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Cost Action Es1006. Evaluation, Improvement and Guidance of Local-Scale Emergency Prediction and Response Tools for Airborne Hazards in Built Environments: Ongoing Activities, Experiments and Recent Results

Claudio Gariazzo*[a], Bernd Leitl[b], SilviaTrini Castelli[c], Kathrin Baumann-Stanzer[d], Tamir G.Reisin[e], Fotios Barmpas[f], Gianni Tinarelli[g], Claire M. Milliez[h], Elisabetta Bemporad[a], Patrick Armand[i]

[a] INAIL Research Center via Fontana Candida 1 Monteporzio Catone (RM) Italy.
[b] Meteorological Institute University of Hamburg Bundesstrasse 55 D-20146 Hamburg Germany.
[c] Istituto di Scienze dell'Atmosfera e del Clima Consiglio Nazionale delle Ricerche Corso Fiume 4 10133 Torino Italy.
[d] Central Institute for Meteorology and Geodynamics Hohe Warte 38 1190 Wien Austria.
[e] SOREQ NRC Yavne Israel.
[f] Aristotle University of Thessaloniki Laboratory of Heat Transfer & Environmental Engineering Thessaloniki Greece.
[g] ARIANET S.r.l. Via Gilino 9 20128 Milan Italy.
[h] CEREA Teaching and Research Center in Atmospheric Environment Joint Laboratory Ecole des Ponts ParisTech - EDF R&D Universite Paris Est Electricite de France R&D 6 quai Watier 78400 Chatou Cedex France.
[i] CEA, DAM, DIF, F-91297 Arpajon, France
c.gariazzo@inail.it

The COST Action ES1006 is mainly aimed at evaluating and improving the reliability of neighbourhood-scale emergency response tools on the basis of a comprehensive, concerted and harmonized cross-national approach. The main focus is the evaluation of the air dispersion models, when used in urban or industrial environments with complex building structures, and their integration in emergency response systems. In the frame of this research, three working groups are carrying out several activities such as: to inventory models, tools and methodologies currently applied in the context of emergency management and local-scale threat reduction; to categorize and characterize local-scale threat scenarios; to identify the main gaps, deficiencies and limitations in presently available knowledge and models and to determine the directions for the development of the next generation of models; to test and evaluate available models by model inter-comparison and by comparison against test data from qualified field and laboratory experiments. The ongoing activities in the three WGs and the latest available results will be presented.

1. Introduction

COST Action ES1006 (2013) "Evaluation, improvement and guidance for the use of local-scale emergency prediction and response tools for airborne hazards in built up environments" aims at assuring the quality of the airborne hazardous material modelling tools used for emergency response and providing guidance for their use and improvement, within an harmonized European approach. The Action focuses on urban and industrial areas, and pays a particular attention to the specific needs of stakeholders and decision makers.
Identifying gaps in knowledge related to local-scale emergency response modelling is one of the main aims, supported by the development of an evaluation strategy designed to consider requirements of airborne hazard modelling. In this context, not only the validity and accuracy of dispersion models is of concern, but also their demands regarding input data, their operational performance as well as their robustness considering the uncertainty of input data. The main tasks of the Action are summarized below:

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- To elaborate a complete inventory of local threat scenarios and related modelling systems presently used, and to establish a scientific and methodical reference for local-scale airborne hazards modelling. Possible sources and release situations have to be characterized and categorized considering specific model requirements and assessing the fitness for purpose of different modelling approaches.
- To setup a dedicated comprehensive inventory of models applicable to local-scale accidental releases. A complete and consistent European catalogue of tools and models is not yet available.
- To test and evaluate available models by model inter-comparison and by comparison against test data from qualified field and laboratory experiments, extending the existing model evaluation and validation strategies towards task- and application-specific measures for accidental release scenarios.
- To identify the main gaps, deficiencies and limitations in presently available knowledge and models and to determine the directions for the development of the next generation of models.
- To address the integration of airborne hazards modelling tools in existing and/or evolving information systems for urban/industrial emergency management, considering both the output results of local-scale airborne hazards modelling and the possible quality improvement of the input information.
- To classify existing test data with respect to completeness and usefulness for the present purpose. The uncertainty in the test data has to be assessed and possibly quantified. Identification of desirable test scenarios for which data may be collected during field and/or laboratory experiments in the future.

