Analysing the risks of chemical accidents including those caused by natural hazards (NATECH)

Serkan Girgin, Ph.D. serkan.girgin@ec.europa.eu

Luciano Fabbri, Ph.D. luciano.fabbri@ec.europa.eu

The European Commission's science and knowledge service

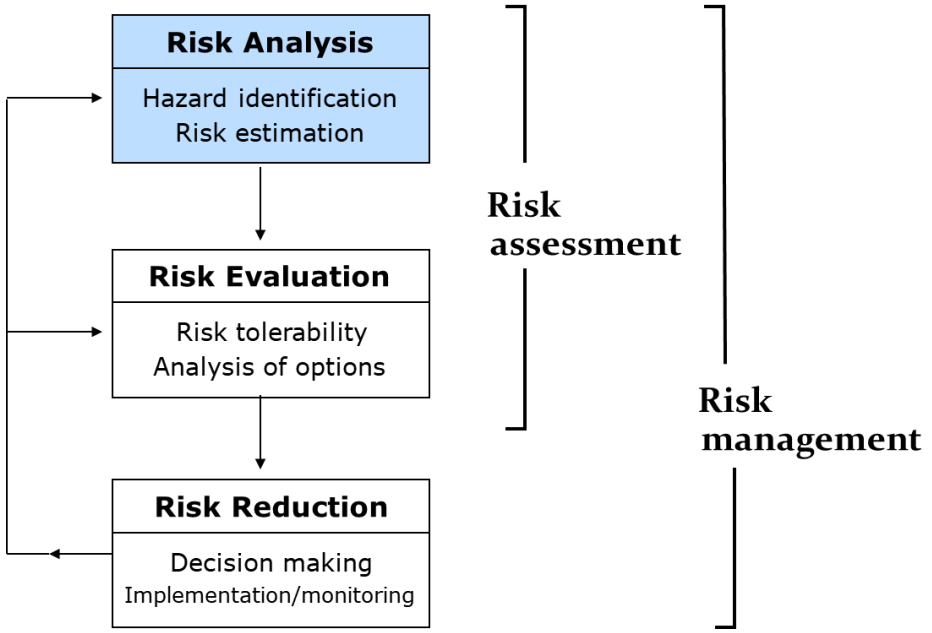
Joint Research Centre

European Commission

Chemical Accident Risk Analysis

- **Risk analysis** is a prerequisite for understanding likelihood and severity of possible **chemical accidents** originating from hazardous industrial activities.

- The analysis allows:
  - **Identification** of critical equipment.
  - Evaluation of **effectiveness** of prevention and mitigation measures.
  - **Prioritization** of safety measures needed to reduce the risk.
  - **Better** decision making process.



IEC 300-3-9 (1995)
IEC Guide 73 (2002)

Risk Analysis Process

What can go wrong?

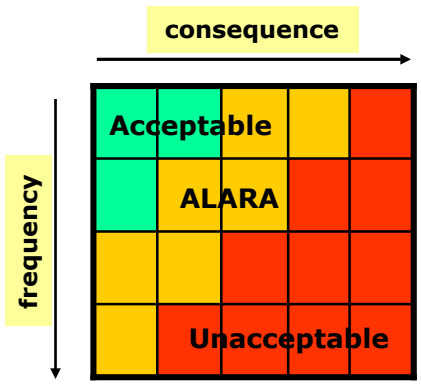
HAZARD IDENTIFICATION

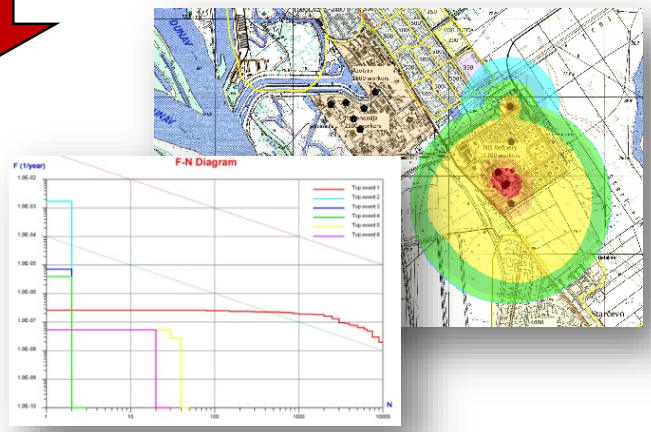
How likely?

How dangerous?

