Overview of HSE's approach to dispersion modelling of major accident hazards in Great Britain

Refinery and Chemical Industry Emissions Symposium (RACIE)
UC Davis, California, 6-8 November 2019

Simon Gant[1]*, Harvey Tucker[1], Graham Tickle[2], Simon Coldrick[1] and Mike Wardman[1]

[1] UK Health and Safety Executive (HSE)

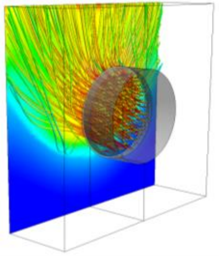
[2] GT Science & Software

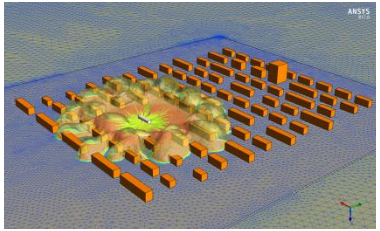
Outline

- Background
- UK regulatory context and HSE's roles
  - Control of Major Accident Hazards (COMAH)
  - Land-use planning
- Other HSE activities
- Dispersion modelling tools and applications
- Recent research
- Challenges and knowledge gaps

HSE Science & Research Centre

- Multi-disciplinary laboratory:
  - Fire and process safety
  - Computational modelling
  - Exposure control
  - Toxicology etc.
- Approx. 400 staff
- 550 acre test site
- Fire galleries and burn hall
- Impact track
- Anechoic chamber
- Thermal test chamber





Control of Major Accident Hazards (COMAH) regulations

- **Aim**: Prevent or mitigate the impact of major accidents from industrial processes that could harm people and/or the environment
- Duties for Site Operators, Competent Authority, Local Authority/ Emergency Services
- Higher risk "Upper Tier" Site Operators must prepare a Safety Report that demonstrates their understanding of the hazards and the potential consequences of a major accident (performance-based regulation)

© SFEPA (Syndicat des Fabricants d'Explosifs, de Pyrotechnie et d'Artifices)

Enschede, Netherlands (2000)
23 killed, 1000 injured

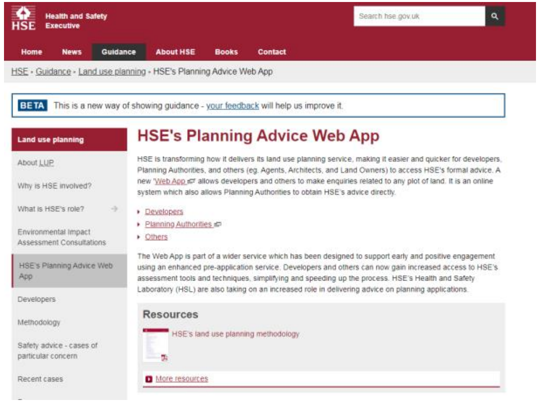
Source: http://dx.doi.org/10.1016/j.jhazmat.2004.02.039

Toulouse, France (2001)
30 killed, 2242 injured, $1.6 billion

Buncefield, UK (2005)
0 killed, 43 injured, $1.3 billion

Land-Use Planning Legislation

- Aim: To manage population growth around major hazard sites and help mitigate the consequences of major accidents
- HSE's roles:
  - Hazardous substances consent
  - Advice on land-use planning to planning authorities and property developers



HSE provides three-zone maps of residual risk for:
- Around 2,000 major hazard sites
- 28,000 km of major accident hazard pipelines

