RAPID-N: Assessing and mapping the risk of natural-hazard impact at industrial installations

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www.jrc.ec.europa.eu
Ecuadorean Amazon oil slick heads towards Peru
Crude discharged after pipeline was ruptured by landslide has entered Napo river

Hurricanes Destroyed 109 Oil Platforms: US Government
Oil Spill Into Verdigris River Adds to Kansas Flooding Problems as E
China quake hits chemical industry

Chemical leaks threaten Prague as floods hit Dresden
Natural hazard triggered technological accidents

- A natech accident is a chemical accident caused by a natural hazard.

- Particular characteristics:
  - Simultaneous hazardous-materials releases from multiple sources
  - Damage to prevention and mitigation systems including lifelines (e.g. water, power)
  - Complicated response
Natech Risk

- Natech risks are expected to **increase** due to:
  - **more hazards** (climate change, industrialization)
  - **higher vulnerability** (urbanization, interconnectedness)

... in a situation where Natech risk assessment methodologies & tools and guidelines for Natech risk management are missing.

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Priority work areas*:

- Implement and enforce regulations for Natech risk reduction
- **Develop methods, tools and guidance for Natech risk management**
- Develop dedicated Natech emergency management plans
- **Develop Natech risk maps**
- Raise awareness and improve risk communication
- Train stakeholders on Natech risk reduction

JRC Activities

• Accident analysis and guidance
  • Site surveys for damage assessment (China, Japan)
  • Statistical analysis
  • Lessons learned and recommendations
  • Natech database: eNatech
    http://enatech.jrc.ec.europa.eu

• Risk analysis tools
  • Framework for natech risk assessment and mapping: RAPID-N
    http://rapidn.jrc.ec.europa.eu
RAPID-N: Rapid Natech Risk Mapping Framework

- Easy and quick data entry
- Rapid analysis
- Visualization
- Collaboration
- Cloud-based
- Modular architecture
  - Scientific Tools
  - Natural Hazards and Natechs
  - Facilities and Process Units
  - Risk Assessment
**Natural Hazard**

- Hazard Map
  - Probabilistic
  - Deterministic
- Manual Input
- Hazard Parameter Estimation Methods

**Damage**

- Site Data
- Process Unit Data
- Damage Probability
- Fragility Curves
- Historical Data
  - Hazard Parameters
  - Damage states
  - Consequences

**Consequence**

- Risk States
- Consequence Analysis
- Natech Risk
- Risk Receptor Data
  - Land-use
  - Population
Natural Hazard

Hazard Map
- Probabilistic
- Deterministic

Site Data

Natural Hazard Parameters

Manual Input

Hazard Parameter Estimation Methods

Natech Information

Hazard: Kocaeli Earthquake, Turkey, 1999/08/17
Facility: Turkish Petroleum Refineries Corp. (TUPRAS) Izmit Refinery, Turkey

On-site Hazard Parameters

European Macroseismic: Destructive
Horizontal peak ground acceleration: 0.25 g
Vertical peak ground acceleration: 0.2 g
Peak Ground Displacement: 40–60 cm

References
4. Demir, H.; Gorgun, M., "Marmara earthquake and TÜPRAS fire", 2005

Created: Serkan Girgin, 2011/10/16 15:48:13

Natech Damages

<table>
<thead>
<tr>
<th>No</th>
<th>Process Unit Type</th>
<th>Process Unit Properties</th>
<th>Damage Classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Storage Tank</td>
<td>Storage Condition: Atmospheric, Roof Type: Floating Roof, Construction Material: Steel, Base Support Type: Unanchored</td>
<td>Seligson et al. (1996)</td>
</tr>
</tbody>
</table>
Damage Process Unit Data

Damage Probability

Fragility Curves

Historical Data
- Hazard Parameters
- Damage states
- Consequences

**Fragility Curve Information**

- **Name:** HAZUS, On-ground anchored steel tank
- **Process Unit Type:** Storage Tank
- **Damage Classification:** HAZUS (Water Storage Tanks)
- **Hazard Parameter:** Peak ground acceleration (PGA)
- **Unit:** %
- **Type:** Pre-defined
- **Functional Form:** Log-normal (median)

**Conditions**

- **Base Type:** On-ground
- **Base Support Type:** Anchored
- **Construction Material:** Steel

**Data**

<table>
<thead>
<tr>
<th>No</th>
<th>Damage State</th>
<th>Median</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>~ DS2</td>
<td>0.3</td>
<td>0.6</td>
</tr>
<tr>
<td>2</td>
<td>~ DS3</td>
<td>0.7</td>
<td>0.6</td>
</tr>
<tr>
<td>3</td>
<td>~ DS4</td>
<td>1.25</td>
<td>0.65</td>
</tr>
<tr>
<td>4</td>
<td>~ DS5</td>
<td>1.6</td>
<td>0.6</td>
</tr>
</tbody>
</table>

**References**


**Fragility Curve**

- Probability (%) vs. Peak ground acceleration (PGA)
Consequence Analysis

Risk States

Natech Risk

Risk Receptor Data
- Land-use
- Population

Risk Assessment Information

Name: Kocaeli Earthquake Single Plant
Date: 2012/08/28 13:11:13
Type: Private

Hazard Information
- Hazard: Kocaeli Earthquake, 1999/08/17
- Hazard Map: ShakeMap (XML, Gridded), 2008/11/09 03:19:14

