DE LA RECHERCHE À L'INDUSTRIE

ATMOSPHERIC DISPERSION MODELLING AND HEALTH IMPACT ASSESSMENT IN THE FRAMEWORK OF A CBRN-E EXERCISE IN A COMPLEX URBAN CONFIGURATION

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HARMO'16 | Varna (Bulgaria) | 8 – 11 September 2014

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Introduction – General context of this work

- Even if not the most prominent threats, CBRN-E attacks cannot be excluded or ignored!
- In many countries, civilian and / or military training centers have been set up in order to improve the capabilities of the local / national authorities to face CBRN-E events
- Training centers have to create crisis scenarios and to organize exercises gathering all the actors likely to be involved (fire brigade, police, medical teams, experts, etc.)
- Great attention is paid to the necessary realism of the scenario in all aspects, notably evaluation of the affected area and the health effects of the hazardous materials
- However, when considered, the dispersion is very often only modeled by an angular sector of a fixed arbitrary length, even in a complex environment (e.g. urban district)
- On the other hand, AT&D modelling followed by health consequences assessment are more and more often considered by rescue teams and decision makers as an essential component of emergency preparedness and crisis management

Introduction and outline of the presentation

- Objective – New approach to the modelling and simulation of a terrorist action exercise striking a public place (hall of exhibition) in a large town (in the South of France)

- The toxic material distribution and its potential health effects on the people present at the exhibition center and in the nearby district are evaluated using all scenario data: buildings geometry, “real” meteorological conditions, nature / quantity of the chemical

- Computations with CERES® CBRN-E modeling and decision-support system of CEA

  → In this study, flow and dispersion solver used inside CERES® was PMSS

- The paper is structured as follows:
  1) Main features of the attack scenario (restricted to necessary information)
  2) Modelling system and assumptions of the study
  3) Principal simulation results and lessons learned

Brief excerpt of the CBRN-E attack scenario

- 3:00 pm – Triggering of the FALSE terrorist attack inside a big exhibition hall located near a stadium in a public park of a large city
- 3:06 pm – Site security manager informs the fire brigade that many people in the hall smell a very unpleasant odor and begin to get out of the building (more than 1,000 people gather on the plaza in front of the hall)
- 3:12 pm – Arrival of the rescue team
- 3:18 pm – A sulphur-containing chemical is detected in the air while an empty dispersal device is found in the hall (decision to fully evacuate the hall and close the public park)
- 3:22 pm – Mustard gas (yperite) is identified while several people show more or less severe signs of contamination

  (Following of the synopsis is mainly dedicated to the application of medical treatment and security procedures in the public park and in the surrounding urban area)
- 4:29 pm – Mobile lab' of the fire brigade indicates that three more dispersal devices have been discovered in the hall where the average conc. of yperite is about 1 $mg.m^{-3}$

  (Application of emergency procedures goes on…)

Location of the fictitious CBRN-E attack

Satellite view of the area of interest

Oblique view of the urban area North to the hall

Assumptions and computations conditions (1/2)

- Albeit the chemical is released inside the exhibition hall, part or all yperite is transferred out of the building due to both ventilation and the movement of escaping people

