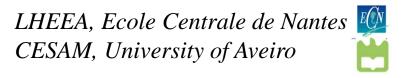
15th International Conference on Harmonisation within Atmospheric Dispersion Modelling for Regulatory Purposes 6-9 May 2013, Madrid, Spain

Effects of released hazardous gases (EFRHA) model: development and validation



Richard Tavares and Ana Isabel Miranda

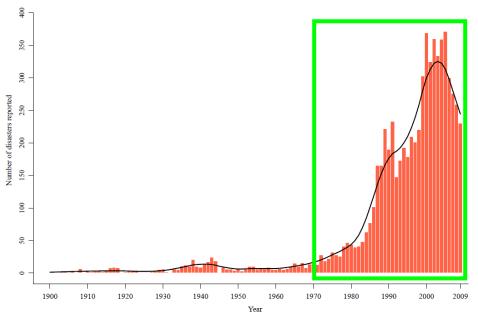


The Problem



Introduction & Main goal

Technological accidents



Reported Technological accidents recorded between 1900 and 2009 [EMDAT].

Seveso, Italy (1976)

Bhopal, Índia (1984)

Toulouse, France (2001)

Viareggio, Italy (2009)

Sendai, Japão (2011)



Prevention and Control of accidents involving the release of hazardous gases

Increased awareness of the consequences from technological accidents, in particular the exposure to hazmat gases released into the atmosphere



Development a implementation of regulatory and guidance instruments

(e.g. Consequence Analysis (CA) methodologies and studies)



Gave numerical tools (software packages or models):

- unique value to support control, training, decision, emergency response and post-events studies
- large efforts have been taken in the development and implementation of local-scale modelling tools able to predict short-term pollution episodes and exposure effects on humans and the environment

Consequence Analysis modelling tools

Despite the number and variety of existing CA modelling tools/software packages some limitations are recognized

- Number and type of accident scenarios
- Level of knowledge/experience of the user
- Computational and hardware capacity and resources



Simple modelling tools:

- Cannot properly represent the actually occurring real conditions in industrial and built-up areas

More complex modelling tools:

- Turn the tool powerless to provide fast response information

Main goal

<u>Development</u> and <u>Validation</u> of the <u>EFRHA</u> – '<u>EFfects</u> of <u>Released</u> Hazardous gAses' integrated CA modelling tool designed to:

Predict short-term pollution episodes and exposure effects on humans and the environment in case of accident with hazardous gases (hazmat),

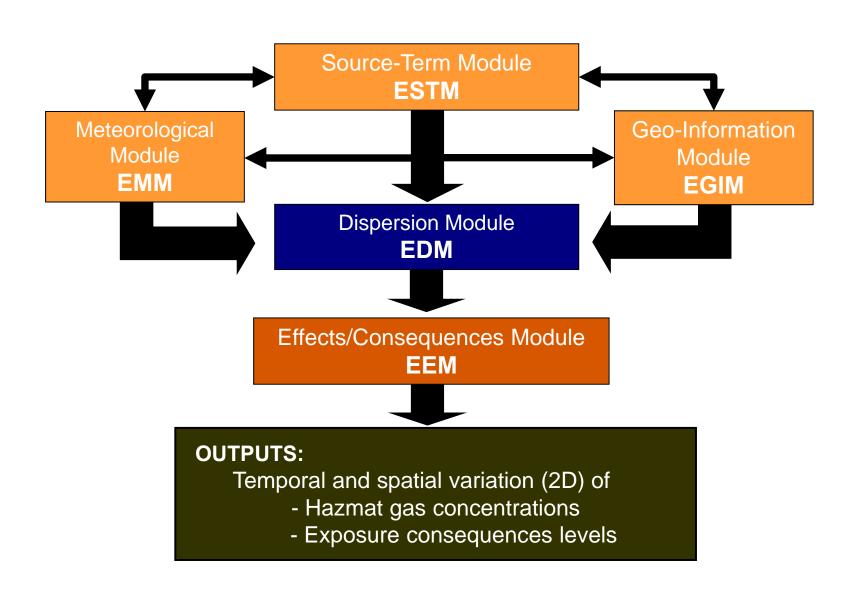
Capable to:

- Simulate the outflow and atmospheric dispersion of heavy and passive hazmat gases in complex and build-up areas,
- Estimate the exposure consequences of short-term pollution episodes in accordance to regulatory/safety threshold limits.