2. Scientific work plan methods and means

The scientific work of the Action is carried out in three structured task-specific Working Groups (WGs).
Working Group 1 - Threats, Models and Data Requirements - is characterizing and categorizing existing models as well as typical release scenarios. Main task is to evaluate, complete and uniformly document existing test data.
Working Group 2 - Test, Evaluation and Further Development - is defining open and blind test scenarios, testing and assessing different modelling approaches and working on scientific strategies for improving the implementation of corresponding tools. In this context, the Action’s scientific interest is not to rank individual modelling approaches but to identify specific reasons for diverging model results and possible ways for improving modelling quality. The strengths and weaknesses of particular modelling approaches are identified, quantified, and documented in order to stimulate further improvement of model quality. A first version of a best practice manual for the application of neighbourhood-scale airborne hazards models will be compiled and released in order to immediately improve the quality of model results.
Working Group 3 - Applicability, Implementation and Practical Guidance – is dealing with the practical constraints in the use of local-scale emergency response models. The specific needs of first responders and authorities in charge of neighbourhood-scale emergency response management have to be taken into account in order to successfully implement scientific improvements. From a clear user's point of view, the work covers tasks such as: the collection of requests and demands of the emergency-response experts for improving the practical applicability of the modelling systems; the provision of guidance regarding the suitability of different types of models and methodologies for specific problems at different stages of an incident or the identification, characterization, visualization and quantification of the uncertainties of emergency response modelling facilitating the proper interpretation by decision makers.

3. The ongoing activities and latest results

3.1 The Inventory of Available Datasets.

A first database (Tsiouri and Trini Castelli, 2012) was elaborated in order to classify existing test data with respect to completeness and usefulness for the purpose of validating dispersion models specifically for emergency response systems. Since specific datasets suited for emergency response models are rare, datasets originally gathered in atmospheric dispersion models are mainly described in this document. For each dataset the possible limitations, related to their use when validating models in the frame of emergency response assessment, are discussed. A few features for a qualified dataset for model testing and demonstration of model performance in emergency response in built environments were identified, such as: being representative of an accidental release; addressing some important aspect or issue affecting the dispersion modelling reliability; availability of concurrent meteorological and concentration measured data of possible high quality; describing a variety of meteorological conditions.

3.2 The Inventory of Emergency Modelling Tools.

A summary of the state-of-the-art of emergency response tools for airborne hazards from accidental/deliberate releases in complex urban and industrial areas was compiled (Tavares and Baumann-Stanzer, 2012) and a dedicated model inventory was established. A pilot version of the Model

Inventory Database Tool (MIDT) was prepared, with the intention to catalogue information of available emergency response models, tools and methodologies developed for local-scale airborne hazards and incidents scenarios. Available information are: computational approaches and models integrated, aspects of hazards and incident scenarios addressed, physical background, input data demands, computational demands and information on model application/use, verification or related performance measures. The MIDT was developed in the form of an Excel workbook comprising a set of eight information worksheets. It comprises specific information concerning emergency response computational tools and models used individually or incorporated in these tools, applicable to individual or multiple interdependent aspects of local-scale airborne hazards and incident events. The following elements are considered in the MIDT: Emergency Response Computational Tools Database (ERCTD); Meteorological Models Database (MMD); Source Term Models Database (STMD); Dispersion Models Database (DMD); Consequence Analysis Models Database (CMD); Risk analysis Models Database (RAMD). This inventory will allow for model-specific guidance regarding an efficient and reliable use of different model tools.

3.3 The Model Evaluation Procedures for Emergency Response Applications.

A thorough review (Barmpas and Trini Castelli, 2013) of all recent developments in model evaluation procedures for the validation of dispersion models and that can potentially be applied in cases of accidental or deliberate releases of airborne hazards in urban areas was performed. In order to measure the quality of model results and to improve their implementation, a task-specific validation and application procedure was adopted. According to the latter, the necessary steps that should form the proposed evaluation modelling procedure is the following: 1) definition of the variables which should be compared; 2) definition of how the model is run and the results interpreted; 3) Processing of the experimental data; 4) Exploratory data analysis; 5) Metrics for Model Validation; 6) definition of the quality acceptance criteria. This procedure will be further developed and it will form the basis for the model evaluation exercises planned within the frame of Action.

3.4 The end-users and stakeholders questionnaires/interviews.

Questionnaires dedicated to survey the use of Emergency Prediction and Response Tools (EPRT) by stakeholders and their needs and requirements related to the modelling suites was elaborated and distributed to end-users and stakeholders. Compiled questionnaires (61) were received from the main European Countries (17). The results presented here refer to Italy, from where the highest response rate was obtained (received/sent ratio = 25/61): however, according to the overall results, they are consistent with those obtained in other Countries. Table 1 lists the kind of Institutions who responded from Italy.

Table 1: List of Italian institutions participating at the ES1006 questionnaires

Institutions	Received questionnaire
Local authorities	1
Fire brigade	17
University	1
Consultants	4
National authority	1
industry	1
TOTAL	25

Questions were related to different aspects on the use of modelling tools in emergency planning and response, such as: type of model used, preferred data fed, operators involved, context and aims for modelling applications. The main results are summarized in Tables 2a,b,c.

