Atmospheric Dispersion Modelling
Liaison Committee (ADMLC)

PROTECTING PEOPLE
AND PLACES

HSE

Atmospheric dispersion projects at HSE and the ADMLC

Simon Gant

Fluid Dynamics Team, Health and Safety Executive (HSE) Science and Research Centre, Buxton, UK

ADMS User Group Meeting, 29 November 2023, York, UK

Overview

- Introduction to HSE
- HSE research activities
  - Jack Rabbit III
  - Skylark
  - Hydrogen
  - MODISAFE
- Introduction to ADMLC
- ADMLC projects
  - Effect of NWP resolution
  - Model evaluation
- ADMLC future events
  - Katabatic flows webinar
  - Wildfires webinar

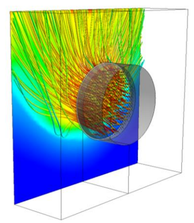
Introduction to HSE

- HSE is the UK regulator for workplace health and safety
  - Includes onshore/offshore pipelines, chemical/oil/gas infrastructure, offshore platforms etc.
  - Activities: evidence gathering, policy development, consultation, regulation, incident investigation, enforcement
  - HSE acts as an enabling regulator, supporting the introduction of new technologies
  - 2,400 total staff
  - £230M ($280M) budget: 60% from Government, 40% from external income

- HSE Science and Research Centre, Buxton, UK
  - 400 staff, 550 acre test site
  - Scientific support to HSE and other Government departments
  - “Shared research” or joint-industry projects co-funded by HSE
  - Bespoke consultancy on a commercial basis





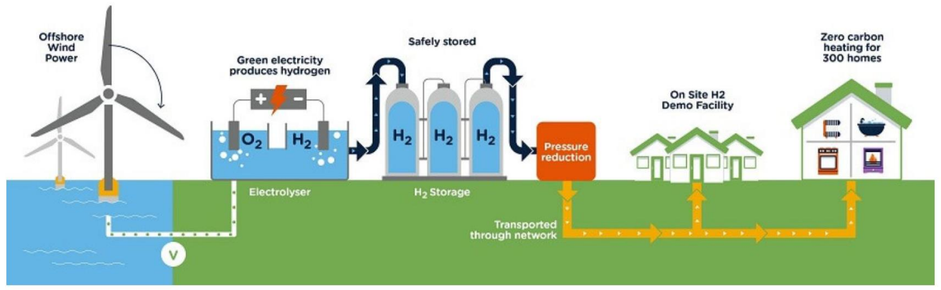


HSE Research Activities: Motivation

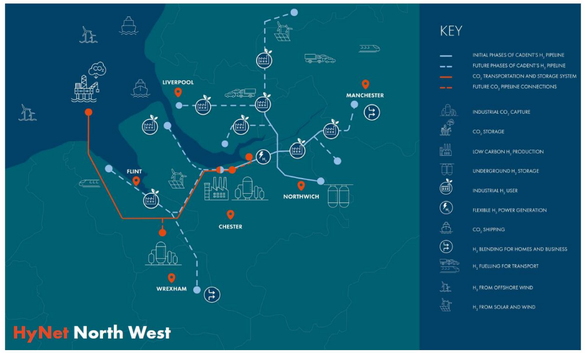
- Net Zero: hydrogen, ammonia and Carbon Capture and Storage (CCS)

H100 Fife

https://www.h100fife.co.uk/



New green project set to heat Fife homes



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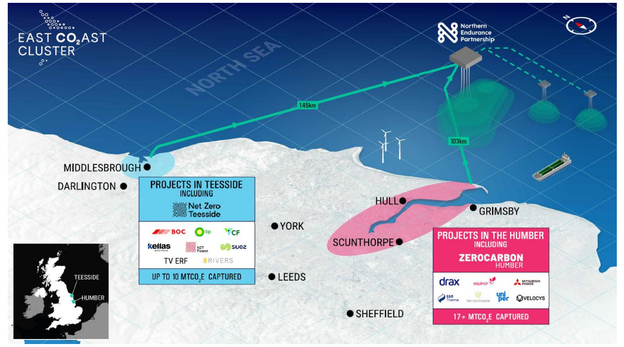


https://eastcoastcluster.co.uk/

https://www.neom.com

World's first full scale ammonia engine test - an important step towards carbon free shipping

