THE DECISION SUPPORT SYSTEM LASAIR: NEW FEATURES FOR EVALUATING DIRTY BOMB SCENARIOS

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Dirty bomb, a realistic thread?

- What is a “dirty bomb”

- Thread?
  What others say...

Nuclear Summit The Hague, March 2014
What is a Dirty Bomb?

- Radionuclides
- Explosives
Is it a thread? What others say…..

Nuclear Security Summit in The Hague, 2014
(Obama, Xi Jinping, …, Merkel,…..)
58 leaders, 5000 delegates,…..

Results
• Reducing the amount of dangerous nuclear material in the world
• Improving the security of all nuclear material and radioactive sources
• Improving international cooperation
LASAIR background: Effects after a „dirty bomb“ explosion
Questions in a „dirty bomb“ scenario

- What is the radiation exposure?
- What’s the size of the affected area?
- How long will the radioactive cloud be in that area?
- Have people to be evacuated?
Development of a decision support system

LASAIR

Programme system for the Lagrange-Simulation of the dispersion (German: Ausbreitung) and Inhalation of Radionuclides

Lagrange := meteorological mathematical procedure
LASAIR (Version 4) basic model features

- Lagrange particle model (500,000 particles),
- simulation area 40 x 40 km²,
- 3-dimensional flow model with orography,
- individual characterisation of topography,
- very quick response time (1 – 10 minutes).
LASAIR input

Meteorology
- wind speed
- wind direction
- stability class

Kind of release
- short term release
  or
- continuous release

Orography, Topography
- individual roughness length
LASAIR output

Radionuclides

- max. 5 radionuclides (out of 800),
- activity concentration in base layer,
- deposition on the surface,
- cloud arrival time.

Exposure

- inhalation,
- groundshine,
- cloudshine.
Decision Support System LASAIR

- LASAIR 4

Example
Varna Airport
LASAIR special features and model validation

- parameterisation of the explosion cloud as initial volumina (LASAIR source term)
- consideration of spectral aerosol distribution
- validation (EMRAS*, MODARIA**, Kamenna experiments)
  * Environmental Modelling for Radiation Safety, IAEA project
  ** Modelling and Data for Radiological Impact Assessments, IAEA project
- air flow influenced from buildings or orography (Version 4)
LASAIR Harmonisation (turbulence parametrisation)

• Harmonisation of turbulence parameterisation

VDI, Association of German Engineers

Environmental meteorology – Turbulence parameters for dispersion models supported by measurement data

VDI 3783, Blatt 8, 17.Vorentwurf, 2014-08-01

• Used within Germany, but can be used elsewhere
LASAIR  Harmonisation (turbulence parametrisation)

- Association of German Engineers
  Turbulent Diffusion Coefficients $K_{u,v,w}$

\[ K_{u,v}(z) = A_v \cdot F_{u,v} \cdot \frac{h_m}{10} \cdot \frac{\sigma_{u,v}}{f_{u,v}} \cdot u(z) \]

\[ K_w(z) = \kappa \cdot u_\ast \cdot z \cdot \frac{1}{1 + p_s \cdot z / L_M} \cdot e^{-6\alpha/h_m} \]

\[ K_w(z) = \kappa \cdot u_\ast \cdot z \cdot \left( e^{-12\alpha/h_m} + p_1 \cdot \left( \frac{-z}{L_M} \right) \cdot \left( 1 - \frac{z}{h_m} \right)^4 \right)^{1/2} \]

Lit.: VDI 3783, Blatt 8, Vorentwurf, 2014-08-01, to be published in 2015
LASAIR Verification: Kamenna experiments

- Kamenna
LASAIR Verification: Kamenna experiments

roughness length

3 areas

$z_0 = 0.1 \text{ m}$
(center and far vicinity)

$z_0 = 1.0 \text{ m}$
(trees in close vicinity)

$z_0 = 1.5 \text{ m}$
(obstacles [bus])

release position

49.626796° N
13.994526° E
(explosion)
LASAIR Verification: Kamenna experiments (Nr. 4)

SURO, Czech Republic
LASAIR Verification with 6 Kamenna experiments

- Kamenna Experiment 3, good results
- Kamenna Experiment 4, poor results
LASAIR4, Experiment 3, deposition [Bq/m$^2$], 0-60 min
LASAIR4, Experiment 3, deposition [Bq/m²], 0-60 min
LASAIR4, Experiment 3, deposition \([\text{Bq/m}^2]\), 0-60 min

