Operational Emergency Response Modeling Systems for Use with Major Releases of Airborne Hazards

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Presented at
Air Quality In Emergency Response
California Air Response Planning Alliance
October 15, 2008
Sacramento, CA

This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344. LLNL-PRES-407706
Tools for Estimating Hazard Areas

1. Guidebooks and guidelines

2. Computer models of atmospheric transport, dispersion and deposition

3. Measurements of air concentration and ground contamination
The Emergency Response Guidebook Table is Based on a Series of Default Model Runs

Pre-determined hazard distances and protective action recommendations are based on type of accident and hazardous material.

### TABLE 1 - INITIAL ISOLATION AND PROTECTIVE ACTION DISTANCES

<table>
<thead>
<tr>
<th>No.</th>
<th>Name of Material</th>
<th>SMALL SPILLS</th>
<th>LARGE SPILLS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>First Day</td>
<td>First Day</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Isolate in all Directions</td>
<td>Isolate in all Directions</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Meters (ft)</td>
<td>Meters (ft)</td>
</tr>
<tr>
<td>902</td>
<td>Ammonia, anhydrous</td>
<td>0.5m (1.6ft)</td>
<td>0.1m (0.3ft)</td>
</tr>
<tr>
<td>904</td>
<td>Ammonium nitrate</td>
<td>3m (10ft)</td>
<td>0.1m (0.3ft)</td>
</tr>
<tr>
<td>905</td>
<td>Barium nitrate</td>
<td>3m (10ft)</td>
<td>0.1m (0.3ft)</td>
</tr>
<tr>
<td>916</td>
<td>Carbon monoxide, compressed</td>
<td>3m (10ft)</td>
<td>0.1m (0.3ft)</td>
</tr>
<tr>
<td>917</td>
<td>Chlorine</td>
<td>10m (33ft)</td>
<td>0.4m (1.3ft)</td>
</tr>
<tr>
<td>922</td>
<td>Coal gas</td>
<td>3m (10ft)</td>
<td>0.1m (0.3ft)</td>
</tr>
<tr>
<td>923</td>
<td>Coal gas, compressed</td>
<td>3m (10ft)</td>
<td>0.1m (0.3ft)</td>
</tr>
<tr>
<td>926</td>
<td>Cyanogen</td>
<td>0.3m (1ft)</td>
<td>0.2m (0.7ft)</td>
</tr>
<tr>
<td>928</td>
<td>Cyanogen gas</td>
<td>0.3m (1ft)</td>
<td>0.2m (0.7ft)</td>
</tr>
<tr>
<td>943</td>
<td>Styrene</td>
<td>3m (10ft)</td>
<td>0.1m (0.3ft)</td>
</tr>
<tr>
<td>945</td>
<td>Styrene oxide with nitrogen</td>
<td>3m (10ft)</td>
<td>0.1m (0.3ft)</td>
</tr>
<tr>
<td>946</td>
<td>Nitric acid</td>
<td>3m (10ft)</td>
<td>0.1m (0.3ft)</td>
</tr>
<tr>
<td>955</td>
<td>Hydrogen cyanide, hydrosulfuric acid</td>
<td>3m (10ft)</td>
<td>0.1m (0.3ft)</td>
</tr>
<tr>
<td>958</td>
<td>Hydrogen cyanide, anhydrous</td>
<td>3m (10ft)</td>
<td>0.1m (0.3ft)</td>
</tr>
<tr>
<td>959</td>
<td>Hydrogen cyanide, alkaline</td>
<td>3m (10ft)</td>
<td>0.1m (0.3ft)</td>
</tr>
<tr>
<td>961</td>
<td>Hydrogen cyanide, solutions, with less than 20% hydrogen cyanide</td>
<td>3m (10ft)</td>
<td>0.1m (0.3ft)</td>
</tr>
<tr>
<td>962</td>
<td>Hydrogen cyanide, stabilized</td>
<td>3m (10ft)</td>
<td>0.1m (0.3ft)</td>
</tr>
<tr>
<td>963</td>
<td>Hydrogen cyanide, anhydrous</td>
<td>3m (10ft)</td>
<td>0.1m (0.3ft)</td>
</tr>
<tr>
<td>964</td>
<td>Hydrogen cyanide, hydrosulfuric acid</td>
<td>3m (10ft)</td>
<td>0.1m (0.3ft)</td>
</tr>
</tbody>
</table>

Used for transportation accidents with known material and quantity at risk.
Dispersion Models are Useful for Estimating Impacts from Major or Complex Airborne Releases

Major incidents include:
- Large industrial fires
- Major chemical spills
- Explosions
- Weapons of Mass Destruction
  - Chemical
  - Biological
  - Radiological
The Choice of Dispersion Model Depends on the Complexity and Type of Incident

- Gaussian Plume
- Gaussian Puff
- Lagrangian Particle
Characteristics:
- Fast-running
- Analytic & empirical
- Single meteorology input
- Steady-state and spatially uniform meteorology
- Simple source geometry
- Provide near-source magnitude of hazard area
- Downwind distance to 10 km

Applications:
- Planning calculations
- Real-time response

Runs on stand-alone PC
Time- and Space-Varying Meteorological Models are Employed for More Complex Dispersion Modeling Systems

- **Diagnostic**
  - Local and regional flows from *observed* meteorological data
  - Adjustment for conservation of mass
  - Empirical adjustments for terrain and thermal-stratification
  - Idealized similarity-theory parameterization

- **Prognostic**
  - *Forecast* boundary-layer and mesoscale flows (fronts, precipitation, land-sea breeze, mountain effects)
  - Assimilate observations
  - Solve conservation equations for thermodynamic energy, momentum and mass