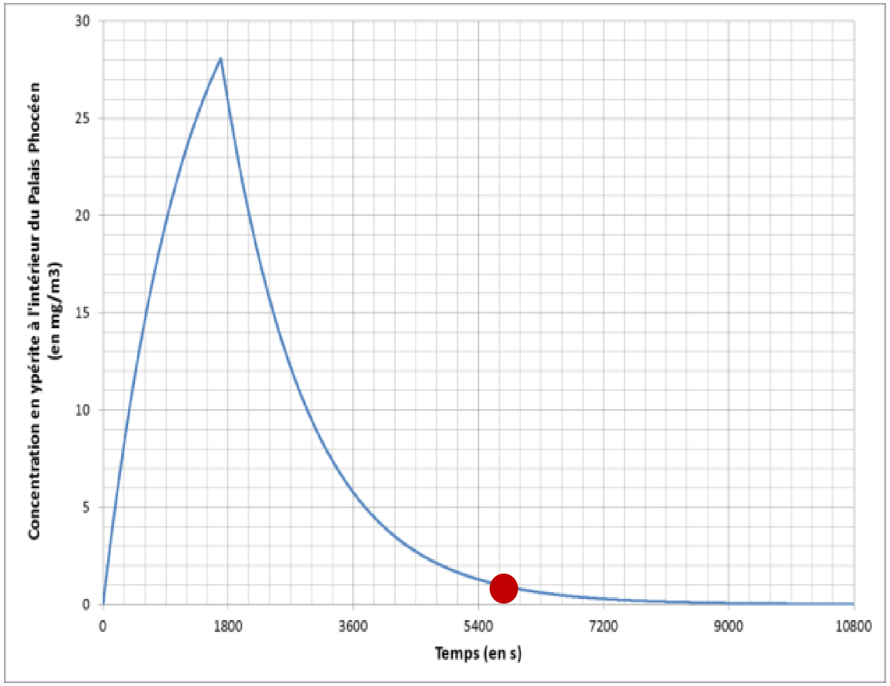
- As the toxicity of yperite is high even with low concentration levels, many people likely to be affected (not only public in the hall, but district inhabitants, and first responders)

- Calculations hypotheses (derived from the chemical attack scenario)
  a) Wind blows from the south at 20 km.h^{-1} (at 10 m AGL in an open area)
  b) Released volume of yperite is 4 L (inferred from discovery of dispersal device)
  c) As the smell occurs at 3:06 pm, release supposed to begin earlier, at 2:50 pm
  d) Release duration less than 30 min. as disp. device found empty at 3:18 pm

Assumptions and computations conditions (2/2)

- Indoor / outdoor transfer (no detailed CFD computation carried out inside the building)
  a) Uniform concentration in the hall (around 100,000 m^3) evolving with time
  b) Release rate of yperite droplets from the disp. device is estimated to 3 $g.s^{-1}$
  c) Aerosol transf. through venting (turnover 2 h^{-1}) and gates (time constant 1 h^{-1})
  d) Two-thirds of the chemical exist through 3 outlets on the roof of the hall
  e) One-third transferred through the 21 gates of the building for whom:
     i. One-third of the chemical goes through the main entrance
     ii. The rest through the other doors (emergency exit, access for delivery…)
  f) (Total number of point sources is 24)

Indoor / outdoor transfer of the toxic chemical



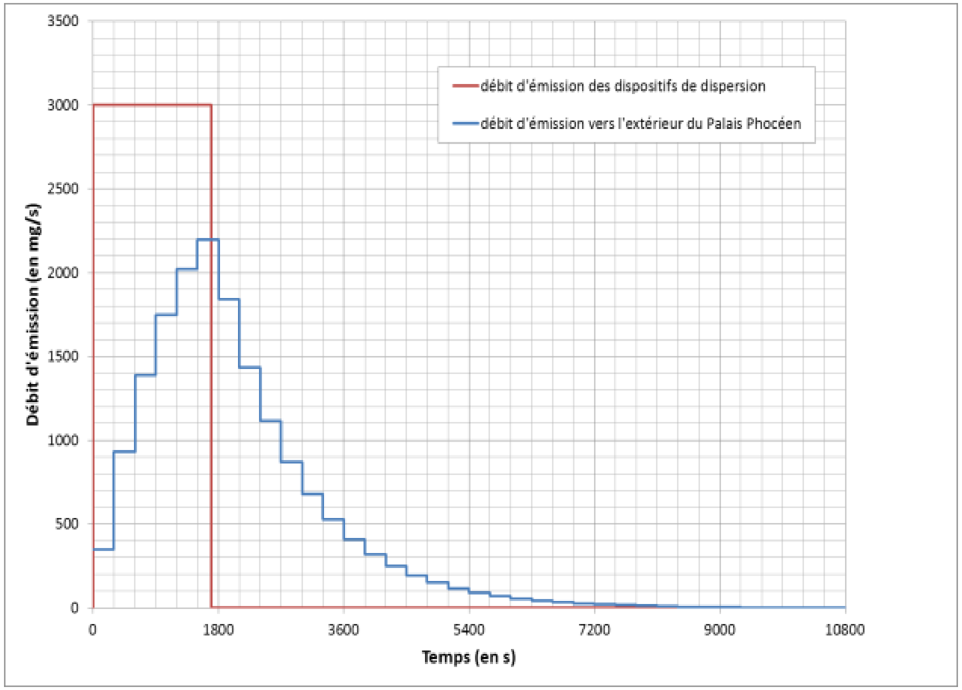
Yperite mean concentration (in mg.m^{-3})