LASAIR Experiment 3 deposition (Bq/m2)

Kamenna Experiment 3 deposition (Bq/m2)
LASAIR Verification Kamenna experiments

- Kamenna Experiment 4, poor results
LASAIR4, Experiment 4, deposition [Bq/m$^2$], 0-60 min

Jet

Experiment 4 Deposition

- Average LASAIR
- Average Experiment 4
- Maximum LASAIR
- Maximum Experiment 4
LASAIR4, Experiment 4, deposition [Bq/m²], 0-60 min

Jet

LASAIR Experiment 4 deposition (Bq/m²)
LASAIR4, Experiment 4, deposition [Bq/m\(^2\)], 0-60 min

Jet

LASAIR Experiment 4 deposition (Bq/m2)

Kamenna Experiment 4 deposition (Bq/m2)
LASAIR  Orography

• Orography, example (Sostanj, Slovenia )
LASAIR  Orography

• Orography, example (Sostanj, Slovenia ☀️)
LASAIR  Topography

- Topography characterisation

Individual definition of topography

- meadow,
- forest
- city, hamlet
- crop field
LASAIR  Harmonisation with Open Street Maps

- OSM: use world wide is possible (e.g. Varna airport)
LASAIR Harmonisation with Open Street Maps

- OSM: use worldwide is possible (e.g. Varna airport)
LASAIR Urban structures

• Rapid online integration of urban structures
LASAIR buildings, „definition“ 2 d + height
LASAIR building effects, Open Street Map, close view
LASAIR buildings, 3 dimensional
LASAIR with buildings, windfield, surface

Wind direction 220°
LASAIR with buildings, windfield at building height

Wind direction 220°
LASAIR   Inhalation dose
Summary

• LASAIR has proven to be quick and easy usable decision support system

• LASAIR is able to handle microscale effects (urban areas, topography, orography)

• Harmonisation process in LASAIR (past and future)

• Model validation of local scale effects within IAEA project EMRAS/MODARIA has proven good results
Backup
LASAIR special feature

- parameterisation of the individual cloud as initial volumina (LASAIR source term)
Initial cloud parametrisation

- mathematical description of a cloud after an explosion
German Army test site, explosives
German Army test site, explosives
Initial cloud volumina with investigation marks
Initial cloud volumina, Explosive experiments 2003 / 2007

Initial volumina for LASAIR

100 kg explosives (PETN)

06.06.2007 11:42
LASAIR Effects of different initial clouds

- Single point source
- Volume source (100 kg explosives)
LASAIR  Effects of different initial clouds (point source – volumina source)

Difference for inhalation dose at maximum:

factor 32
**LASAIR aerosol spectra**

- **LASAIR standard aerosol size ranges and related deposition velocities**

<table>
<thead>
<tr>
<th>Aerosol size range (µm)</th>
<th>Deposition velocity (10^-4 m/s)</th>
</tr>
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<tbody>
<tr>
<td>0 – 2.5</td>
<td>10</td>
</tr>
<tr>
<td>2.5 - 10</td>
<td>100</td>
</tr>
<tr>
<td>10 - 50</td>
<td>500</td>
</tr>
<tr>
<td>&gt; 50</td>
<td>2000</td>
</tr>
</tbody>
</table>
LASAIR aerosol spectra, fraction of respirable aerosols after the explosion

Metallic samples
fraction depends on the size of the metal sample
less than 5 % is dispersed in the atmosphere

Liquids
fraction differs from 10 – 50 %

Ceramics
differs between roughly 0.1 % and 50 %
depending on the compressive strength of the material
LASAIR aerosol spectra

Different aerosol spectra

Aerosol completely respirable

Simulation
Not real!
LASAIR Effects of different aerosol spectra

Difference for inhalation dose at maximum:

factor ≈ 11

(! But range can be wider depending on the real material !)
Grids Kamenna-Experiments – LASAIR 3 grid

Kamenna grid

red bullets represent measurements

LASAIR 3 grid

25 m
LASAIR results for EMRAS („Kamenna-Experiments“)

EMRAS Kamenna Experiment 4

- measured centerline (x=0)
- ADDAM
- CFD
- CLMM
- HOTSPOT (HR)
- HOTSPOT (HPA)
- USEV
- LASAIR
LASAIR building effects

Quelle: Fv. TÜV Süd, von Haustein, Rall, 2000
LASAIR building effects, Use of Open Street Map
LASAIR Deposition
LASAIR Deposition, close