Facility Information
- Facility: Kocaeli, Turkey: Power Plant, Turkey

Damage Estimation
- Damage Classification: Auto
- Flexible fragility curve selection: Yes

Facilities

1. Kocaeli, Turkey: Power Plant, Turkey

<table>
<thead>
<tr>
<th>No</th>
<th>Process Unit</th>
<th>Hazard Parameters</th>
<th>Fraility Curve</th>
<th>Damage Estimate</th>
<th>Damage Parameters</th>
<th>End-point Distance</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Storage Tank (T-STR) [gasoline]</td>
<td>PGA: 16.777 m/s²; BMS: Slightly damaging; MM: Strong; MSK: Strong; NM: 6.4866; Ge: 101.29 km; Gd: 102.79 km; PdA: 74.415 cm/s²; PGV: 15.972 cm/s</td>
<td>OS00-F50-0</td>
<td>≥ D5: 4.0546%</td>
<td>Fire/Explosion Event: Vapor Cloud Explosion; ξ: 4250 kg; η: 10%; V: 3.7432 m/s; D: 342 TDU; Q: 270.56 m³; Qmax: 4250 kg; Pu: 6146.1 ft²; Pou: 3 cm Release, r: 425 kg/m²; T: 1 R: 0.4; Qe: 5000 W/m²; Tavg: 40 s; Dv: 342 TDU</td>
<td>271 m: 4.0546%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>≥ D3: 0.004531%</td>
<td>Fire/Explosion Event: Vapor Cloud Explosion; ξ: 8500 kg</td>
<td>341 m: 0.004531%</td>
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<tr>
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<td></td>
<td></td>
<td></td>
<td>≥ D4: Very low</td>
<td>-</td>
<td>-</td>
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</table>
# Property Estimation Framework

<table>
<thead>
<tr>
<th>Description</th>
<th>Estimator</th>
<th>Unit</th>
<th>Validity conditions</th>
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</thead>
<tbody>
<tr>
<td>Default ambient temperature</td>
<td>25</td>
<td>°C</td>
<td>–</td>
</tr>
<tr>
<td>Wind speed</td>
<td></td>
<td>m/s</td>
<td>RMP Scenario = Worst-case</td>
</tr>
<tr>
<td>H/D ratio from diameter</td>
<td></td>
<td>m/m</td>
<td>Shape = Spherical</td>
</tr>
<tr>
<td>Storage condition from roof type</td>
<td></td>
<td>–</td>
<td>Roof Type = Floating Roof</td>
</tr>
<tr>
<td></td>
<td></td>
<td>–</td>
<td>Roof Type = Internal Floating Roof</td>
</tr>
<tr>
<td></td>
<td></td>
<td>–</td>
<td>Roof Type = Open Roof</td>
</tr>
<tr>
<td>Diameter from volume</td>
<td></td>
<td>m</td>
<td>Shape = Spherical</td>
</tr>
<tr>
<td>Energy magnitude from radiated seismic energy</td>
<td></td>
<td>–</td>
<td>Region = Western U.S.A.</td>
</tr>
<tr>
<td>Peak ground acceleration</td>
<td></td>
<td>–</td>
<td>Fire/Explosion Event = BLEVE</td>
</tr>
<tr>
<td>U.S. EPA RMP Liquid Factor Boiling</td>
<td></td>
<td>–</td>
<td></td>
</tr>
<tr>
<td>Duration of fireball</td>
<td></td>
<td>–</td>
<td></td>
</tr>
</tbody>
</table>

## Properties

- **Storage Condition:** Atmospheric
- **Shape:** Cylindrical Vertical
- **Roof Type:** Floating Roof
- **Construction Material:** Steel
- **Volume:** 22285 m³
- **Height:** 14.00 m
- **Diameter:** 147.64 ft (45.00 m)
- **H/D Ratio:** 0.3114 m/m
- **Fill Level:** 85 %v

```latex
\text{return } 2.6 \times \text{pow}(\text{QFL:kg}, 1/6);
```
Status and Data Availability

- Currently implemented for earthquakes and fixed installations
- \( \sim 20,000 \) earthquakes (> M 5.5)
- > 52,500 earthquake catalog data
- \( \sim 10,000 \) shakemaps
- > 5,500 industrial facilities
  - Refineries
  - Power plants
- > 64,000 plant units
  - Storage tanks

- Complete implementation of U.S. EPA RMP Offsite Consequence Analysis methodology
- > 200 properties
- > 400 property estimators
Application Areas

- Rapid local and regional natech risk assessment
- Land-use and emergency planning
- Identification of neighboring infrastructures at risk
- Early warning
- Preliminary damage assessment
Example: Earthquake Case Study

- Istanbul Earthquake
- JICA (2002) Model A
- Mw 7.5
- Fault length 120 km
- Strike-slip
Industrial Facility

- Located in Izmit Bay
- Distance: 6.3 km
- PGA: 0.77 g
- PGV: 1.66 m/s
- MMI: 10
- 17 storage tanks

- Kerosene
- Acrylonitrile
Release of toxic substance

Impact area for 1-hr exposure without irreversible health effects
Ongoing and Future Research

- Extension to other natural hazards and infrastructures
- Automated natech damage and consequence estimation (Alert)
  - Reporting to interested parties and authorities
- Cascading (domino) effects
- Consideration of risk receptors
- Fragility curve creation tool
  - Statistical analysis of natech damage data
Thank you for your attention!

http://rapidn.jrc.ec.europa.eu

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