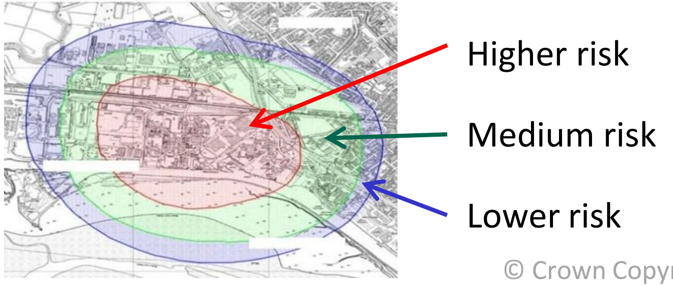


Figure for illustration purposes only

Dispersion modelling for land-use planning

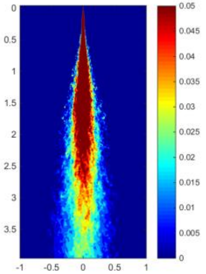
- Simulations performed by HSE using the DRIFT dispersion model
- Dispersion modelling scenarios chosen based on maximum inventory of hazardous substances that an operator is permitted to have onsite by virtue of their hazardous substances consent
  - Generic classes of hazardous substances (acute toxic, flammable gas etc.)
  - Named hazardous substances (chlorine, carbonyl dichloride, phosphine, etc.)
  - Catastrophic releases and range of hole sizes, based on failure frequency model, depending on vessel type
- Weather: four categories (D2.4, D4.3, D6.7 and F2.4) and wind directions with probabilities assigned from Met Office weather data near the major hazards site
- Obstructions (e.g. buildings) modelled as surface roughness
- Three-zone maps defined by HSE will typically remain the same for the duration of the operations on the major hazards site, which can be 20 – 30 years

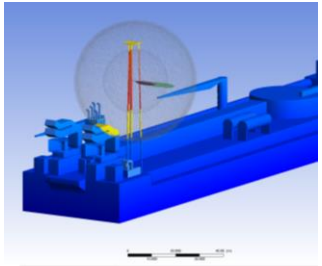
Outline

- Background
- UK regulatory context and HSE's roles
  - Control of Major Accident Hazards (COMAH)
  - Land-use planning
- Other HSE activities
- Dispersion modelling tools and applications
- Recent research
- Challenges and knowledge gaps

Other HSE Science Activities

- Incident investigations
  - e.g. Buncefield, Bosley Mill explosion
- Input to guidance and standards
  - e.g. Energy Institute EI15 (area classification)
- Research
  - Support to Jack Rabbit II chlorine release experiments
  - Review of vapor cloud explosion incidents
- Consultancy
  - Maersk Oil GP3 FPSO ignition incident investigation
  - JIP on flammable mists of high-flashpoint fluids





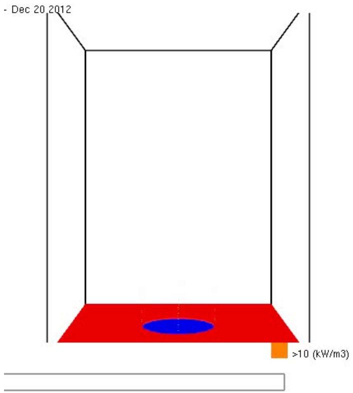
Outline

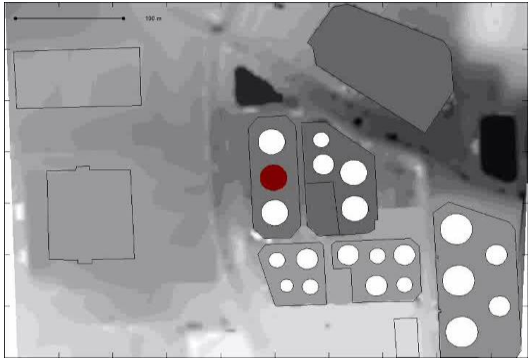
- Background
- UK regulatory context and HSE's roles
  - Control of Major Accident Hazards (COMAH)
  - Land-use planning
- Other HSE activities
- Dispersion modelling tools and applications
- Recent research
- Challenges and knowledge gaps

Dispersion Modelling Tools

- Integral dispersion models
  - ESR Technology **DRIFT**
  - DNV GL **PHAST**
- Computational Fluid Dynamics (CFD)
  - Ansys **CFX**, **Fluent**, **Autodyn**
  - NIST Fire Dynamics Simulator (**FDS**)
  - GexCon **FLACS**
- Source models (examples)
  - **GASP** evaporating spills
  - **PiRRaM** pipeline model

- Other tools developed by HSE
  - **Quadvent** simple model for jets and plumes in ventilated rooms
  - **SPLOT** shallow-layer model for liquid spills