Wärtsilä Corporation, Trade press release, 30 June 2020 at 10:01 UTC+2

https://www.wartsila.com/

Ammonia flagged as green shipping fuel of the future

Marine operators are looking to clean up their act

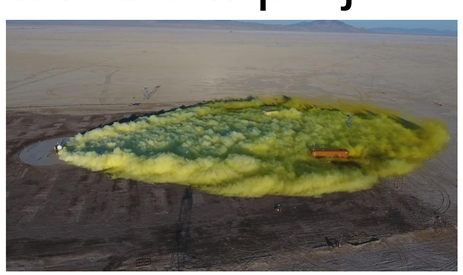
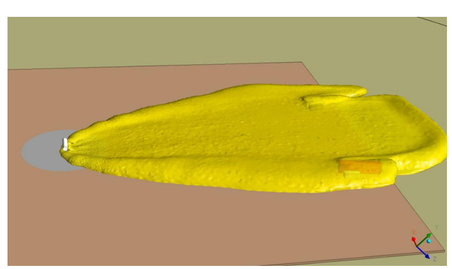
Adaptive behaviour: the Viking Energy supply vessel which is planned to run on ammonia fuel cells

Charlotte Middlehurst MARCH 30 2020

https://www.ft.com/content/2014e53c-531f-11ea-a1ef-da1721a0541e

HSE Research Activities: Jack Rabbit III

- Continuation of earlier Jack Rabbit I and II projects on ammonia and chlorine

https://www.uvu.edu/es/jack-rabbit/ © Images copyright DHS S&T CSAC and UVU

- Aim: to conduct large-scale ammonia release experiments and improve our understanding of dispersion behaviour, hazards and emergency response
- Initial work: lab-scale dry deposition experiments at University of Arkansas
- Further indoor release experiments currently in planning stage
- Target of 2026-2027 for large-scale outdoor trials (multiple tons releases)
- SINTEF SafeAM project is studying small ammonia spills on water (lab-scale)
- French ARISE project is studying large ammonia spills at sea

Jack Rabbit III Model Inter-Comparison Exercise

- Aim: to assess performance of dispersion models against existing field-scale ammonia dispersion data
- Exercise coordinated by HSE/Joe Chang in 2020-2022
- Three trials each from the Desert Tortoise and FLADIS
- Desert Tortoise
  - Tests conducted in 1983 at DOE Nevada Test Site
  - Release rates of 81 – 133 kg/s
  - 10 – 41 tonnes of ammonia released
  - Dispersion measurements at 100 m and 800 m
  - Largest tests to date on ammonia
- FLADIS
  - Tests conducted in 1993-4 at Landskrona, Sweden
  - Release rates of 0.25 – 0.55 kg/s
  - Dispersion measurements at 20 m, 70 m and 240 m (transition from dense to passive dispersion)

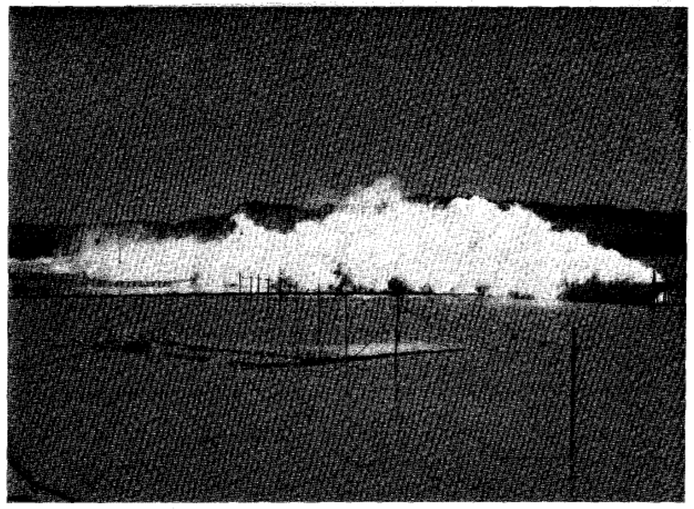
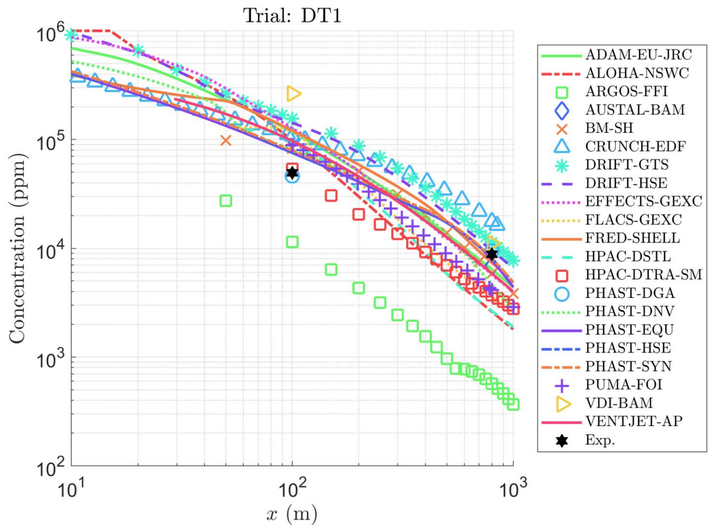