*inside the exhibition hall **

Yperite release rate (in mg.s^{-1})

from the dispersal device

and to the atmospheric environment



* Result consistent with the conc. of 1 mg.m^{-3} measured at 4:29 pm by the mobile lab'

Modelling and decision-support system (1/2)

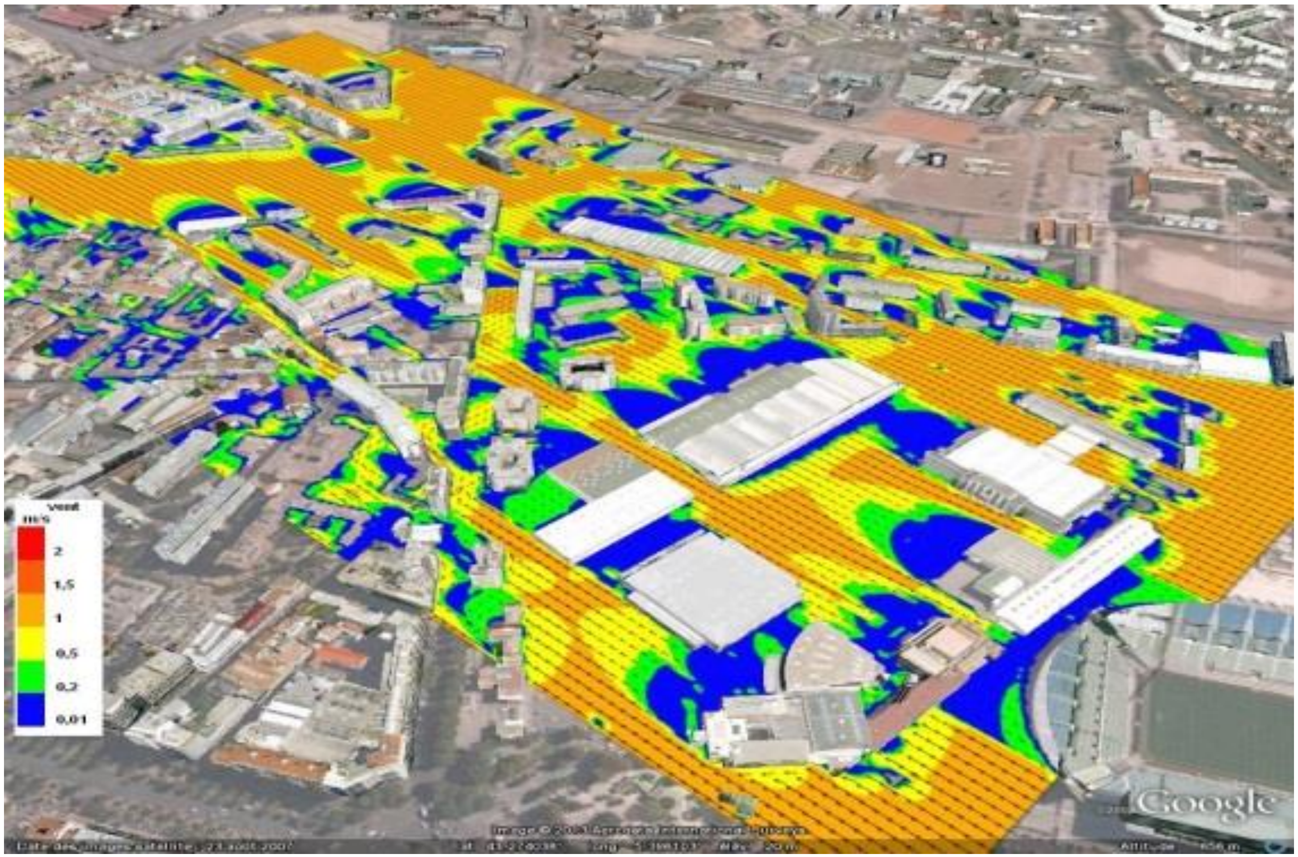
- New operational 4D modelling and decision-support tool CERES® CBRN-E
  - Developed by CEA in the framework of academic / industrial collaborations
  - Devoted to assess AT&D, environmental impact and human health consequences of possibly deleterious, accidental or chronic, releases in the atmosphere
  - Can cope with all categories of CBRN agents, Explosions, and all kinds of natural (rural) or built (industrial plant, urban district...) environments
  - Has a graphical interface fitting the needs of rescue teams / decision-makers
  - Can be utilized for safety studies and emergency preparedness or management
- When applied in an emergency, CERES® committed to deliver operational results, e.g. danger zones, in less than 15 min whatever the situation (accident or a malevolence)
- CERES® is modular and flexible by design, offering the user multiple possibilities, e.g. regarding the range of dispersion models (standard or urbanized Gaussian or LPDM)