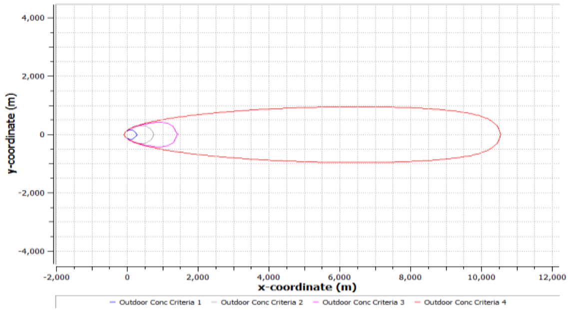


DRIFT integral dispersion model

- **D**ispersion of **R**eleases **I**nvolving **F**lammables or **T**oxics (DRIFT)
- Originally developed by UK Atomic Energy Authority (UKAEA) in late 1980's
- Developed with support from HSE over last 30 years
- Capabilities:
  - Passive, buoyant and dense gas dispersion
  - Instantaneous, steady, time-varying releases
  - Two-phase flashing releases, droplet evaporation
  - Condensation of atmospheric water vapor (HF, ammonia)
  - Rainout and pool evaporation (using GASP)
  - Along-wind diffusion effects
- Validated using the NFPA LNG Model Evaluation Protocol

ESR Technology
Engineering, Safety & Risk

GT Science & Software



Outline

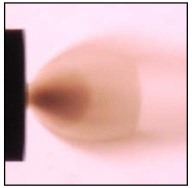
- Background
- UK regulatory context and HSE's roles
  - Control of Major Accident Hazards (COMAH)
  - Land-use planning
- Other HSE activities
- Dispersion modelling tools and applications
- Recent research
- Challenges and knowledge gaps

Recent Research

- Indoor hydrogen leaks, vented deflagrations, hydrogen fires in confined spaces (HyIndoor)
- Hydrogen refuelling stations (HyApproval)
- Stationary hydrogen and fuel cell applications (HyPER, H2FC)
- Hydrogen release, dispersion, fire and explosion model evaluation (Susana)
- Fire testing on composite hydrogen cylinders (FireComp)
- Hydrogen in the gas distribution network (H21, HyDeploy, Hy4Heat, H100)
- Flame-out and re-ignition of hydrogen-powered gas turbines (ETI High Hydrogen)
- Carbon capture and storage (CO_2PipeHaz, COOLTRANS)





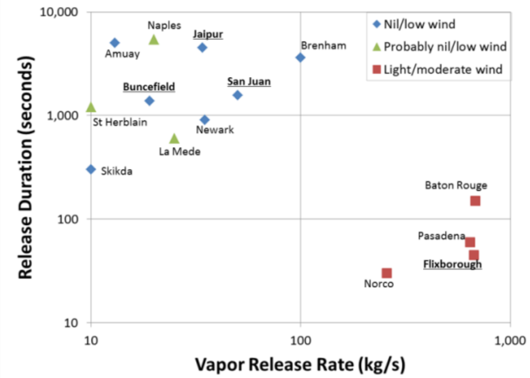



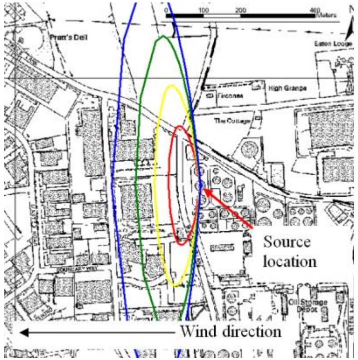

Outline

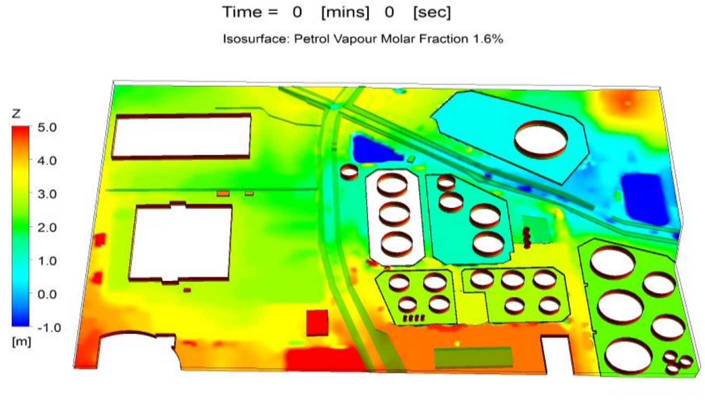
- Background
- UK regulatory context and HSE's roles
  - Control of Major Accident Hazards (COMAH)
  - Land-use planning
- Other HSE activities
- Dispersion modelling tools and applications
- Recent research
- Challenges and knowledge gaps