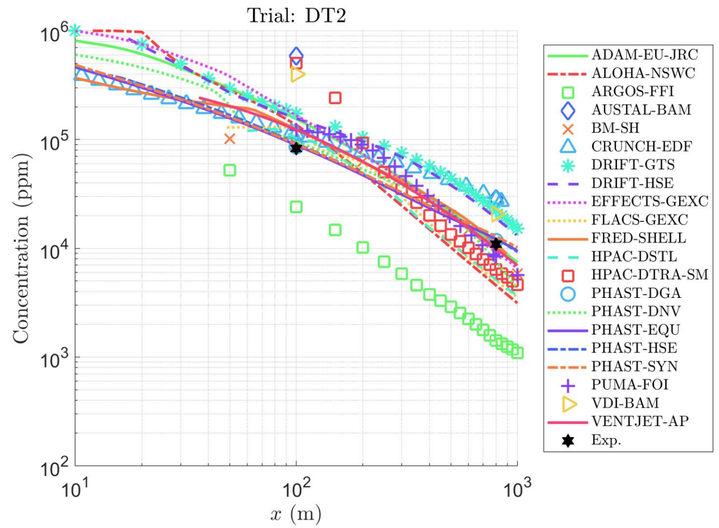
Fig. 15. Desert Tortoise 2 (upwind wide angle camera) Time = 230s. Lawrence Livermore National Laboratory

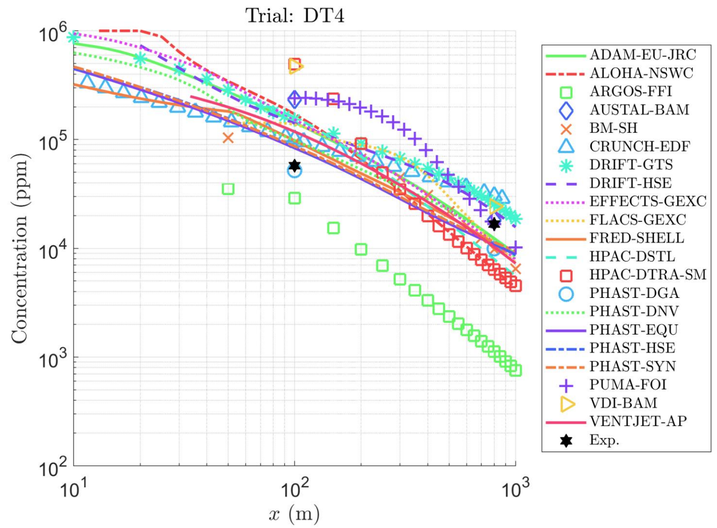
Participants in Desert Tortoise and FLADIS exercise

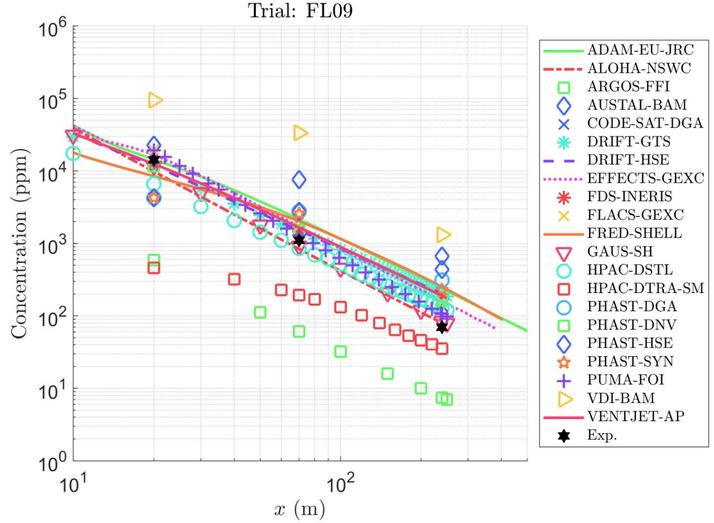
#	Organization	Model	Model Type				Desert Tortoise			FLADIS		
			Empirical nomogram/ Gaussian plume	Integral	Gaussian Puff/ Lagrangian	CFD	1	2	4	9	16	24
1	Air Products, USA	VentJet		■			■	■	■	■	■	■
2	BAM, Germany	AUSTAL			■		■	■	■	■	■	■
3		VDI	■				■	■	■	■	■	■
4	DGA, France	PHAST v8.6		■			■	■	■	■	■	■
5		Code-Saturne v6.0				■				■	■	■
6	DNV, UK	PHAST v8.61		■			■	■	■	■	■	■
7	DSTL, UK	HPAC v6.5			■		■	■	■	■	■	■
8	DTRA, ABQ, USA	HPAC v6.7			■		■	■	■	■	■	■
9	DTRA, Fort Belvoir, USA	HPAC			■		■	■	■	■	■	■
10	EDF/Ecole des Ponts, France	Code-Saturne v7.0				■					■	
11		Crunch v3.1		■			■	■	■			
12	Equinor, Norway	PHAST v8.6		■			■	■	■	■	■	■
13	FFI, Norway	ARGOS v9.10			■		■	■	■	■	■	■
14	FOI, Sweden	PUMA			■		■	■	■	■	■	■
15	Gexcon, Netherlands	EFFECTS v11.4		■			■	■	■	■	■	■
16	Gexcon, Norway	FLACS				■	■	■	■	■	■	■
17	GT Science & Software	DRIFT v3.7.19		■			■	■	■	■	■	■
18	Hanna Consultants, USA	Britter & McQuaid WB	■				■	■	■			
19		Gaussian plume model	■							■	■	■
20	HSE, UK	DRIFT v3.7.12		■			■	■	■	■	■	■
21		PHAST v8.4		■			■	■	■	■	■	■
22	INERIS, France	FDS v6.7				■				■	■	■
23	JRC, Italy	ADAM v3.0		■			■	■	■	■	■	■
24	NSWC, USA	RAILCAR-ALOHA		■			■	■	■	■	■	■
25	Shell, UK	FRED 2022		■			■	■	■	■	■	■
26	Syngenta, UK	PHAST v8.61		■			■	■	■	■	■	■