Modelling and decision-support system (2/2)

- In this study, CERES® features Parallel-Micro-SWIFT-SPRAY (PMSS)
- The interest to embed PMSS in CERES® is to combine a fast response simplified CFD module and CBRN-E impact models with the benefit of CEA expertise in this field
- PMSS is developed by ARIA Technologies, ARIANET, MOKILI and CEA
  - P-SWIFT is a 3D mass-consistent diagnostic model interpolating meteorological measurements and / or model results and taking into account the influence of the buildings on the wind field according to Röckle approach
  - P-SPRAY is a 3D Lagrangian particle dispersion model able to deal with the particles bouncing off onto the buildings and deposition on all exposed surfaces

Results of the simulation: local-scale wind field

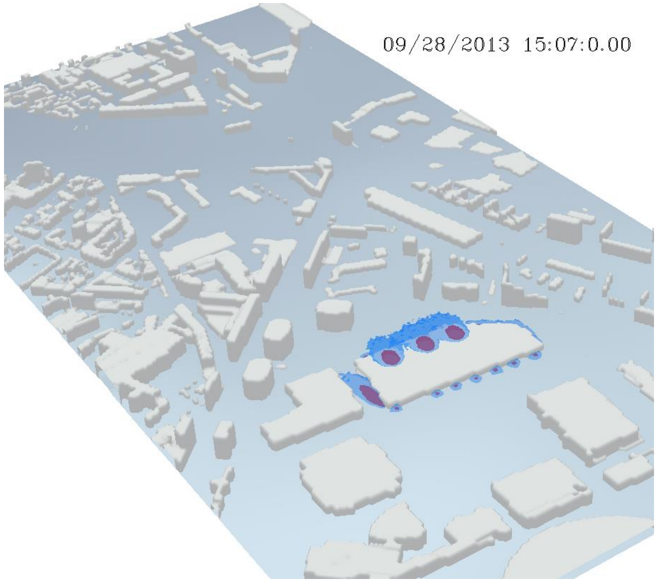
- In this scenario, the meteorological conditions are supposed to remain unchanged
- Flow is oriented S to N what can be seen in areas not influenced by buildings
- North of the large buildings, low wind wake zones are clearly visible as, in some densely built areas, channeling effect of streets not aligned with the wind direction