EFRHA model Main Structure



EFRHA model – EMM

Surface meteorological observations

Upper air soundings

EMM

- Quantitative Monin-ObukhovSimilarity Theory approach
- Logarithmic wind vertical profile

OUTPUTS:

- -ABL scalar parameters
- ABL mixing layer height
- Vertical profiles

Terrain and land-use

EFRHA model – EGIM

Spatial distribution of:

- Buildings
- Sources
- Receptors

Meteorological data (EMM)

EGIM

- Spatial interpolation method
- Diagnostic Wind Model

OUTPUTS:

- Receptors grids
- Terrain and land-use characteristics
- Wind fields

Topography and land-use

EFRHA model – **ESTM**

Chemical Properties

Release Characteristics Initial storage or transpor conditions

Meteorology (EMM)

ESTM

Initial Physical States

Compressed Gas

Liquids

Pressurized Liquefied Gas

Evaporation pool

Containment:

- Vessel
- Pipes
- Pipelines
- Liquid pools

Type of release:

- Instantaneous
- Transient
- Continuous

OUTPUTS:

- Source-term characteristics (e.g. dimensions, location, outflow rate, release duration)
- Hazmat gas physical and thermodynamical properties

EFRHA model – EDM

Chemical properties

Outflow rate (ESTM)

Meteorology and wind fields (EMM+EGIM)

Receptors grids (**EGIM**)

lopograpny and land-use (**EGIM**)

EDM

- Shallow layer modelling approach for heavy gases dispersion
- Multi-puff approach for transient sources

OUTPUTS:

- 2D concentration fields (based on receptors grids)
- Peak concentrations temporal variation

Control parameters

EFRHA model – EEM

Concentration fields (EDM)

Control parameters

EEM

 Direct comparison with reference 'control' limits (temporal and/or spatial)

Regulatory and/or Safety control threshold limits

OUTPUTS:

- 2D Consequences/effects fields
- Danger areas
- Peak Concentrations time evolution



Validation of EFRHA model

EFRHA model Validation

Validation Exercise:

- Qualitative and quantitative analyses validation techniques suggested in the COST Action 732 **Model Evaluation Guidance Protocol** (Britter and Schatzmann, 2007)
 - Graphical comparisons of measured VS modelled concentrations
 - Estimation of quality metrics

EFRHA model validation in its entire scope

 Direct comparisons of modelled and measured peak concentrations from well-established full-scale field test trials

concentration fields were estimated between 0.4 and 1.5 m high from the ground level to maintain a somewhat consistency with measurements, but also, for corresponding to 'normal heights of exposure to hazmat gases'.

EFRHA model Validation

Set of full-scale field experimental set-ups test trials simulated

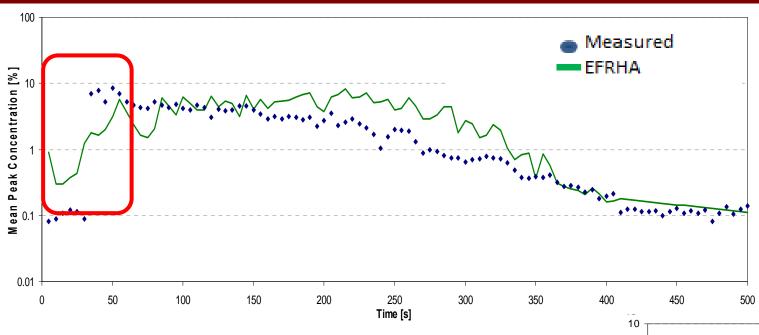
ID	Test Trial	Substance	Spill Flow (kg/s)	Duration (s)	Release Type	Meteorological Conditions
VT1	TI 8	Freon 12-N ₂	3967.0	1.0	Instant. Puff	$T_a = 17.2 ^{\circ}\text{C}$ $P = 1 \text{ bar}$ $u_{\text{ref}} = 2.4 \text{ m/s}$ class D
VT2	В3	LNG	88.0	167.0	Evapo. Pool	$T_a = 33.8 ^{\circ}\text{C}$ $P = 0.94 \text{bar}$ $u_{\text{ref}} = 5.4 \text{m/s}$ class B
VT3	DT 3	Ammonia	133.0	166.0	Continuous Jet	T _a = 17.2 °C P = 1 bar u _{ref} = 2.4 m/s class D

TI – *Thorney Island* full-scale experimental trials

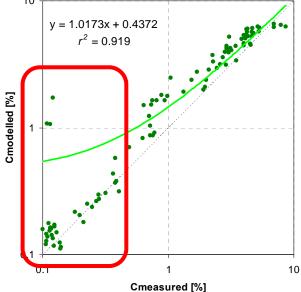
B – *Burro* Test full-scale experimental trials