Knowledge Gaps and Challenges

- Dense-gas dispersion in low/zero wind speeds
  - Common factor in severe vapor cloud explosion incidents
  - Cannot use common integral models, e.g. Phast
  - Terrain effects/vapor fences potentially important
  - Full CFD is costly, complex, user-variability issues
- CFD modelling of atmospheric dispersion







Knowledge Gaps and Challenges

- Atmospheric Dispersion Modelling Liaison Committee www.admlc.com
- Prioritisation exercise in 2019 ranked the top four topics for future ADMLC research projects
  1. Deposition modelling
  2. Modelling of sources in an emergency
  3. Fire source terms and plume rise
  4. Understanding the impact of meteorological uncertainties
- Partnership with other funding agencies on topics of mutual interest?
- ADMLC seminar on emergency planning and response, Harwell, UK, 12 March 2020

Acknowledgements

Thanks to:

- Co-authors: Harvey Tucker, Graham Tickle, Simon Coldrick and Mike Wardman
- Enschede incident image © SFEPA (Syndicat des Fabricants d'Explosifs, de Pyrotechnie et d'Artifices)
- INERIS for use of the AZF Toulouse incident photo http://dx.doi.org/10.1016/j.jhazmat.2004.02.039
- TOTAL E&P UK for use of the GP3 FPSO photo
- Sponsors: Maersk Oil, Mists JIP sponsors, H21, HyDeploy, ETI High Hydrogen
- ADMLC Members
- RACIE conference organisers

The contents, including any opinions and/or conclusions expressed, are those of the authors alone and do not necessarily reflect HSE policy, or those of other funding organisations.

Extra Material

COMAH: Duties for Operators

Operators of industrial sites handling hazardous substances must:

- Take all reasonably practicable measures necessary to prevent major accidents and limit their consequences (performance based, not standards-driven)
- Prepare a Major Accident Prevention Policy (MAPP) and implement it through a Safety Management System
- Provide information to the Competent Authority and the Public

COMAH: Duties for Operators

Higher-risk “upper tier” COMAH sites must:

- Prepare a Safety Report to:
  - Demonstrate that a MAPP and SMS have been put into effect
  - Demonstrate adequate safety and reliability in design, construction, operation and maintenance
  - Present the emergency plan
- Review Safety Report every 5 years
- Cooperate with neighbouring domino-effect sites

COMAH: Duties for Competent Authority and Local Authority/Emergency Services

HSE

Competent Authority

- Examine the Safety Report
- Prohibit operation if prevention and mitigation measures are seriously deficient
- Inspect establishments and investigate major accidents
- Involves HSE, Environment Agency, Scottish Environmental Protection Agency, Natural Resources Wales, and Office for Nuclear Regulation

Local Authority/Emergency Services

- Prepare and implement an off-site emergency plan based on information provided by the Operator
- Consult with relevant agencies, authorities (e.g. health) and the public
- Participate in tests of external emergency plan

Links to some relevant information

- NFPA LNG Model Evaluation Protocol
  - https://www.nfpa.org/News-and-Research/Data-research-and-tools/Hazardous-Materials/LNG-model-evaluation-protocol-and-validation-database-update
- DRIFT model validation
  - http://www.hse.gov.uk/research/rrhtm/rr1100.htm
- Gant S.E. and Tucker, H (2018) "CFD modelling of atmospheric dispersion for land-use planning around major hazards sites in Great Britain", Journal of Loss Prevention in the Process Industries, 54, p340-345 (https://doi.org/10.1016/j.jlp.2018.03.015)
- Gant S.E., Weil J., Delle Monache L., McKenna B., Garcia M.M., Tickle G., Tucker H., Stewart J., Kelsey A., McGillivray A., Batt R., Witlox H. and Wardman M. (2018) "Dense gas dispersion model development and testing for the Jack Rabbit II Phase 1 Chlorine Release Experiments", Atmospheric Environment, 192, p218-240 (https://doi.org/10.1016/j.atmosenv.2018.08.009)