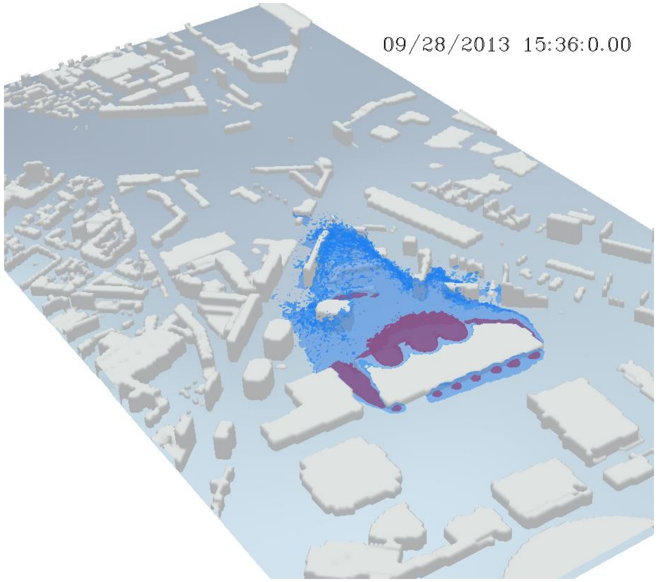


Horizontal section of the wind field (vectors and modulus) at 2 m AGL

Results of the simulation: toxic chemical AT&D

- From the chemical release rate, yperite is emitted out of the exhibition hall in two hours (also the duration chosen for the dispersion simulation)
- The chemical distribution is complicated even for this simple meteorological condition and predominantly depends on the buildings configuration!
- Distances at which different concentration levels are reached:
  - 1 $mg.m^{-3}$ at some tens of meters around the exhibition hall
  - 0.3 $mg.m^{-3}$ on the opposite side of the street where the hall is located
  - 0.1 $mg.m^{-3}$ at 600 m from the hall 45 min after the release start

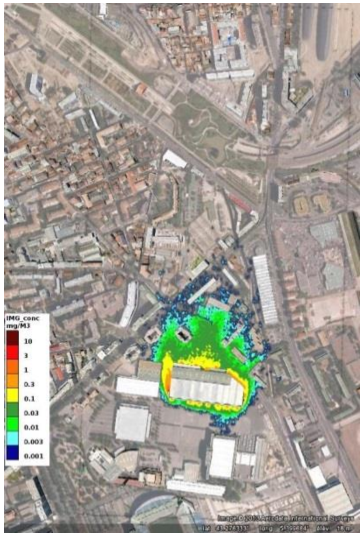




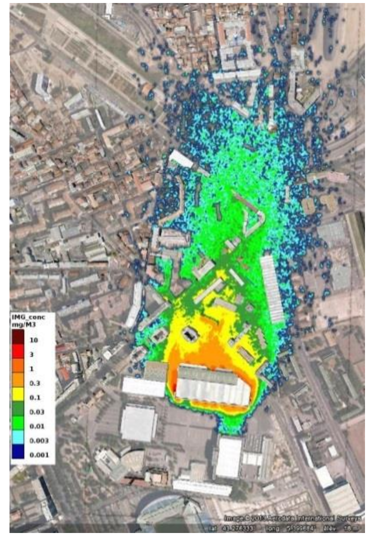
3D view of the plume at 7 min and 36 min (isopleths 1 mg/m³ and 0,3 mg/m³ respectively in violet and blue)