ACCIDENT FREQUENCY ANALYSIS

ACCIDENT CONSEQUENCE ANALYSIS





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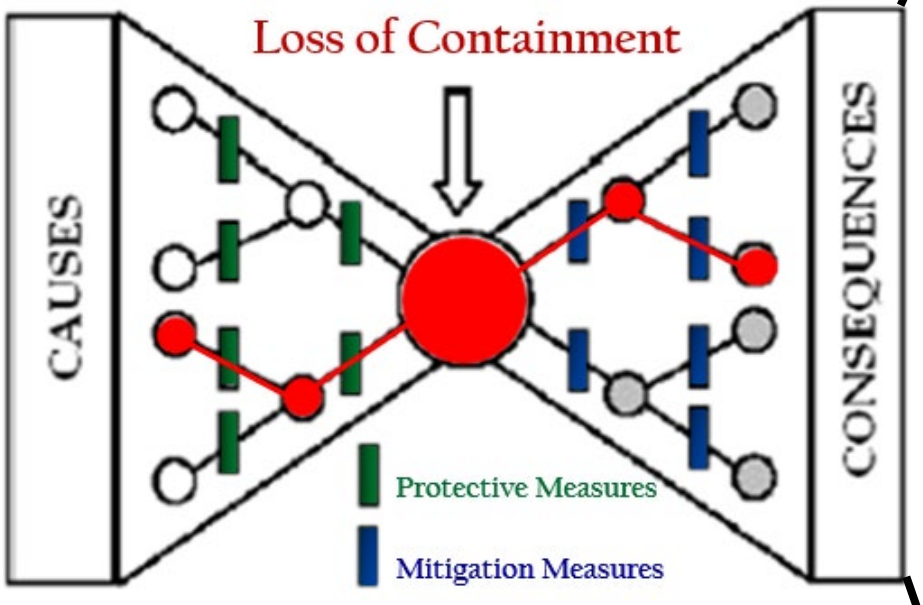
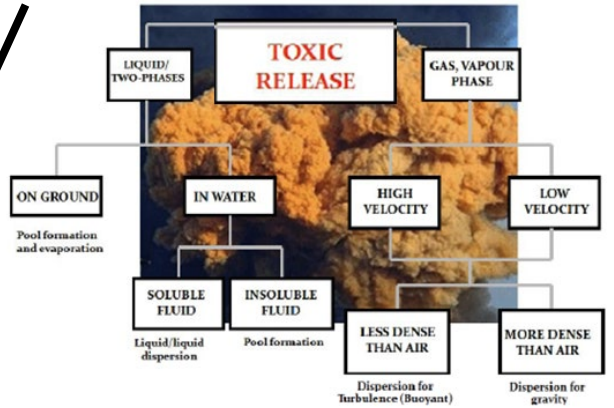
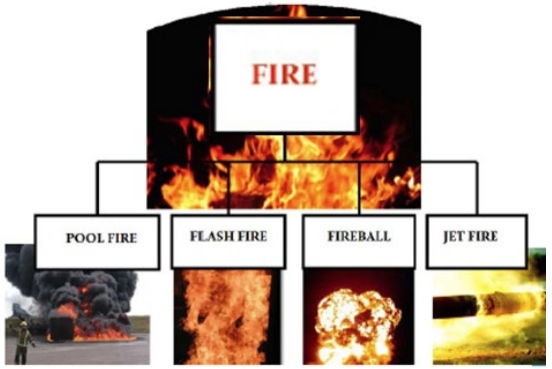
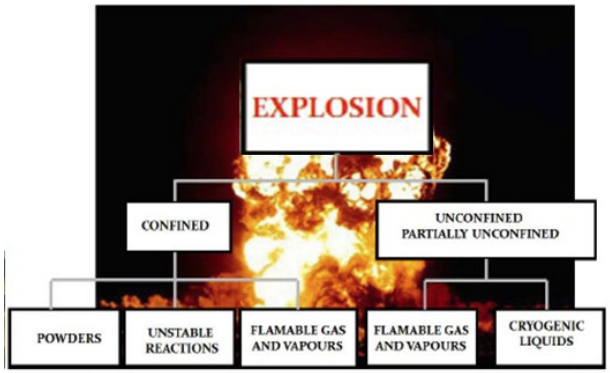
Accident Scenarios









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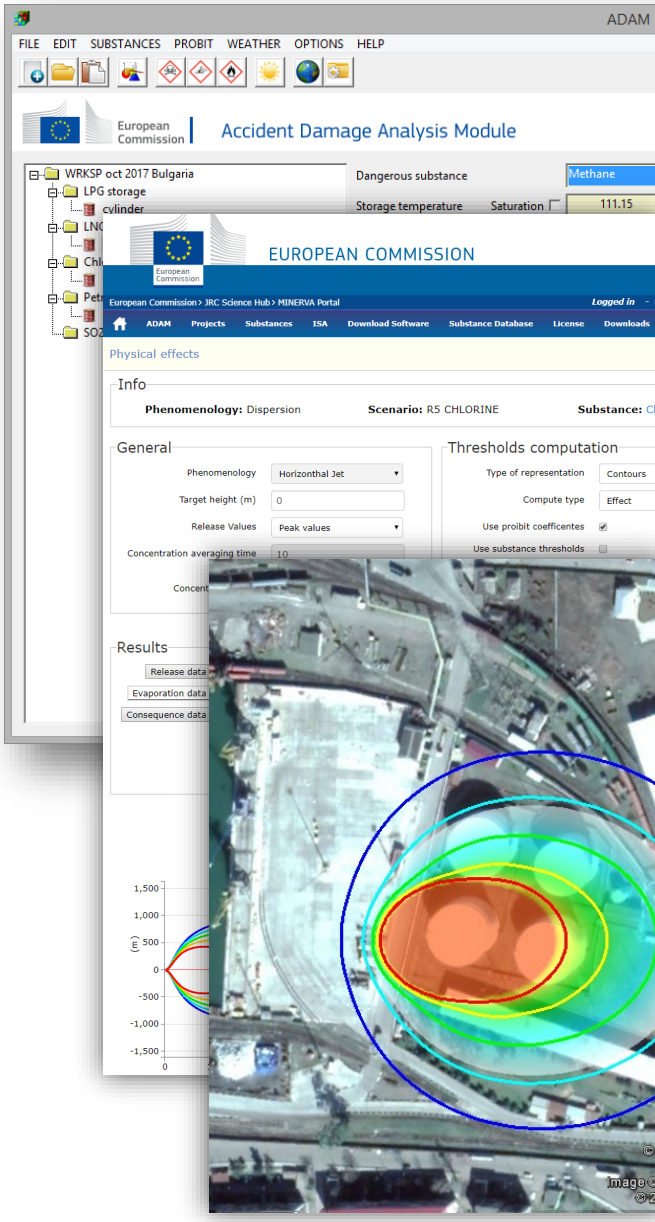
Prerequisites of Chemical Accident Risk Analysis

- Understanding of the **fundamentals** of risk analysis
- Knowledge on industrial units and processes
- Knowledge on accident scenarios
- Knowledge on hazardous consequences
- **Natech:** Knowledge on natural hazard impacts
- **Natech:** Knowledge on Natech accident scenarios
- Methods and models
- Tools

Accident Damage Analysis Module

- **ADAM** is a software **specifically developed** to assist the **Competent Authorities** of the EU Member States and Neighbouring Countries in **quickly** assessing the **potential consequences** of a chemical accident.
- It calculates the **physical effects** of an accident in terms of thermal radiation, overpressure or toxic concentration that may result from the loss of containment of a **flammable or toxic** substance.
- **Desktop** and **online** versions are available for governmental and research organisations by request.