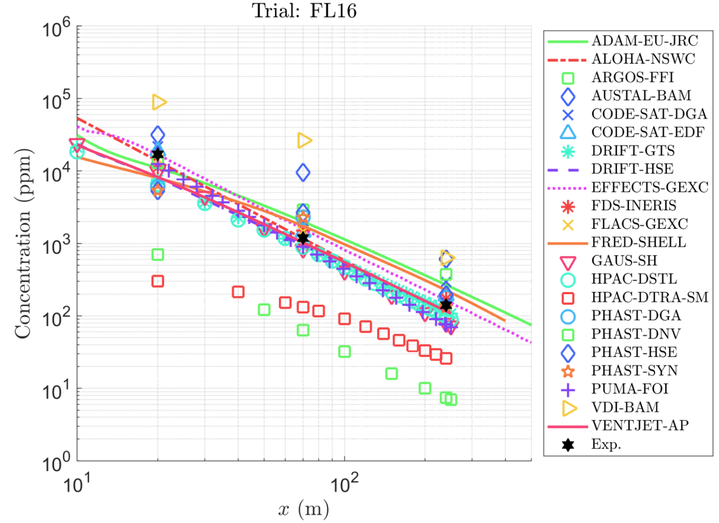
Desert Tortoise and FLADIS: Model Results

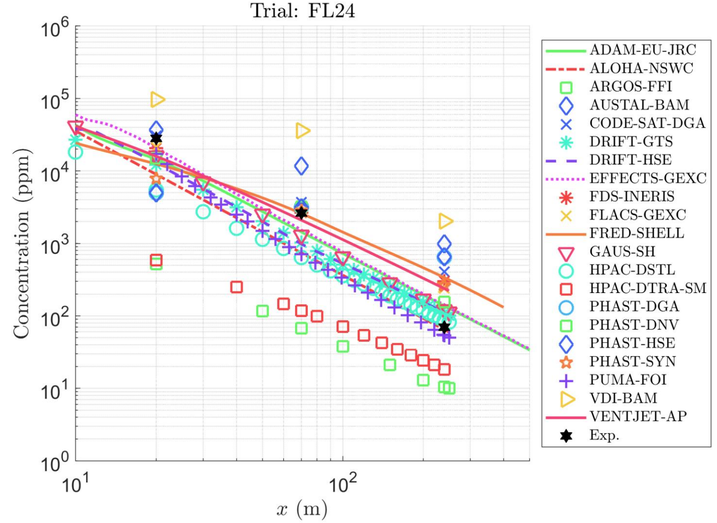












Satartia CO_2 pipeline incident, 2020

- Failure of Denbury 24-inch CO_2 pipeline near Satartia, Mississippi due to landslide
- Dense CO_2 cloud rolled downhill and engulfed Satartia village, a mile away
- Approximately 200 people evacuated and 45 required hospital treatment
- Communication issues: local emergency responders were not informed by pipeline operator of the rupture and release of CO_2
- Denbury's risk assessment did not identify that a release could affect the nearby village of Satartia