Results of the simulation: toxic chemical AT&D

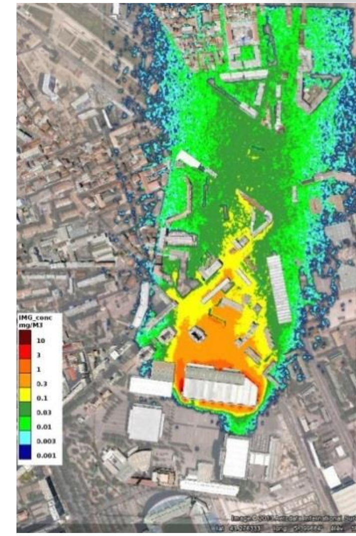
t = 5 min



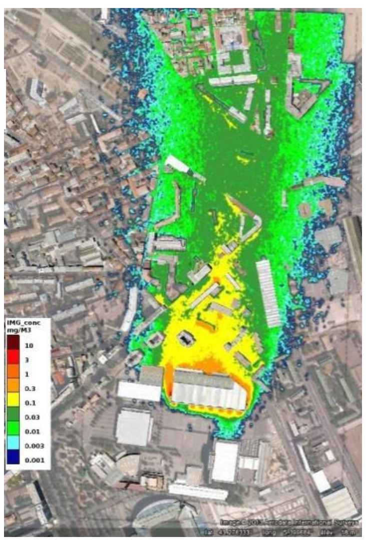
t = 15 min



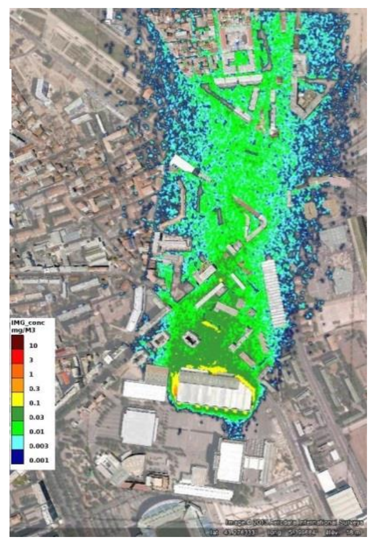
t = 30 min



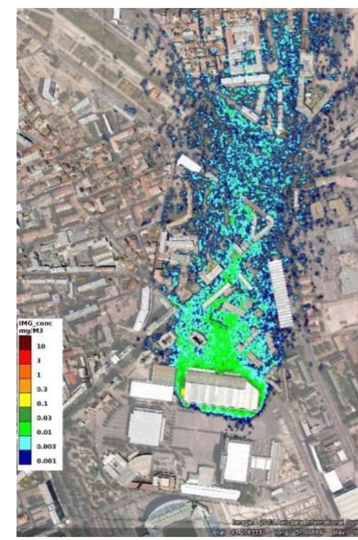
t = 60 min



t = 90 min



t = 120 min



Section at 2 m above the ground of the yperite concentration (in mg.m^{-3})