ADAM: Methodology

INPUT DATA

Substance Amount
Operating Conditions
Failure mode

Database on Substances

Environment Conditions

Model Assumptions

CALCULUS MODULES

Module 1
Source Terms

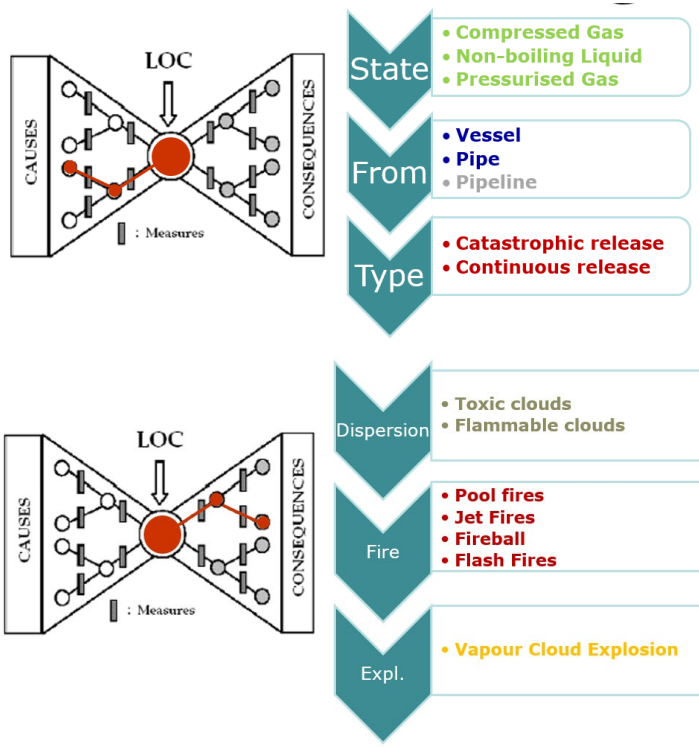
Releases
Pool evaporation

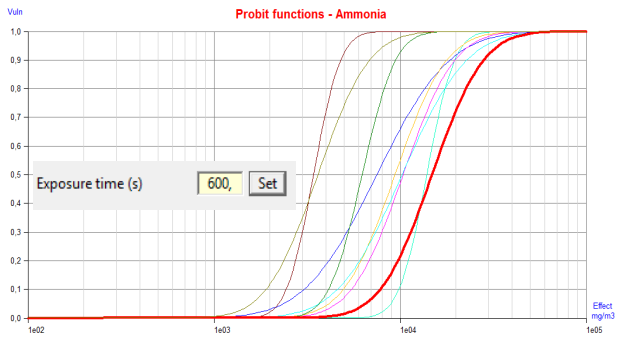
Module 2
Physical Effects

Toxic dispersions
Fires
Explosions

Module 3
Vulnerability

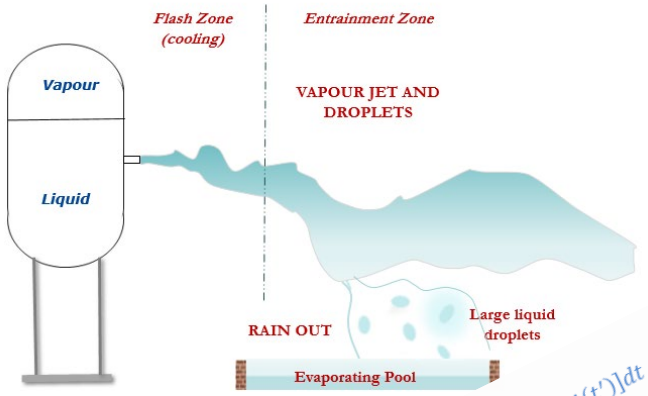
Probit Functions
Thresholds (PAC, LC50,....)





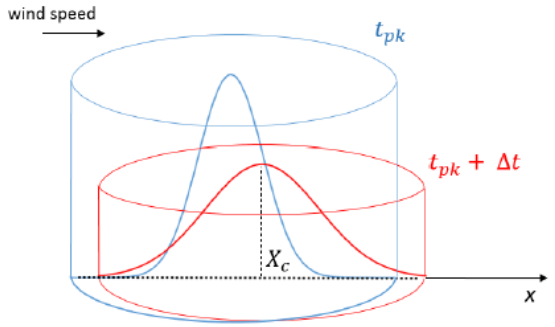
ADAM: Features

- Numerous source and consequence models
  - Instantaneous & finite duration releases
  - Pool formation & evaporation
  - Pool fire (Modified TNO; Shokri & Beyler; Mudan)
  - Jet fire (Chamberlain; Johnson; Cook)
  - Fireball
  - VCE (Equivalent TNT; TNO multienergy; BTS)
  - Toxic dispersion (SLAB, time-dependent, w/rainout)
- Fast analysis
  - Fine-tuned
  - Optimised
- Advanced visualization



$$H_c = -\lambda\frac{\Phi(t)}{\sqrt{\pi\alpha t}} - \frac{\kappa}{A(t)\sqrt{4\pi\alpha}}\int_0^t (t-t')^{-\frac{3}{2}}[\Phi(t)\,A(t) - \Phi(t')\,A(t')]dt$$

$$F_{view} = \iint_{A_i} \frac{\cos(\beta_i)\,\cos(\beta_j)}{\pi d^2} dA_i$$



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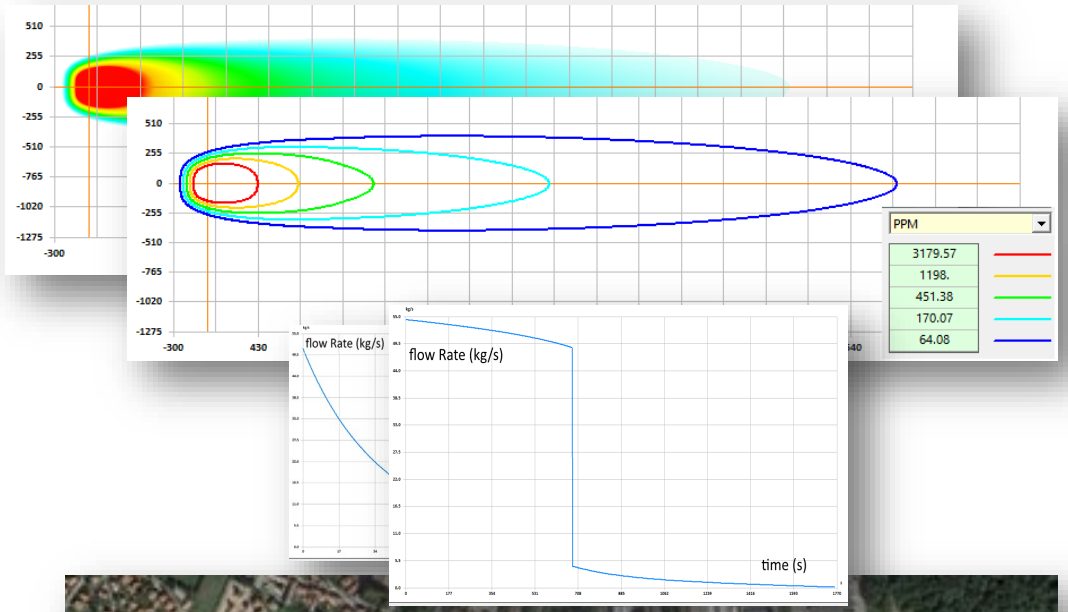
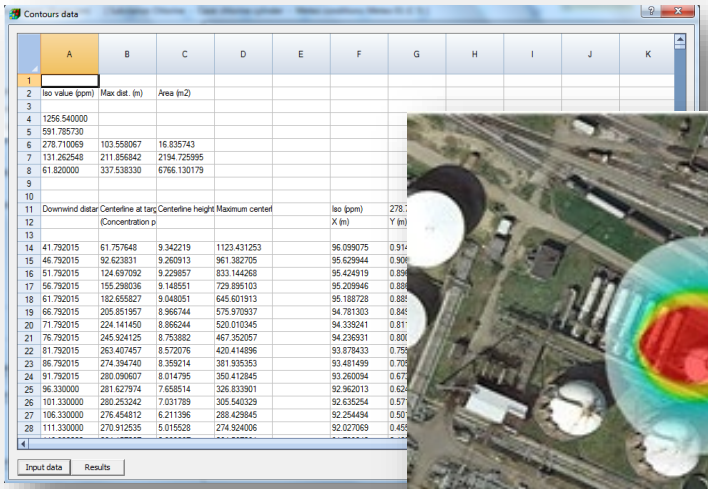
ADAM: Output

- Source term graphs
- Iso-effect contours
- Consequence maps
- Lethality curves / maps
- GIS data
- Tabular data



