations, damage classifications and fragility curves for plant units collected from the literature are also provided. RAPID-N also includes the complete set of parameters and equations of the U.S. EPA's Risk Management Program (RMP) Guidance for Offsite Consequence Analysis methodology (U.S. EPA, 1999) for natech consequence analysis.

The structure of RAPID-N is based on modules, which are self-contained but interconnected subsystems focusing on different aspects of natech risk assessment. There are four main modules:

- The *Scientific* module includes the *property definition and estimation framework* that is a key component of damage assessment and consequence analysis calculations. It also provides support for bibliographic citation, unit conversion, and GIS analysis.
- The *Natural hazards* module provides source and site specific (on-site) natural hazard data.
- The *Industrial plants and units* module covers information on industrial plants, their units, and hazardous substances found therein.
- The *Natech risk assessment* module covers the elements needed for performing natech risk assessment, such as fragility curves, damage states, and risk states. It is the core module of RAPID-N.

2.1. Scientific module

The scientific module serves two main purposes. The first is supporting scientific tasks and computations. For this purpose, the module has a built-in scientific computation library for descriptive statistics, interval arithmetic, fuzzy statistics, interpolation, and unit conversion. It also contains a GIS library for spherical geometry calculations, proximity analysis, and mapping support. A bibliographic database for the citation of scientific references is provided as well. The second purpose of the module is to provide the *property definition and estimation framework*, which forms the basis of the natech risk assessment functionality of RAPID-N.

2.2. Property definition and estimation framework

Natechs are complex incidents where natural hazards and technological systems collide. Naturally, the two major components of natech risk assessment are natural hazards (trigger) and industrial plants together with their units (source). Because the occurrence of natech events requires the presence of hazardous substances, the amount and characteristics of substances contained in the plant units are also important. Therefore, RAPID-N deals with four major *entities*, which are natural hazards, industrial plants, plant units, and hazardous substances.

The natech risk assessment depends on the *properties* of these entities, i.e. site characteristics of the industrial plants, physical characteristics of the plant units, physicochemical properties of the hazardous substances, and the severity parameters of the natural hazards. Although they have distinct and diverse definitions, properties of different entities have the following similarities: