From Assessment to Management: new needs in the control of risk due to NaTech scenarios

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Natech Events: definition

- Natural events (earthquake, floods, etc.) may cause damage to industrial installations and infrastructures.
- Damage caused by natural events may start the release of hazardous substances triggering a technological accident.
- These cascading events are defined “Natech” scenarios (Natural hazard triggering Technological disasters).
- NaTech scenarios are potentially high impact – low probability (HILP) events.
“Case-Histories” – Na-Tech events

Kocaeli Earthquake, Turkey, August 17th 1999

- An earthquake having a magnitude Mw of 7.4 struck an industrial area near to Izmit
- Several industrial installations were damaged. Particularly severe damage was experienced by an oil refinery and by a fertilizers plant
“Case-Histories” – NaTech events

Tohoku earthquake and tsunami, Japan (2011)

- Total destruction of several industrial sites due to tsunami wave
- Damage of an oil refinery (triggered by the failure of a spherical tank in hydraulic test conditions at the moment of the earthquake)
“Case-Histories” – NaTech Events

Flash-flood, Livorno, Italy, 9-10 september 2017
Quantitative Assessment of Natech

- Quantitative assessment of Natech scenarios deals with:
  1. HILP events - falling outside common experience of analysts and responders
  2. A high number of complex overall scenarios - simultaneous events, alternative final scenarios, escalation
  3. Complex characterization of hazard
  4. Complex description of impact area
  5. Need to include non-perfect safety barriers in the analysis
  6. Need to consider the role of utilities and their potential damage

- Such complexity makes slower the “lessons learning” process and the correct understanding of the Natech framework
Even if QRA is a tool widely used in current practice, application to Natech is recent (2007) and still limited mostly to pilot studies.
A simplified description of the natural event is needed: intensity-time of return pairs

Vulnerability models for equipment are required

Specific event trees may be needed to capture Natech specific scenarios

Similar to procedures for domino effect risk assessment: multiple simultaneous scenarios should be considered
“Key enabling models” for quantitative or semi-quantitative assessment of Natech scenarios are those addressing equipment vulnerability (= probability of failure)

A relevant work was carried out in the field in recent years, and a number of models are now available, paving the way to assessment and management approaches of such scenarios.
Expected modification of risk in the presence of Natech

\[ EV = \sum F(N) \]
\[ RI = \sum F(N)N \]
In the conventional approach assumed to date to represent Natech events, the Natech scenario is caused by natural events that produce a structural damage to equipment units.

Is this assumption correct?
Fukushima, Japan, 2011

Loss of cooling water supply caused by flooding lead to explosion and meltdown in a nuclear power station
(Tohoku earthquake and tsunami 2011)
Loss of cooling water supply caused by flooding lead to explosion and fire in a chemical plant

(Hurricane Harvey, 2017)
The role of utilities in causing accidents needs to be recognized as a specific feature of Natech accidents.

The specific behavior of safety barriers in Natech scenarios is also a relevant factor in the analysis.
Selection of reference flooding conditions

Selection of a reference flooding event

Assessment of flooding intensity and frequency

Identification of possible targets by hazard ranking

Calculation of damage probability for each target

Consequence analysis of credible scenarios

Identification of credible combinations of events

Calculation of frequency of combined events

Calculation of overall consequences and vulnerability

Calculation of Risk indexes

Failure of Utilities

Beside direct damage also the role of utilities failure needs to be considered

Specific scenarios due to utility failure need to be considered
## Failure of Utilities – Relation to Substances