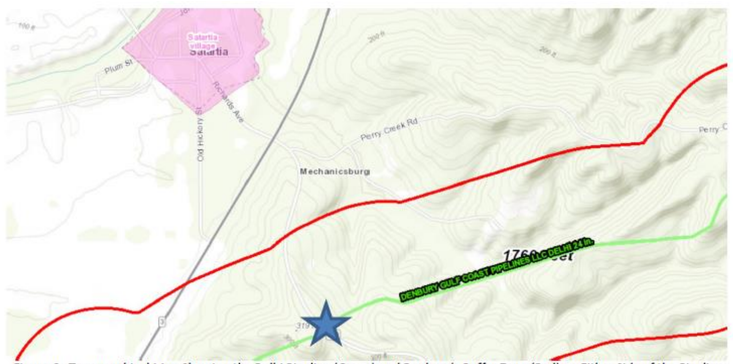
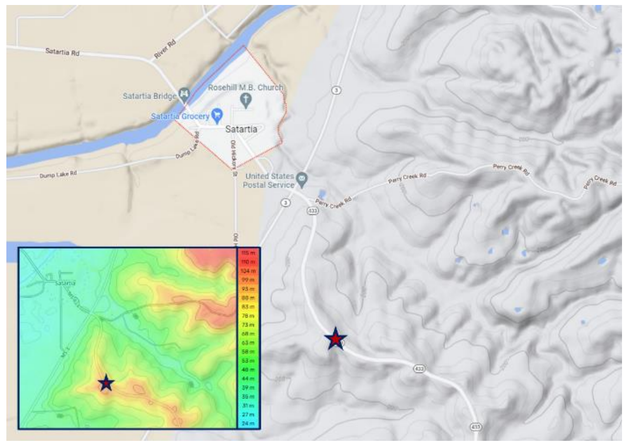


Figure 6: Topographical Map Showing the Delhi Pipeline (Green) and Denbury's Buffer Zone (Red) on Either Side of the Pipeline and the Proximity to Satartia (Blue Star Indicates the Rupture Site)



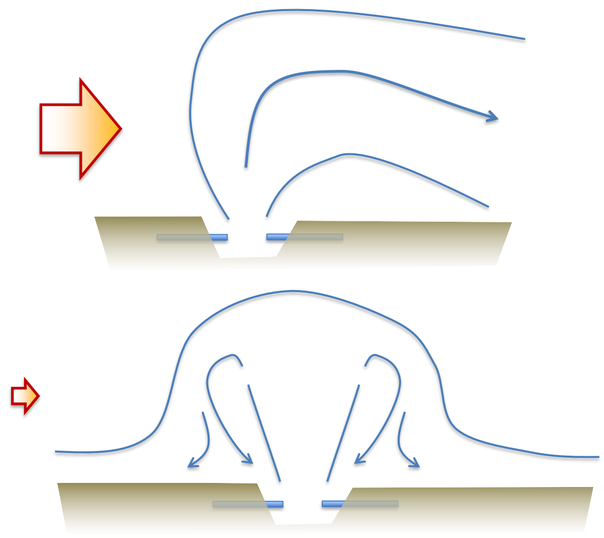
Terrain map taken from Google Maps and contour map taken from topographic-map.com. Approximate location of release marked by a star.

Image sources: Yazoo County Emergency Management Agency/Rory Doyle for HuffPost and PHMSA

- https://www.huffingtonpost.co.uk/entry/gassing-satartia-mississippi-co2-pipeline_n_60ddea9fe4b0ddef8b0ddc8f
- https://www.phmsa.dot.gov/sites/phmsa.dot.gov/files/2022-05/Failure%20Investigation%20Report%20-%20Denbury%20Gulf%20Coast%20Pipeline.pdf

Skylark CO_2 Dispersion Joint Industry Project

- Aims:
  - Undertake field-scale and wind-tunnel experiments to improve our understand of CO_2 dispersion from pipelines (including releases from craters and vents)
  - Coordinate model validation activities using the new experimental data
  - Help prepare emergency responders to deal with possible CO_2 release incidents
- Delivery partners: DNV, University of Arkansas, HSE, Hanna, Chang and Tickle
- Budget: ~ £10m, starting summer 2024 for 3 years



© National Grid / DNV

Fig. 4. The visible cloud at 10 s (top), 30 s and 120 s (bottom) after the rupture.

http://dx.doi.org/10.1016/j.ijggc.2015.04.001

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HSE Research Activities: Hydrogen

Hydrogen pipeline purging

N.C. Daish and P.F. Linden

September 1991

A MODEL OF GAS/AIR PIPE PURGING

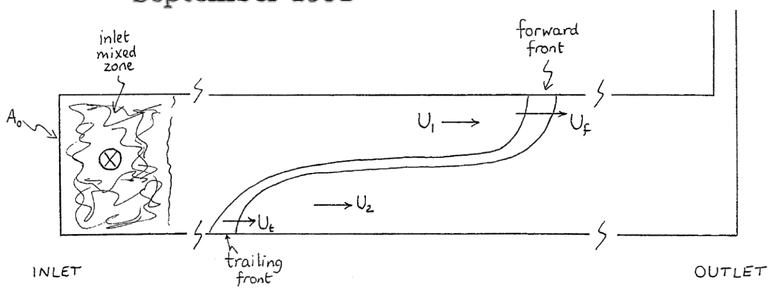
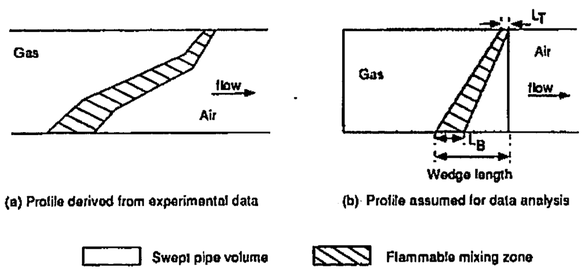


