Atmospheric dispersion knowledge gaps and research priorities: Results from a recent survey of ADMLC members

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Overview

- Background to the ADMLC
- Aims
- Survey questions
- Interests and activities of ADMLC members
- Knowledge gaps and other issues
- Summary
Background to ADMLC

- **1977**: Representatives of UK government departments, utilities and research organisations met to discuss calculation methods for atmospheric dispersion of radioactive releases
  - Informal steering committee formed to review recent developments in dispersion modelling (predecessor to ADMLC)
- **1995**: ADMLC formally formed with an initial focus on the nuclear industry
- **Since 1995**:
  - Focus widened to include range of interests of its members, including UK and Irish industrial and regulatory organisations
  - **Aim**: to review atmospheric dispersion and related phenomena for application primarily to authorization or licensing of discharges to atmosphere resulting from industrial, commercial or institutional sites
  - Main interests on fixed sources, rather than transport sources, including both routine releases and releases in accident or “upset” conditions
Background to ADMLC

Current membership:

- AWE
- dstl
- Met Office
- HSE
- SEPA
- EPA
- defra
- Food Standards Agency
- Environment Agency
- Public Health England
- Office for Nuclear Regulation
Background to ADMLC

• ADMLC Committee meetings held 3 times per year
• Each member organization contributes £3k each year
• ADMLC public workshop/seminar every 2 to 3 years
• Small research projects commissioned, e.g.:
  – Modelling pollutant dispersion from non-point sources (2016)
  – Presenting uncertain information in radiological emergencies (2016)
  – Sensitivity of dispersion modelling results to source terms (2017)
  – Dispersion modelling of odour emissions (ongoing)
• New Projects:
  – Applicability of Gaussian modelling techniques to near-field dispersion
  – Dense-gas dispersion for industrial regulation and emergency response
• Dispersion model validation datasets, e.g. Thorney Island
• Reports and datasets publicly available: http://www.admlc.com
Aims

• Conduct survey amongst the ADMLC committee members to:
  – Identify common interests
  – Prioritise future ADMLC research

• Originally intended as ADMLC internal discussion

• Objective of disseminating more widely at Harmo’19:
  – Engage with other stakeholders and research organisations
  – Raise awareness of knowledge gaps
  – Encourage discussion of issues and collaboration
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Survey Questions

ADMLC members asked to complete a questionnaire on:

“Primary areas of interest in the field of atmospheric dispersion modelling”

Three headings:

- Area of interest
- How mature is the topic
- Problem to solve / what is hindering the solution?

Example:

<table>
<thead>
<tr>
<th>Area of interest</th>
<th>How mature is the topic</th>
<th>Problem to solve / what is hindering application of solution</th>
</tr>
</thead>
</table>
| **Local-scale dispersion** (5 m to 5 km range):  
  • Dense/passive/buoyant gases  
  • Flammable/toxic substances  
  • Multi-component gases  
  • Water-reactive substances  
  • Terrain/obstacle effects  
| Many field-scale trials undertaken since 1970’s  
  • Various Gaussian, integral, shallow-layer, Lagrangian and CFD models developed/validated  
  • Models in widespread use for risk assessment  
  • Uncertainties still remain, particularly in: terrain/obstacle effects and water-reactive substances |  
  • Lack of validation data for terrain/obstacle effects  
  • Lack of data for low/nil wind speeds  
  • Uncertainties for reactive substances (for deposition effects – see below) |
| **Complex source terms, e.g.**  
| Many experiments conducted since 1970’s, primarily |  
  • Lack of validation data for larger-scale releases |
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Interests and activities of ADMLC members

Grouping of topics used on later slides:

- **Dispersion modelling scale** (indoor, local, regional, global)
- **Hazard** (e.g. air quality, chemical, biological, radiological)
- **Consequences** (e.g. acute effects, long term effects, odour)
- **Tasks** (e.g. emergency response, source attribution, permitting)
- **Substance of interest** (e.g. gas, particulate, liquid aerosol)
- **Source terms** (e.g. stack emission, fire, spray, evaporating pool)
- **Physics** (e.g. dense, passive, dry deposition, atmospheric chemistry)
- **Models used** (e.g. Gaussian, Lagrangian, CFD)
Interests and activities of ADMLC members