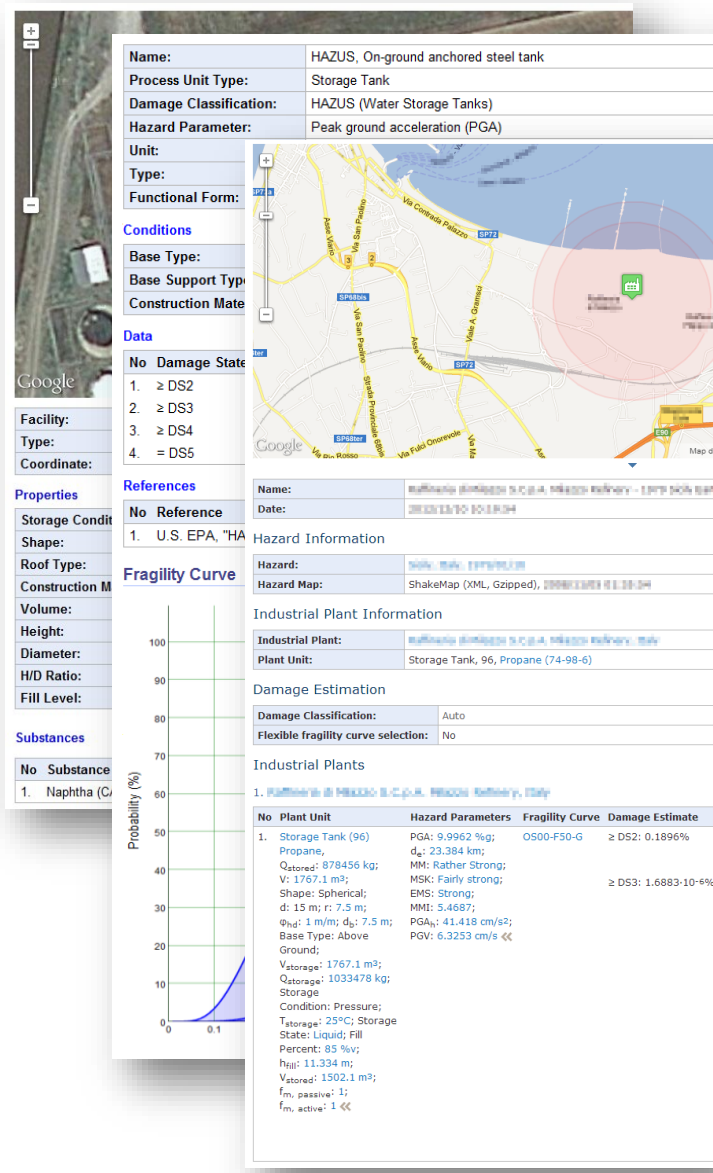


Natech Risk Analysis

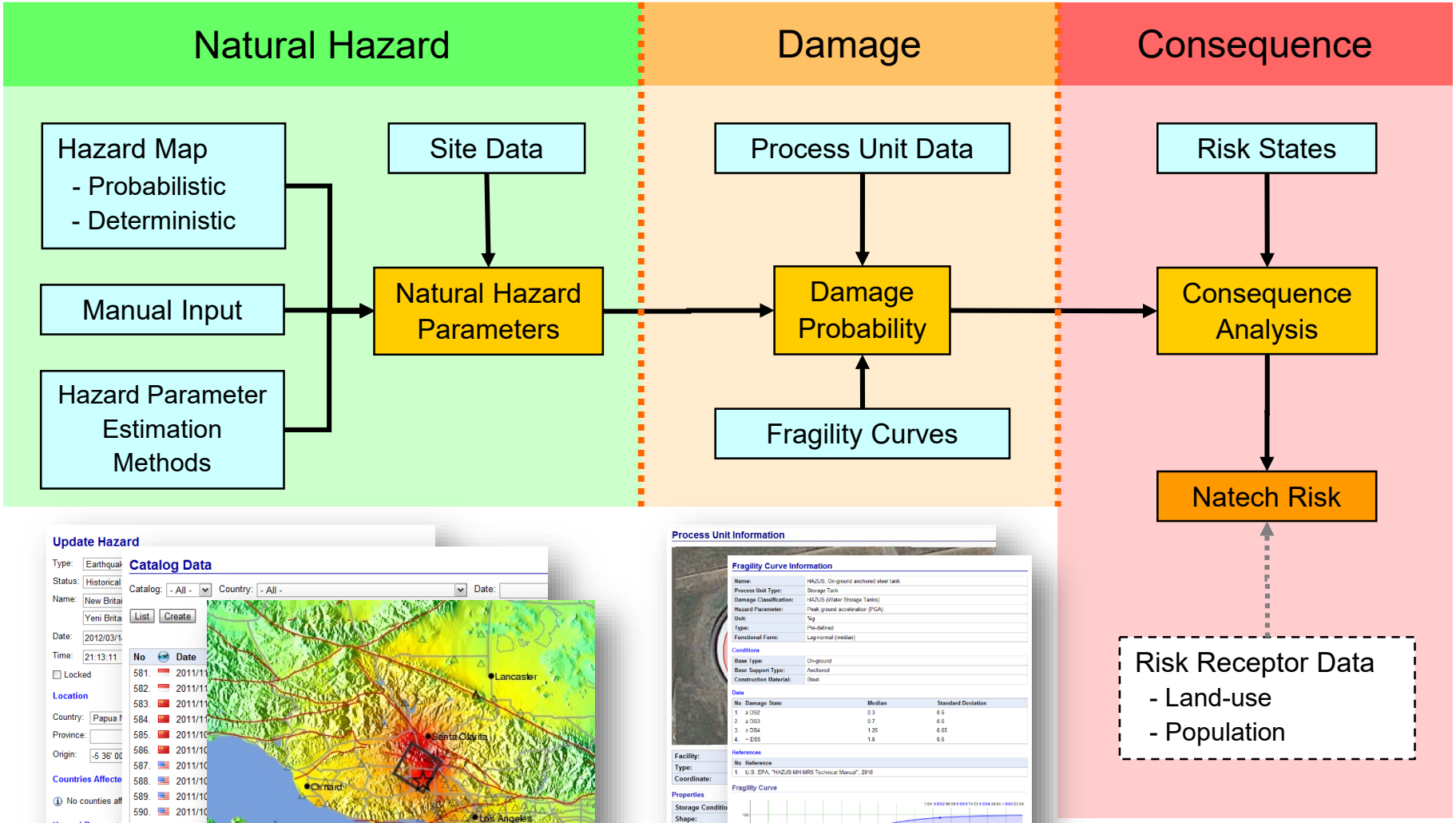
- Characteristics that differ from ordinary chemical accidents
  - **Simultaneous** releases from **multiple sources** over wide areas
  - **Extreme** environmental conditions
  - **Malfunctioning** of accident prevention measures
  - **Unavailability of lifelines** needed for accident mitigation
  - **Competition** for scarce response resources
  - **Hazardous** releases **hampering** emergency response activities
  - **Non-functional** or **inappropriate** standard civil protection measures
- Necessary additional risk analysis steps
  - **Characterization** of natural hazard severity
  - **Identification** of vulnerable critical equipment
  - **Estimation** of severity and likelihood of **natural-hazard damage**
  - **Estimation** of potential Natech accident scenarios
  - **Analysis** of consequences considering simultaneity and abnormality

Rapid Natech Risk Analysis and Mapping System

- **RAPID-N** is a web-based, publicly available **decision-support** system for Natech risk analysis and mapping.
- **Unites** natural-hazard impact assessment, Natech scenario development and consequence analysis in **one tool**.
- Features a **modular**, **extensible** and **collaborative** architecture facilitating data entry and **quick** analysis.
- Users are from **> 120** institutions globally.