*Expertise on local conditions resides with the National Weather Service forecast office*
Dispersion Models – Gaussian Puff

Capabilities:

• Represent plume as superposition of multiple Gaussian spatial distributions for contaminant mass
• Time- and space-varying dispersion if coupled to appropriate meteorological data
• Empirical representation of physics such as denser-than-air or urban effects

Applications:

• Real-time response
• Post-event assessment

Runs on a stand-alone PC with real-time meteorological feed
**Dispersion Models – Lagrangian Particle**

- **Capabilities:**
  - Simulation of fluid particles marked with contaminant mass
  - Fully 3-D
  - Time- and space-varying
  - Inhomogeneous flows driven by regional- or building-scale models
  - Monte Carlo stochastic dispersion

- **Applications:**
  - Real-time response
  - Post-event assessment

Runs on centralized reach-back system
An Atmospheric Dispersion Modeling System Turns a Dispersion Model into a Useful Emergency Response Tool

**Meteorology**
- Observations
- Forecasts

**Source Model**
- Point, spill, fire, explosions sprayer ...
- Plume rise

**Incident Information**
*Where, When (What, How Much)*

**Dispersion Model**
- Transport
- Turbulence and Diffusion
- Dry deposition
- Wet deposition
- Chemical transformation
- Decay

**Field Measurements**
- Air concentration
- Deposition

**Outputs**
- Air concentration
- Deposition

**Products**
- Wind fields
- Health Effect plots
- Deposition

**Electronic Distribution**
- Web & E-mail
- GIS Layers

**Supporting Databases**
- Default source terms
- Material properties
- Terrain
- Land Use
- Population
- GIS maps
- Health effects criteria
Modeling Systems Need Fast Methods of Receiving and Incorporating Field Monitoring Data to Update Plume Predictions

An initial plot may only show the downwind location only with no estimate of health effects.

A revised plot may be based on updated event data.

A few initial field measurements may be used to make an initial estimate of the amount released.

Example revised data: Updated source location, detailed weather.

Source scaled to initial set of measurements.

Cycle of new products based on updated sets of measurements.

Health-effects plot may be developed based on a source term estimated from field measurements.

When little field data are available, models take a lead role.

If extensive field data become available, that data can be used to describe effects.

More extensive sets of field measurements will improve the accuracy of the source term and health effects calculations.
Indoor Air Concentrations can be Substantially Less than Outdoors

Outdoor Plume Air Concentration

Corresponding Indoor Air Concentration

Building leakiness data may be used with Census data on residences for estimating indoor air concentrations
Building Effects and Dense Gas Releases Dramatically Change Dispersion Patterns

Density and buildings increase vertical mixing, lateral spreading near the source, and upwind dispersion, while potentially reducing downwind concentrations.
Specialized Computational Fluid Dynamics (CFD) Models Treat High-Resolution Building Flows

Capabilities:
- Spatially and temporally resolved flows around individual buildings and building groups
- Concentration fluctuations and peak concentrations

Applications:
- Pre-event planning
- Pre-computed libraries of scenarios
- Post-event assessment
Model Systems Need to be Thoroughly Tested and Evaluated

- **Analytic solutions** test model components versus known, exact results
- **Field and laboratory experiments** test models in controlled, real-world conditions

- **Operational applications** evaluate the usability, efficiency, consistency and robustness of models for operational conditions

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![Graph](image1.png)

Analytical solution vs. Numerical solution for power law wind profile and linear diffusivity.

![Graph](image2.png)

Field and laboratory experiments results.
Different Responders use Modeling Products to Assist in Making Different Emergency Response Decisions

First responders
- Determine safe approach to the incident
- Locate the incident command site
- Select personal protective equipment
- Take initial field measurements
- Control access to incident

Specialized response and support teams
- Guide field measurement and sampling teams
- Determine evacuation routes
- Estimate number of casualties or illnesses to expect for hospitals

Emergency Managers and Public Affairs Officers
- Guidance for making shelter or evacuation recommendations
- Means to communicate decisions to the public (and allay concerns)
Technical Products Need to be Based on Standard Health Effect Criteria

Example for chemical releases:

- **Red**: life threatening effects
  
  (AEGL3, ERPG3 or TEEL3)

- **Orange**: serious long-lasting effects
  
  (AEGL2, ERPG2 or TEEL2)

- **Yellow**: notable discomfort
  
  (AEGL1, ERPG1 or TEEL1)

AEGL: EPA Acute Emergency Guideline Level  
ERPG: American Industrial Hygiene Association (AIHA) Emergency Response Planning Guideline  
TEEL: DOE Subcommittee on Consequence Assessment & Protective Actions (SCAPA) Temporary Emergency Exposure Limits

Reports need to include model inputs, assumptions, and uncertainty
Public Releasable “Briefing” Products Need to Show Protective Action Recommendations in a Simple and Straightforward Manner

Example Shelter-in-Place Maps based on Dispersion Model Calculations
Summary: For Major Releases, Dispersion Modeling Systems Transform Incident Information into Actionable Information

**Incident Information**
- Meteorological data
- Source information (release time, location, height, material …)
- Measurement data and observations

**Dispersion Modeling System**
- Release mechanism models (spills, fires, explosions …)
- Meteorological model (steady-state, 3-D wind field, forecast)
- Transport and dispersion model

**Actionable Information**
- Hazard areas
- Health effect levels based on public exposure guidance
- Exposed populations (casualty and fatality estimates)
- Protective action guidance
- Planning and consequence assessments