DT – *Desert Tortoise* full-scale experimental trials

EFRHA model Validation – Qualitative Analysis

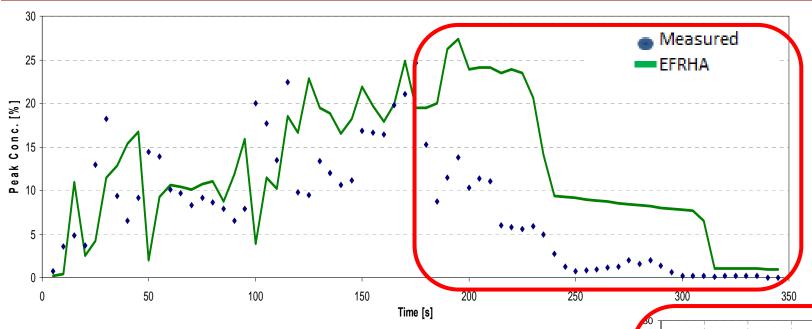


Peak concentration temporal evolution until 500 s after the release

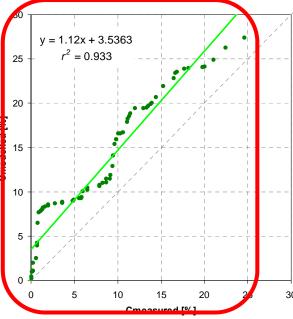


Measured VS Simulated Peak concentration q-q plot

EFRHA model Validation – Qualitative Analysis



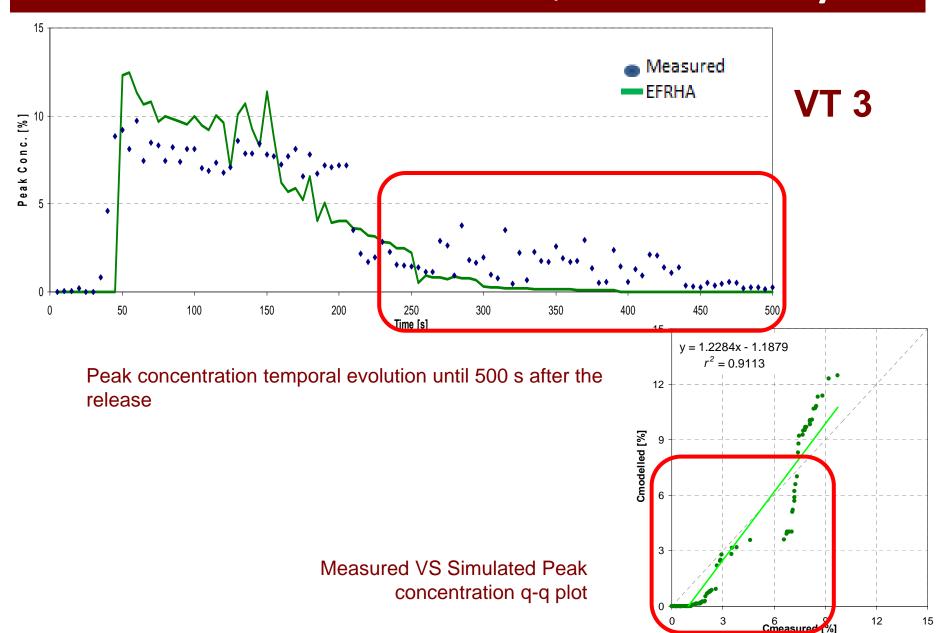
Peak concentration temporal evolution until 350 s after the release



VT 2

Measured VS Simulated Peak concentration q-q plot

EFRHA model Validation – Qualitative Analysis



EFRHA model Validation – Quantitative Analysis

Quality metrics estimated using the statistical BOOT Software [Chang and Hanna, 2004]

Run ID	FB	FAC2	NMSE	r	MG	VG	SB	SDSD
	FB < 0.3	FAC2 > 0.5	NMSE < 1.5	r≈1	0.7 <mg<1.3< th=""><th>VG < 4</th><th>-</th><th>-</th></mg<1.3<>	VG < 4	-	-
VT 1	-1. 340	0.570	0.95	0.57	0.70	2.03	0.592	0.130
VT 2	-0.240	0.506	0.66	0.56	0.43	8.71	0.170	0.100
VT 3	0.121	0.450	0.36	0.84	1.95	2.72	0.160	0.810

FB Fractional bias

FAC2 Factor of 2

NMSE Normalized mean squared error

r Pearson correlation coefficient

MG Geometric mean bias

VG Geometric variance

SB Squared bias

SDSD Standard deviation of modelled results and observations



Main Conclusion

Main Conclusions

- Consistent description of ambient conditions and reasonable prediction of hazmat gas release and dispersion,
- Shallow layer based dispersion approach can be considered a plausible alternative to integral and CFD approaches for intermediate/operational CA modelling tools,
- EFRHA can be used as a straightforward tool to support CA studies in case of hazmat gas accidental release in industrial and/or urban areas,
- Need to develop and/or improve integrated CA modelling tools to support decision and emergency response in case of hazmat gas accidental release and dispersion in obstructed areas.

Thank You!

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