Dispersion modelling scale

<table>
<thead>
<tr>
<th>Scale</th>
<th>Indoor</th>
<th>Local</th>
<th>Regional</th>
<th>Global</th>
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<td><img src="image3" alt="Bar chart" /></td>
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</tbody>
</table>

Hazards

<table>
<thead>
<tr>
<th>Hazard</th>
<th>Air Quality</th>
<th>Chemical</th>
<th>Biological</th>
<th>Nuclear/Rad.</th>
<th>Other</th>
</tr>
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<tbody>
<tr>
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<td><img src="image6" alt="Bar chart" /></td>
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<td><img src="image8" alt="Bar chart" /></td>
<td><img src="image9" alt="Bar chart" /></td>
</tr>
</tbody>
</table>

Consequence

<table>
<thead>
<tr>
<th>Consequence</th>
<th>Acute CBRN</th>
<th>Flammable</th>
<th>Health</th>
<th>Odour</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><img src="image10" alt="Bar chart" /></td>
<td><img src="image11" alt="Bar chart" /></td>
<td><img src="image12" alt="Bar chart" /></td>
<td><img src="image13" alt="Bar chart" /></td>
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Task

<table>
<thead>
<tr>
<th>Task</th>
<th>Emergency response</th>
<th>Source attribution</th>
<th>Incident investigation</th>
<th>Land-use/emerg.plan</th>
<th>Permitting</th>
<th>Industry consultancy</th>
<th>Regulatory enforcement</th>
</tr>
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<tbody>
<tr>
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<td><img src="image15" alt="Bar chart" /></td>
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<td><img src="image19" alt="Bar chart" /></td>
<td><img src="image20" alt="Bar chart" /></td>
</tr>
</tbody>
</table>

Vertical scales shows number of ADMLC member organisations with interest in that topic.
Interests and activities of ADMLC members

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Knowledge Gaps and Other Issues

Grouping of topics used on later slides:

- **Modelling improvements** (e.g. source terms, complex physics)
- **Validation** (e.g. datasets needed, model evaluation exercises)
- **Logistics** (e.g. access to certain information)
- **Sensitivity/uncertainty** (e.g. understanding the effects of input variability)
- **Guidance** (e.g. good practice for air-quality models)
- **Communication** (e.g. presenting results to decision-makers and the public)

Total of 83 separate issues raised

40 issues alone under the heading of “modelling improvements”
Modelling Improvements Needed

• **Gaussian models**
  - Improve downwash effects (currently under-predicted)
  - Improve modelling of wake and cavity regions
  - Improve modelling of sources within complex obstacle arrangements
  - Comparison of Gaussian to Lagrangian models for societal risk
  - Modelling of calm conditions

• **Dense-gas models**
  - Investigate simple dense-gas dispersion models for emergency response
  - Review past incidents to understand trends and characterise model inputs
  - Models for dense gas dispersion in low/nil-wind speeds (not full CFD)
  - Interaction of dense gas with complex meteorology

Horizontal scales shows number of ADMLC member organisations with interest in that topic
Modelling Improvements Needed

• CFD
  – Improve modelling of atmospheric boundary layers with RANS
  – Reduce financial costs of software and computing
  – Reduce runtimes
  – Improve user repeatability
  – More consistent validation for wider range of experiments

• Indoor/infiltration models
  – Develop models for non-fully-mixed rooms, stratification, sedimentation
  – Improve modelling of ventilation systems
  – Definition of inlets/outlets and external pressures
  – Air change rates in naturally-ventilated buildings
  – Dispersion in large indoor spaces, e.g. shopping malls
  – Benchmarking of the PHE infiltration tool INGRESS
Modelling Improvements Needed

• Meteorological models
  – Boundary layer, urban processes, precipitation, turbulence