Figure 1:
Shape of gas-air mixing zone formed during direct purging

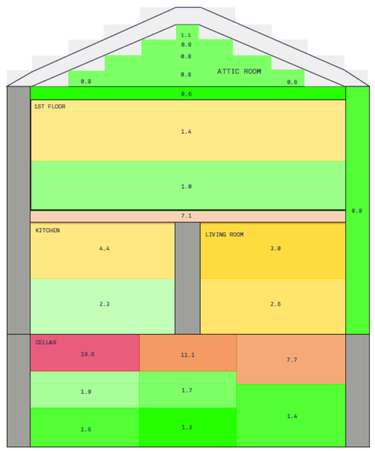


Dr. M. R. Marshall, Dr. R. P. Cleaver and C. L. Hinsley
British Gas Plc, UK

© DNV

Hydrogen tracking through the ground, dispersion in buildings

https://www.dnv.com/oilgas/perspectives/testing-paves-the-way-for-hydrogen-use-in-homes.html



© DNV

https://h21.green/app/uploads/2018/11/H21-Phase-1-Technical-Summary-Report_v6.pdf

Molecular diffusivity in air

Methane	0.20 cm^2/s
Hydrogen	0.61 cm^2/s

HSE Research Activities: MODISAFE

- CBRN MODelling of Sources and Agent Fate (MODISAFE)
- Joint collaborative project (2022-2025)
- Follow-on from MODITIC (2012-2016) https://www.ffi.no/en/search?q=MODITIC

FFI Norwegian Defence Research Establishment

MINISTÈRE DES ARMÉES
Liberté
Égalité
Fraternité
DGA

Direction Générale de l'Armement

FOI

FOrskningsInstitut
(Swedish Defence Research Agency)

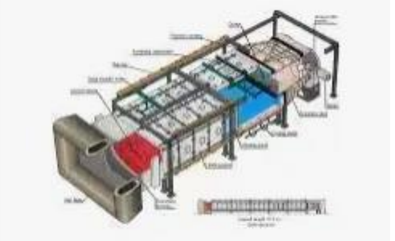
HSE
Health & Safety Executive

- Contractors

RÉPUBLIQUE FRANÇAISE
Liberté
Égalité
Fraternité

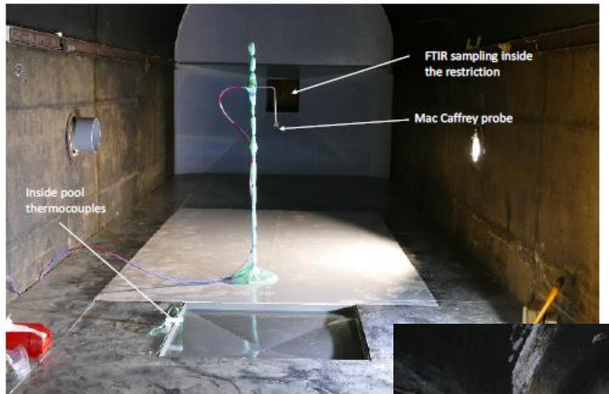
INERIS
maîtriser le risque pour un développement durable

UNIVERSITY OF SURREY

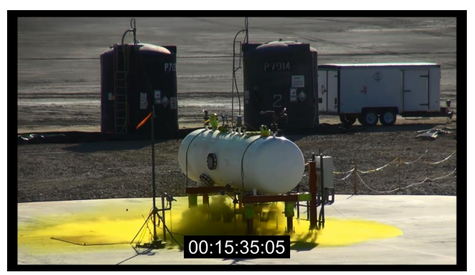


MODISAFE: Work Package 1

- Pool spread and evaporation (FOI led)
  - Analysis of existing INERIS data and potentially new experiments
  - Analysis of Jack Rabbit II Trial 8 chlorine spill data