RAPID-N: Methodology



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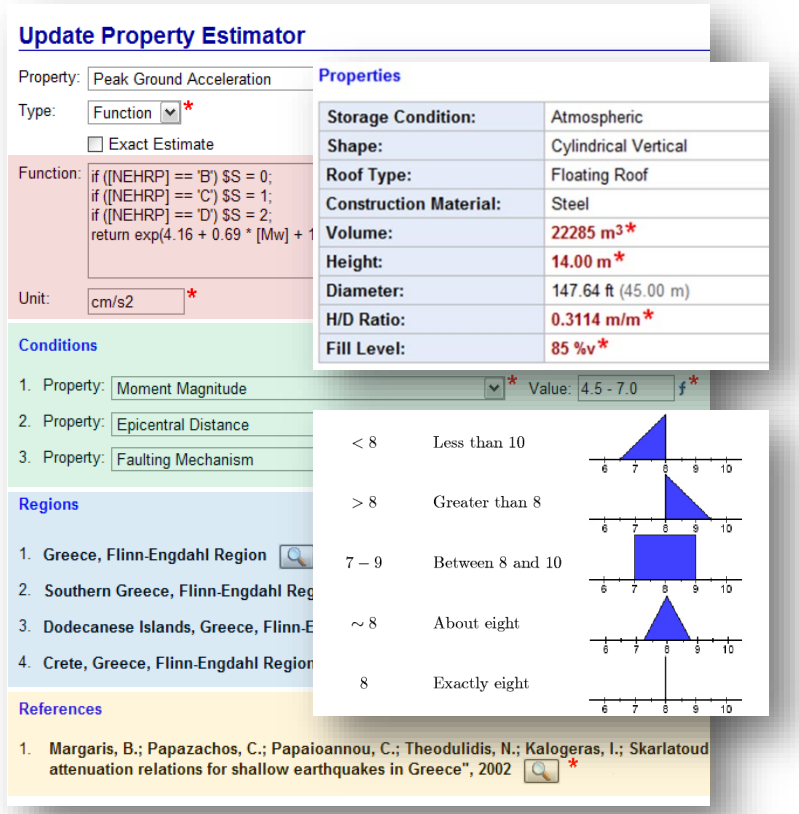
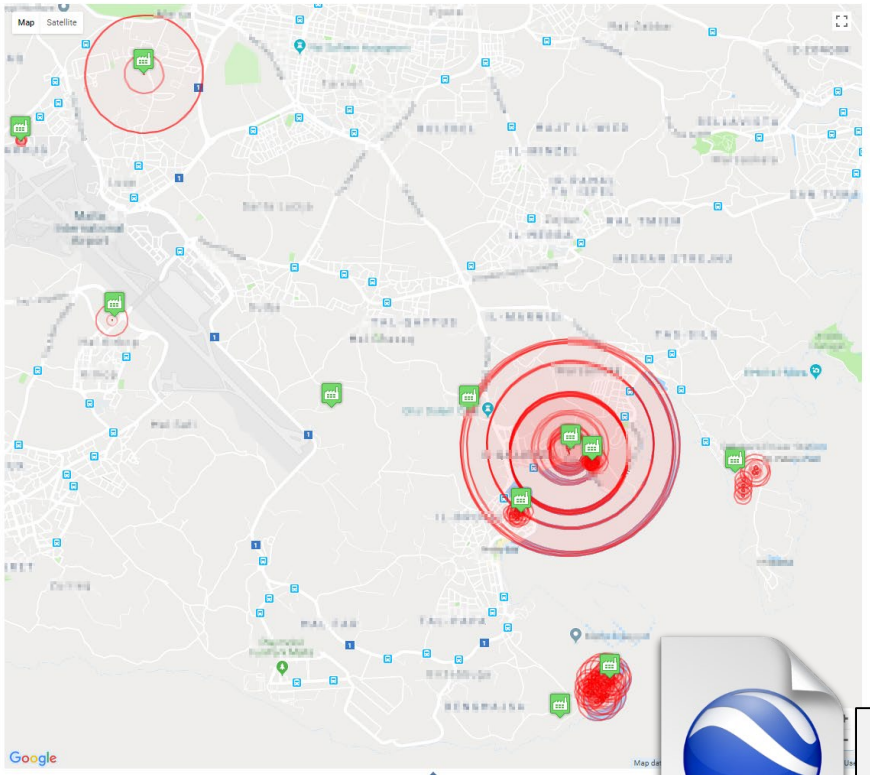
RAPID-N: Features

- Quick local and regional analysis
  - Multiple units
  - Multiple facilities
- Dynamic model building
  - Scalable
- Extensible modeling platform
  - User-defined estimators
- Data estimation
- Global data coverage
  - > 22,000 earthquakes
  - > 5,500 industrial facilities
  - > 64,500 plant units



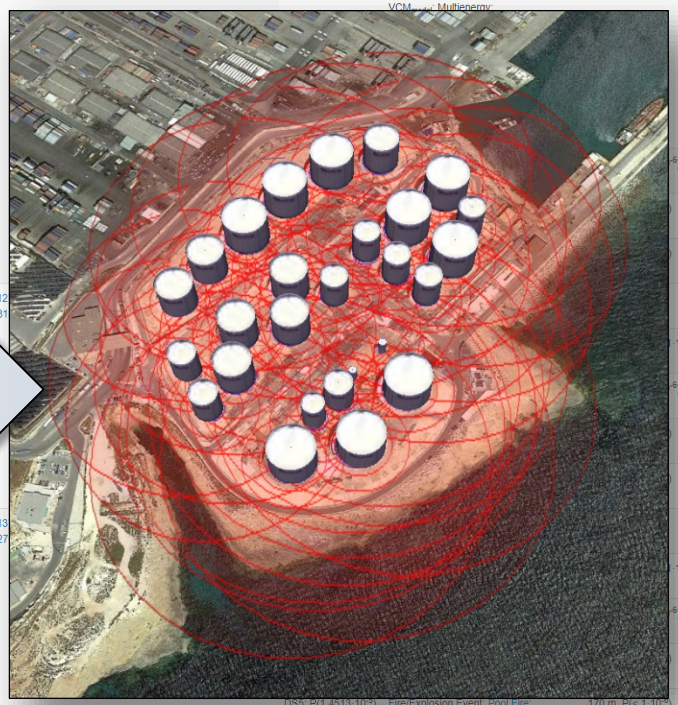
RAPID-N: Output



KML

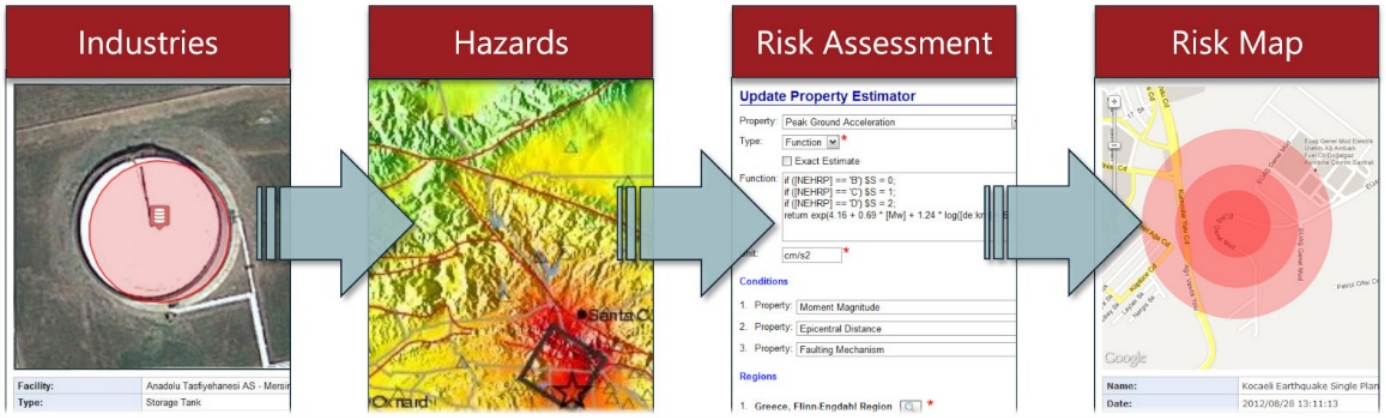
Name	[redacted]
Date	2017/04/15 12:00:00
Hazard	[redacted]
Hazard Map	ShakeMap (XML, Gzipped), 2017/04/07 16:53:00
Damage Classification	Auto
Flexible fragility curve selection	No
Use private property estimators	No
Vapor Cloud Explosion Model	Multienergy
Pool Fire Model	Solid Surface
Access	Private