• Source terms
  – Explosive source terms
  – Spreading evaporating pools, flashing jet sources
  – Fire source terms and plume rise (landfill, chemical, nuclear)
  – Fire source modification from intervention (e.g. water spray, digging out)
  – Definition of sources in an emergency, with limited information

• Complex physics
  – Models for deposition and sorption (including saturation effects)
  – Dispersion in coastal areas with sea breezes
  – Temporal variability of radionuclides in different chemical forms
Modelling Improvements Needed

- Inverse models and data assimilation
  - Simple models for identifying sources based on public complaint data
  - Quantifying measurement uncertainty effects on outputs
  - Mathematical frameworks for optimal solution

- Toxic effects
  - Uncertainty in toxic load models
  - Concentration fluctuation effects
  - Extrapolation from animal studies to humans
  - Assessing effect of variability in human population
  - Definition of toxic effects for landfill fire, chemical fire
  - Annual average dose calculations: evaluate the benefits of using the Met Office NAME Lagrangian model
Modelling Improvements Needed

- Other
  - Modelling psycho-social/behavioural aspects for shelter-in-place advice (response, compliance, effectiveness of action)
  - Use of dispersion models to help design sensor networks and to interpret their data
Validation

Experimental data needed for:

- Dispersion from explosive releases in different environments
- Near-field dispersion
- Terrain/obstacle effects
- Low/nil wind speeds
- Urban stability effects
- Deposition (wet/dry)
- Sorption on/in buildings
- Material degradation (e.g. photolysis)
- Dispersion during precipitation, fog etc.
- Infiltration from outdoor to indoor environments
- Indoor dispersion with buildings
- Toxic effects, especially with fluctuating concentrations
- Volcanic sources
- Large (field-scale) dispersion studies
Validation

Model evaluation

- Datasets need to be organised / coordinated
- Source model evaluation protocols needed, including validation database
- Standards for assessing different types of model performance needed for different classes of models, e.g. source models (FAC2, MG, VG criteria?)
Logistics

• Improved access needed to:
  – Meteorological data
  – Obstacle/terrain geometry data
  – Building information (for infiltration and population)
  – Traffic data
  – Regulated emission source data
  – Monitoring data
Guidance

• Air quality models
  – Sharing of good practice for air quality models, nationally and in urban areas

• Odour modelling
  – Guidance on modelling and assessing uncertainties

• Shelter-in-place advice
  – Guidance on where best to shelter within a building
Sensitivity/Uncertainty

- Assessing uncertainty (general)
- Nuclear emergency preparedness
- Receptors near to the source
- Understanding effects of source term uncertainties
- Multiple point sources
- Understanding the effects of meteorological uncertainties
- Uncertainties when assimilating data from both models and measurements in emergency response
- Frameworks for efficiently sampling uncertainty space
Communication

- Communication with nuclear emergency response decision makers
- Cases with complex urban terrain, where results are difficult to interpret
- Public usage and interpretation
- Clear lexicon of language: input from statistics and comms experts
- Presenting probabilistic estimates of exposure/uncertainty
- Integrating outputs with GIS systems, also with other datasets e.g. measurements from third-parties
- Development of scenario-based guidelines for representative fire/chemical incidents with protective action distances
- Interfacing dispersion models with impact and decision-making models
- Production of indoor-at-risk maps (evolving over time) to complement outdoor risk maps for shelter-in-place advice
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• Top four topics for future ADMLC research projects?
  1. Deposition modelling
     • Review of dry/wet deposition modelling of gases and particulates
  2. Modelling of sources in an emergency
     • When there is limited information available
  3. Fire source terms and plume rise
     • Including landfill, chemical and nuclear fires
  4. Understanding the impact of meteorological uncertainties
     • Partnership with other funding agencies or self-funding research organisations on topics of mutual interest?
     • ADMLC seminar at PHE, Harwell, UK in autumn/winter 2019
     • Come and talk to us
Thank you

This work was funded by each of the respective ADMLC contributor’s organisations. The contents, including any opinions and/or conclusions expressed, are those of the authors alone and do not necessarily reflect the policy of those organisations.

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