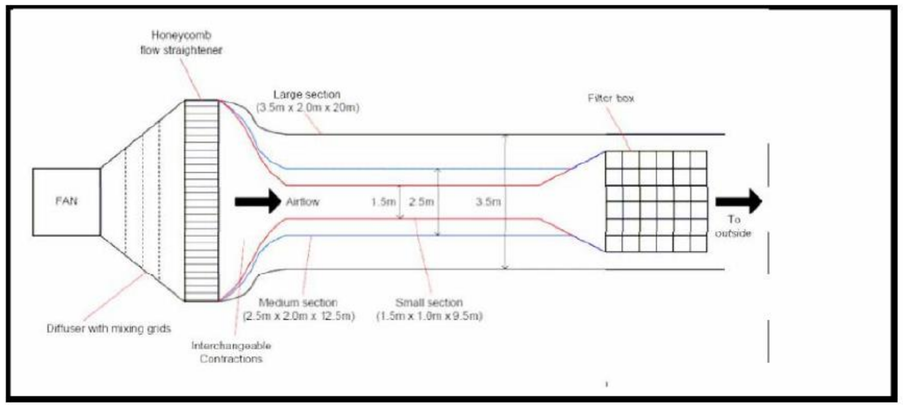
Images © INERIS

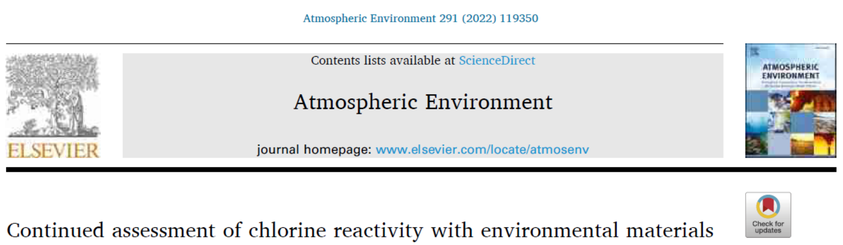


Images © DHS S&T CSAC

MODISAFE : Work Package 2

- Deposition and resuspension of aerosols/particles/vapour (DGA led)
  - New particle deposition/resuspension experiments in HSE dust tunnel
  - Analyse University of Arkansas chlorine and ammonia dry deposition data





Atmospheric Environment 291 (2022) 119350

Contents lists available at ScienceDirect

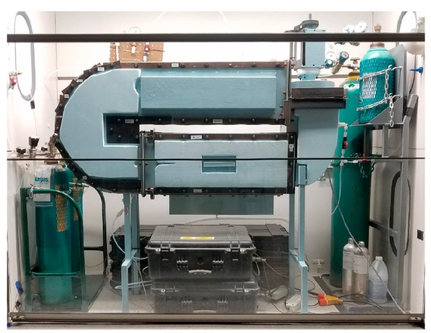
Atmospheric Environment

journal homepage: www.elsevier.com/locate/atmosenv

Continued assessment of chlorine reactivity with environmental materials for hazard assessment of large scale releases

Thomas O. Spicer

University of Arkansas, Ralph E. Martin Department of Chemical Engineering, Fayetteville, AR, USA



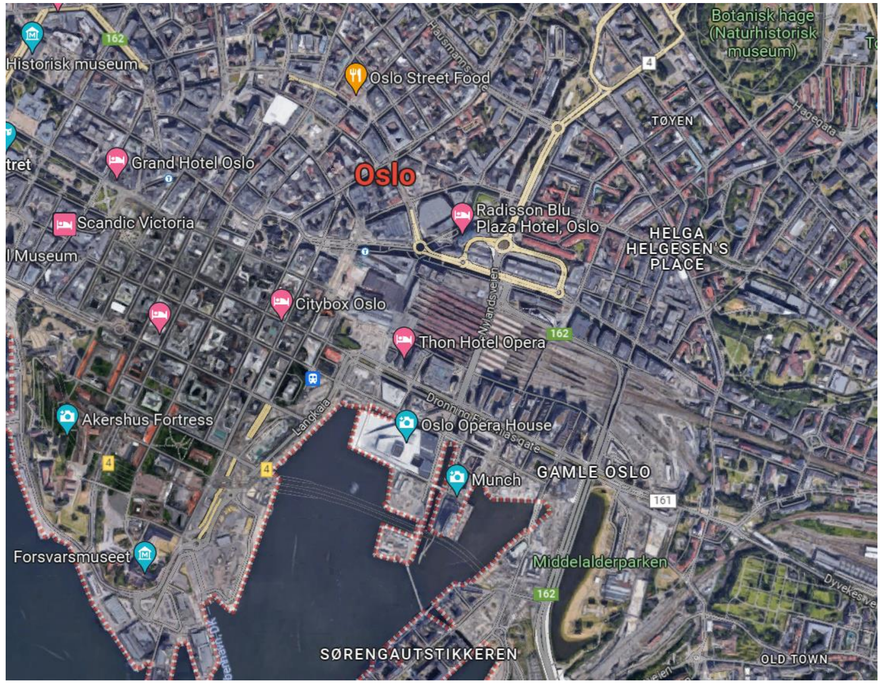
https://doi.org/10.1016/j.atmosenv.2022.119350