No	Plant Unit	Hazard Parameters	Fragility Curve	Damage Estimate	Scenario Parameters	End-point Distance
1.	Storage Tank (T-111) Gasoline, Q_{stored}: 31850000 kg; V: 34636 m^3; Shape: Cylindrical Vertical; h: 25 m; d: 42 m; r: 21 m; φ_{hf}: 0.5952 m/m; d_b: 21 m; Obstruction Class: Obstructed; Status: Operational; A_{roof}: 1385.4 m^2; Roof Type: Internal Floating Roof; A_{base}: 1385.4 m^2; Base Type: On-ground; Base Support Type: Anchored; Construction Material: Steel; $h_{storage}$: 29.721 m; $V_{storage}$: 41176 m^3; $Q_{storage}$: 37470588 kg; Storage Condition: Atmospheric; $T_{storage}$: 25°C; $P_{storage}$: 1 atm; P_g: 0 atm; Storage State: Liquid; Fill Percent: 85 %v; h_{fill}: 25.263 m; V_{stored}: 35000 m^3; D_{dike}: 159.58 m; $l_{dike,eq}$: 141.42 m; Enclosure: Dike; h_{dike}: 3325 mm; A_{dike}: 20000 m^2; A_{dike}^0: 20000 m^2; V_{dike}: 51907 m^3; V_{dike}^0: 66500 m^3; $f_{m,passive}$: 1 ; $f_{m,active}$: 1	PGA: 15.11 %g; d_e: 24.651 km	ALA-G50A	DS1: P(0.9735)	Fire/Explosion Event: No Fire; $Q_{released}$: 0 kg	No Consequence
				DS2: P(0.02621)	Fire/Explosion Event: Pool Fire; $Q_{released}$: 763.06 kg; h_{hole}: 0 m; d_{hole}: 10 mm; A_{hole}: 0.7854 cm^2; C_d: 0.8; $h_{fill,hole}$: 25.263 m; $V_{stored,hole}$: 35000 m^3; $Q_{stored,hole}$: 31850000 kg; P_{damage}: 0.02621 ; d_{pool}: 10.333 m; LOC State: Minor; l_{pool}: 9.1571 m; $f_{Q,released}$: 0.002396%; $f_{V,released}$: 0.002396 %v; $h_{pool,min}$: 1 cm; $P_{release}$: 0.7862%; $t_{release,max}$: 6 h; $P_{c,release}$: 30%; Release State: Liquid; $q_{release}$: 168.23 lb/min; $t_{release}$: 10 min; $T_{release}$: 25°C; $V_{released}$: 0.8385 m^3; A_{pool}: 83.853 m^2; h_{pool}: 0.01 m; F_{flame}: 0.2298 ; h_{flame}: 15.895 m; SEP: 53.494 kW/m^2; SEP_{max}: 135.73 kW/m^2; S_{flame}: Cylindrical; VCM_{model}: Multienergy;	28.67 m, P(7.8621·10^{-6})
2.	Storage Tank (T-112 Gasoline, Q_{stored}: 31					
3.	Storage Tank (T-113 Gasoline, Q_{stored}: 27					
				DS5: P(1.4513·10^{-5})	Fire/Explosion Event: Pool Fire; $Q_{released}$: 27072500 kg	170 m, P(< 1·10^{-6})



RAPID-N in Action: Side Event

SIDE EVENT: Natech Risk Assessment and Mapping with RAPID-N



Natural hazard impacts on hazardous industrial activities can result in **severe cascading industrial accidents (NATECHS)** which may also have **cross-boundary consequences**.

RAPID-N is a unique, publicly available tool that allows the **rapid analysis of NATECH risk**.

Please join us for this side event hosted by **EC Joint Research Centre**, which will introduce the basics of **NATECH risk assessment** and **demonstrate** the capabilities of RAPID-N with case-studies.

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Tuesday, December 4th

14:15 - 15:00, Room VII

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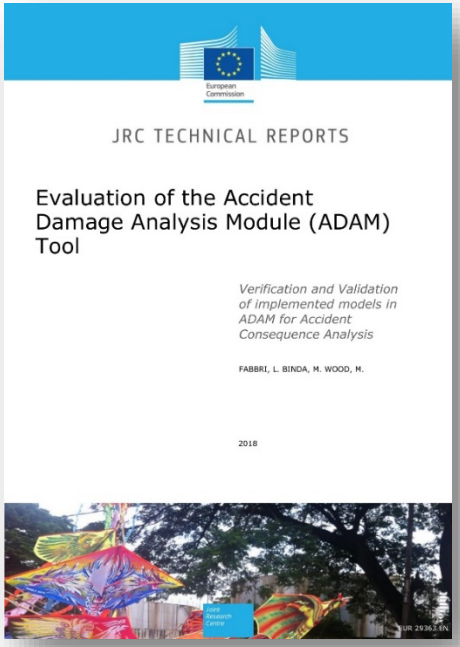
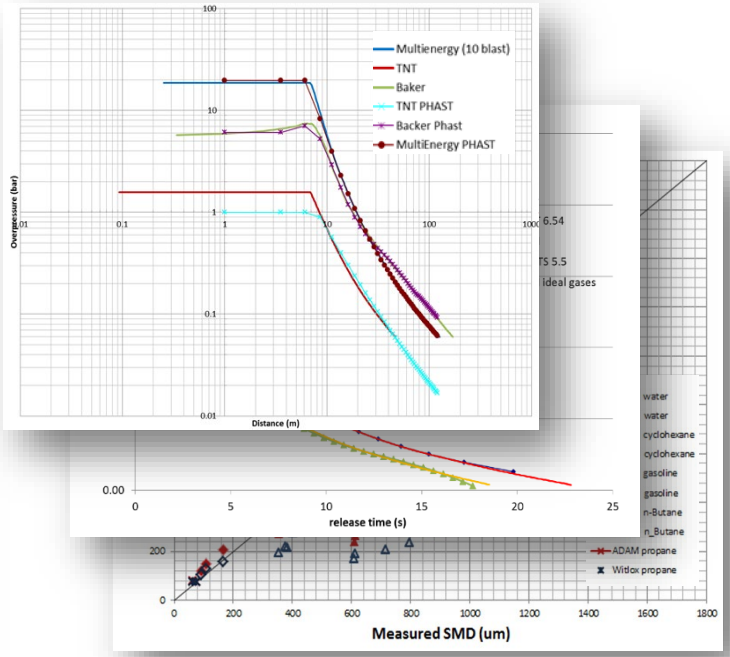
Usability: Quality Control