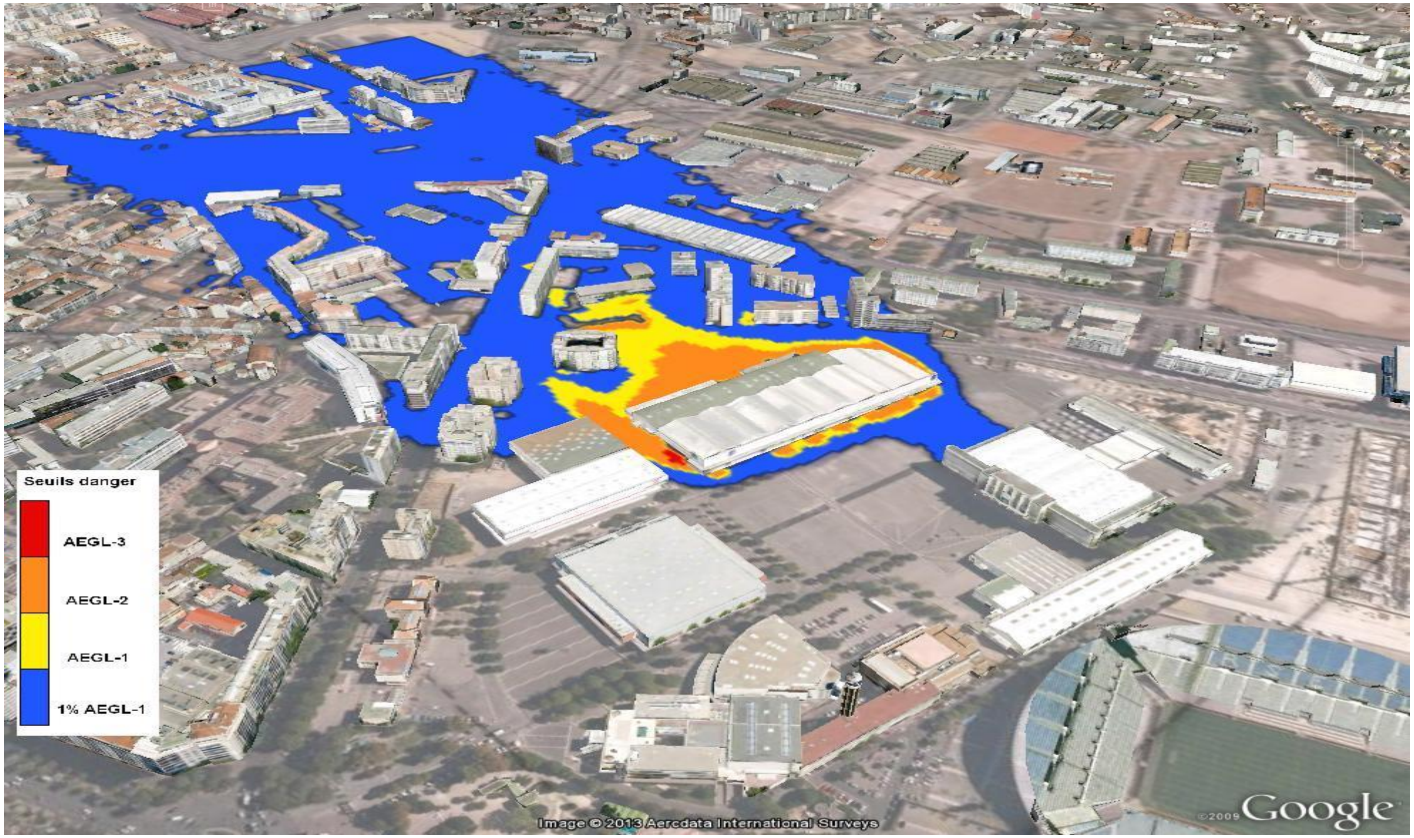
Results of the simulation: toxic chemical AT&D

Evolution of the chemical concentration

at 2 m AGL from 3 to 5 pm

Results of the simulation: health consequences

- Concentration levels and exposure durations are necessary to infer health effects
- In this study, we have used the Acute Exposure Guideline Levels 1, 2, and 3 corresponding resp. to reversible, irreversible, and possibly lethal consequences
- At each location, AEGL chosen using the effective duration of the plume going by



Danger zones corresponding to the AEGL thresholds

Conclusions

- In this presentation, the synopsis and data of a CBRN-E training exercise have been used to develop the physical model and numerical simulation of this crisis scenario
- Computations were carried out with CERES® CBRN-E, the emergency modelling and decision-support system of CEA, featuring Parallel-Micro-SWIFT-SPRAY (PMSS)
- Health impact assessment clearly indicates that irreversible effects would be observed not only in the hall, but also in the park, and in some neighboring residential buildings
- This study confirms our capability to precisely and quickly simulate the distribution and effects of CBRN agents accidentally or intentionally released in a complex environment
- Also shows the role and help modelling can bring to crisis preparedness / management
  - Used to elaborate scenarios, simulation contributes to raise realism of the exercises (correlation between release and its consequences on population / first responders)
  - Used during an exercise or in the course of a real event, simulation could provide additional information, likely to guide rescue teams, police… in decision-making

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Thank you

Questions?

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