Images © University of Arkansas

MODISAFE: Work Package 3

- Atmospheric dispersion of buoyant sources in urban environments (FFI)
  - Wind tunnel experiments for Oslo at Surrey University ENFLO

Figure 3.1 *The Paris model installed in the meteorological wind tunnel.*



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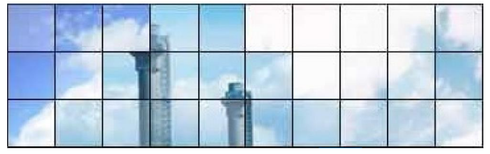
  - Katabatic flows webinar
  - Wildfires webinar

Atmospheric Dispersion Modelling Liaison Committee (ADMLC)

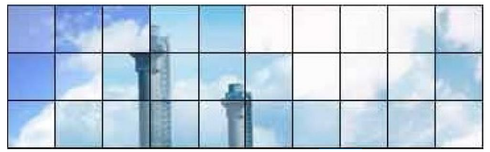
- Committee dates back to 1977, with focus on modelling of radioactive releases
- Membership widened over time, but still primarily UK Government agencies
- Aim: to review atmospheric dispersion and related phenomena for application primarily to authorization or licensing of discharges to atmosphere resulting from industrial, commercial or institutional sites
- Mainly interested in fixed sources, rather than transport sources, including both routine releases and releases in accident or “upset” conditions



Atmospheric Dispersion Modelling
Liaison Committee (ADMLC)

ADMLC: Effect of NWP Resolution

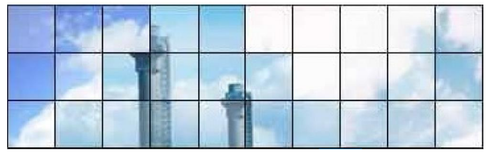
- Investigating the impact of applying different grid resolutions of numerical weather prediction met data in atmospheric dispersion modelling
- Scope:
  - Review of NWP models
  - Comparison of model endpoints for NWP datasets
  - Comparison studies for regulatory atmospheric dispersion modelling
  - Potential for double counting of the impact of terrain
  - Use of NWP met data for probabilistic accident consequence assessments
- Project commissioned with CERC and UKHSA
- Feedback from ADMLC committee provided to contractors
- External peer review by Jonathan Vogel (DTRA)
- Final report edits currently in progress
- Report to be published on ADMLC website soon (November 2023?)



Atmospheric Dispersion Modelling Liaison Committee (ADMLC)

ADMLC: Model Evaluation

- Review of methods used to assess the performance of atmospheric dispersion models
- Scope:
  - Literature review
  - Case studies
  - Guidance on application of model evaluation methods to different scenarios
- Contract awarded to CERC and Steven Hanna
- Timeline: kick-off 17 October 2023, project duration 12 months
- Ron Meris (DTRA) kindly offered to provide external peer review

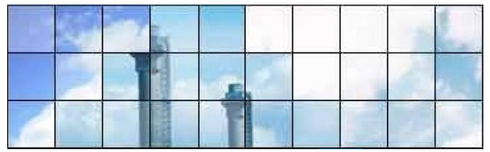


Atmospheric Dispersion Modelling
Liaison Committee (ADMLC)

ADMLC: Seminars and Webinars

- Past events (recordings available at: www.admlc.com/events)
  - May 2021 “Dispersion modelling and satellites”
  - February 2022 “Use of dispersion modelling for sensor network design to facilitate source attribution, emissions estimation and incident response”
  - March 2023 “Dense gas dispersion modelling in complex terrain, with a focus on carbon dioxide pipelines”
  - October 2023 “Dry deposition and surface chemical reactivity”

- Future Events
  - 13 December 2023 “Modelling katabatic flows”
  - Spring 2024 “Modelling wildfires”?



Atmospheric Dispersion Modelling
Liaison Committee (ADMLC)

ADMLC: Concluding Remarks

- ADMLC welcomes suggestions for new research projects and ideas for webinars
- If you'd like to learn about future events, please ask to join our mailing list
- We are keen to host model validation datasets on our website www.admlc.com
- Contact: admlc@ukhsa.gov.uk

Thank you

- Contact: simon.gant@hse.gov.uk

- The contents of this presentation, including any opinions and/or conclusions expressed, are those of the authors alone and do not necessarily reflect HSE policy

Extra material

Why the name Skylark?

- Historical dispersion trials
  - Avocet: LNG
  - Burro: LNG
  - Coyote: LNG
  - Desert Tortoise: ammonia
  - Eagle: nitrogen tetroxide
  - Falcon: LNG
  - Goldfish: hydrogen fluoride
  - Kit fox: carbon dioxide
  - Jack Rabbit: chlorine and ammonia
  - Red Squirrel: ammonia
  - **Skylark: carbon dioxide**

https://www.birdguides.com/gallery/birds/alauda-arvensis/1003602/