- Benchmarking with other existing software tools
- Comparing the results with experimental data
- Comparing the results with reference data



EUR 29363 EN



Unit	g
Exact Estimate	No
Validity Conditions	Moment Magnitude: 3.3–
Precedence	Auto
Disabled	No
References	Boatwright, J.; Bundock, magnitude inferred from
Notes	See Douglas (2004), pag Validation: M = 5.0, d = 10 km, NEH M = 6.0, d = 10 km, NEH M = 5.0, d = 100 km, NE
Access	Public

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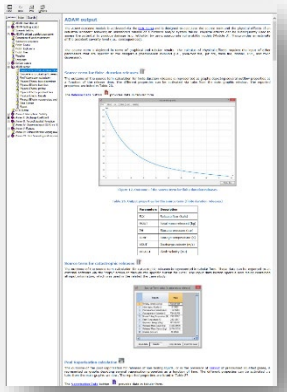
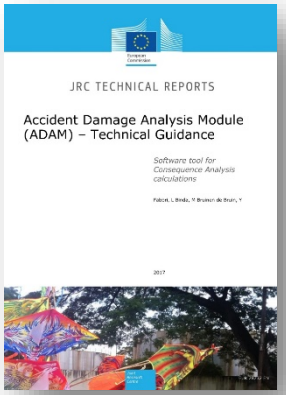
Usability: Resources

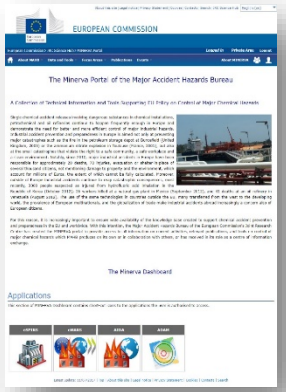
- ADAM



User Manual (Help)

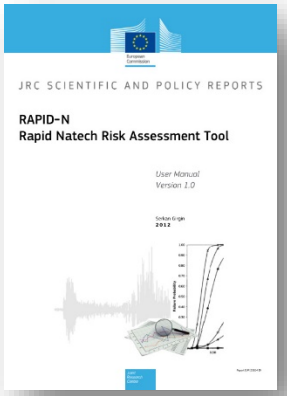


Technical Guidance

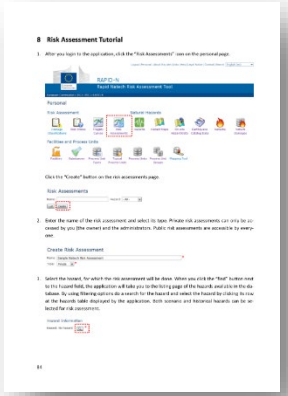


Minerva Portal

- RAPID-N



User Manual



Training Manual*

Case Studies

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Potential Users and Applications

- Risk analysis specialists
- Public authorities
- Inspectors
- Emergency managers
- Emergency responders

- Risk management
- Land-use planning
- Emergency planning

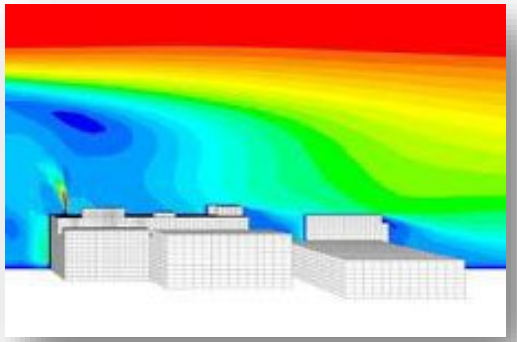
- Early warning
- Preliminary damage assessment
- Preliminary consequence analysis

Support and Capacity Building

- Hands-on trainings
  - EU Member States
  - EU E&IA countries
  - EU Candidate and Neighbour countries
  - Safety experts (e.g. MoE, Bulgaria)
  - Research organisations (e.g. INERIS, France)
- Emergency management support
  - EU RICHTER Caraibes 2017
  - EDREX
- Technical support
  - Regional risk analysis (e.g. Marsaxlokk, Malta)
  - User support (E-mail, not 24/7)

On-going R&D and Outlook

- ADAM
  - Software distribution to the interested stakeholders
  - Systematic sensitivity studies
  - Module on pipelines
  - Module on physical blast of vessels
  - Module on CFD for atmospheric dispersion



- RAPID-N
  - Enhanced scientific computation framework
  - Industrial data set
  - Early warning and alerting
  - Offline version
  - **ADAM / RAPID-N integration**

Stay in touch

ADAM: **http://adam.jrc.ec.europa.eu**

RAPID-N: **http://rapidn. jrc.ec.europa.eu**

EU Science Hub: ***ec.europa.eu/jrc***

Twitter: ***@EU_ScienceHub***

Facebook: ***EU Science Hub - Joint Research Centre***

LinkedIn: ***Joint Research Centre***

YouTube: ***EU Science Hub***

References

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- Fabbri, L., Binda, M., and Wood, M. (2018) Evaluation of the Accident Damage Analysis Module (ADAM) Tool, EUR 29363 EN, doi:10.2760/582513
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- Girgin, S. and Krausmann, E. (2017) Case-study Application I: RAPID-N, in "Natech Risk Assessment and Management", Krausmann et al. (eds.), Elsevier, doi:10.1016/B978-0-12-803807-9.00010-3
- ADAM: http://adam.jrc.ec.europa.eu
- RAPID-N: http://rapidn.jrc.ec.europa.eu