<table>
<thead>
<tr>
<th>Group ID</th>
<th>H statements</th>
<th>Seveso category</th>
<th>Reference scenario</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heat sensitive substances</td>
<td>Heat sensitive</td>
<td>H251 H252</td>
<td>None</td>
</tr>
<tr>
<td></td>
<td>It can explode or burn in case of heating</td>
<td>H229 H240 H241 H242 EUH044</td>
<td>P6</td>
</tr>
<tr>
<td>Water reacting substances</td>
<td>In contact with water it produces flammable gases (even self-ignitable)</td>
<td>H260 H261</td>
<td>O2</td>
</tr>
<tr>
<td></td>
<td>It reacts strongly in contact with water</td>
<td>EUH014</td>
<td>O1</td>
</tr>
<tr>
<td></td>
<td>If in contact with water/acids, it yields toxic gases</td>
<td>EUH029 EUH031 EUH032</td>
<td>O3</td>
</tr>
<tr>
<td>Air reacting substances</td>
<td>Spontaneously flammable in contact with air</td>
<td>H250</td>
<td>P7</td>
</tr>
</tbody>
</table>

### Substances that need specific storage conditions:
- Self heating substances;
- Self reactive substances;
- In contact with air/water produces flammable gas
- ...
Utilities: influence on resilience

Technological event

Normal situation

Single event
(system failure, human error, process failure)

Natech event

Disaster situation

Slow recovery due to limited resources

Utilities: influence on resilience

Technological event

Normal situation

Single event
(system failure, human error, process failure)

Natech event

Disaster situation

Natural
Utilities: influence on resilience

- Scarce attention is usually paid to utilities in risk assessment (both conventional and related to Natech)

- In Natech scenarios, utilities may have an important role:
  1. As mentioned previously, utilities failure caused by the natural event may be an important pathway leading to a technological scenarios
  2. The damage of utilities is usually the more important element in determining post-event downtime of production, thus affecting system recovery
  3. Damage of utilities may affect the response capability, thus affecting the resilience of the system

- A specific management plan is needed to protect critical utilities in Natech scenarios
Barriers may be affected as well by the natural event (common cause failure)

Some barriers may be ineffective to prevent or mitigate NaTech scenarios (e.g. catch basins in the case of a flood)

The presence of barriers as well as their possible failure needs to be taken into account in quantitative assessment of NaTech scenarios.
Examples of Natech-specific barrier failure

- **Koaceli earthquake, 1999 (Turkey)**: in AKZA acrylic fiber plant the earthquake caused the release of 6.5 million kg of acrylonitrile from storage tanks. The concrete containment dikes around the tanks were damaged by the earthquake letting the chemical flow into the drainage channel and the bay, causing fish kills, environmental damages and enhancing population poisoning. *(Girgin, 2011)*

- **Vltava river flood, 2002 (Czech Republic)**: Spolana electrolysis plant (Neratovice) has been flooded. The plant stored an elevated quantity of liquid chlorine. Emergency retention sumps were flooded: more than 80000t of chlorine have been released in air and water. *(eMars)*

*To date, in Natech scenarios neither the role of safety barriers nor the specific failure modes were the subject of systematic assessment*
Factors affecting barrier availability in case of natural events:

- Features of the natural event
- System architecture and related subsystems
- Position of the barrier
- Dependence on lifelines
- Fail-safe design
- Natural event considered in barrier design?

High site-specificity of some factors makes a precise quantification of barrier performance a complex task (e.g., position, detailed architecture). With limited information, a semi-quantitative evaluation seems the most feasible solution for a preliminary screening.
Semi-quantitative approach: traffic-light indicators for barrier availability in case of natural events:

• **Green Light**
  Barrier is considered unaffected by the natural event. It will available in case of demand.

• **Yellow Light**
  Barrier may be affected by the natural event. Detailed consideration about the system are needed for further detailed analysis.

• **Red Light**
  It is really likely that the barrier will be unavailable in case of demand, since it will be heavily affected by the natural event.
A strong role of safety barriers may be recognized in quantitative assessment.

Preventive barriers affect damage probability.

Post-event release and consequences are mostly affected by the safety barriers.
Conclusions

- Recent events point out the need of a more comprehensive framework for Natech assessment and management

- The role of utilities and safety barriers should be recognized as a key point in the assessment of Natech scenarios

- A specific assessment of safety barrier performance in Natech conditions is needed for an appropriate management of Natech risk

- Beside critical equipment, more attention should be devoted to design and protection of critical utilities in Natech conditions