Table 2a: Summary of answers provided by the Italian stakeholders on the use of modelling tools in emergency. Multiple options selected avoid rate to sum up 100.

Use of Emergency Tools	rate (%)	Model operator	rate (%)	Model used	rate (%)
emergency planning	88	risk analyst	75	Gaussian	60
training	32	tech. Emerg. manager	60	Eulerian	0
civil protection	36	technical consultant	10	Lagrangian	20
other	12	modelling expert	15	CFD	20
		specialised technician	15	short-cut	70
		HSEQ tech. manager	5	PUFF	10

Table 2b: Summary of answers provided by the Italian stakeholders on the use of modelling tools in emergency. Input data. Multiple options selected avoid rate to sum up 100.

Meteorological data	rate (%)	Turbulence data	rate (%)	Emission data	rate (%)
local measurements	23	Pasquill classification	84	estimated	27
measurements in the nearest station	23	bulk ABL similarity theory	5	modelled	55
classified from max. impact (D5, F2)	73	k-epsilon theory	11	measurements	23
meteorological simulations	9	statistical fluctuations	5	short-cut assess.	36
local climatological models	23			other	5
classified from extreme conditions	9				

Emission characteristics	rate (%)	Emission characteristics	rate (%)
stationary	79	multiphase	21
non stationary	37	single-phase	42
mechanical or thermal driven	16	light gases	53
inert	32	heavy gases	53
reactive	16	pure chemical	47
		mixture	16

Table 2c: Summary of answers provided by the Italian stakeholders on the use of modelling tools in emergency. Output data and scenario and operator involved. Multiple options avoid rate to sum up 100.

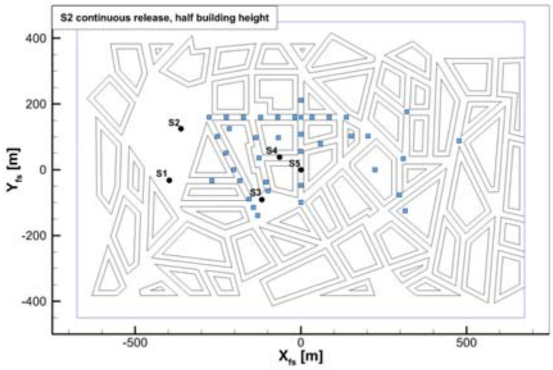
Preferred results	rate (%)	Main interest scenarios	rate (%)	Operator involved in ER	rate (%)
concentration values	44	traffic accident	73	plant emergency team	23
confidence intervals	4	industrial accident	100	plant emergency manager	27
hazardous distances	76	arsons	31	local authorities	32
hazardous area depicted on a map	100	ship accident	35	provincial or national authorities	50
other	0	terrorist attacks	35	other	14
		natural fire	38		

The questionnaires highlighted that EPRT are mainly used by risk analysts and technical emergency managers in the planning phase of industrial and traffic accidents using either Gaussian or simple shortcut parametric models driven by pre-classified meteorological conditions, simple Pasquill atmospheric stability classes and emissions provided by estimates, models or short cut assessments. Hazardous distances or areas are the preferred output. Advanced and more sophisticated models are rarely used as well as combinations with mesoscale meteorological models and consideration of buildings and structures. Questionnaires were integrated with interviews using open answers. Twenty-eight fire brigade operators and emergency responsible (20 Italian, 8 European countries) participated. The general opinion about the usefulness of EPRT ranges from good to essential in their application for emergency planning /management and environmental /health impact assessment. A number of different aspects were considered to limit the use of complex EPTR in emergency, such as: inaccuracy and limited reliability in input data; inaccuracy in model description of relevant phenomena at their spatial/temporal scales; lack of both trained personnel and standardizes operating procedures; model and training costs as well as the long response time. Source term were found another critical point. Therefore models results have to be checked with measurements or damage observations. Consequently, measurements and personal experience, supported by simple and fast modelling approaches, dominate the emergency management procedures. EPRT are not used for post-crisis analysis. Important aspects in using EPRT were: accuracy; availability of validated models in international or national guidelines; standardization of procedures for EPRT applications and rules for risk assessment; needs of training. Simple and robust systems, integrated in a web GIS systems are needed-. Based on these needs, it is important to document the limitations of different local-scale emergency response methodologies by assessing the actual uncertainty of model results. Consequently reference datasets for testing the model performance have to be made and used.

3.5 The Michelstadt Dataset.

A first reference dataset for testing the models was processed, the ‘Michelstadt’ case (Fischer et al., 2010). It was designed to include potential in-homogeneities, characterising the neighbourhood-scale urban areas across Europe with the goal of providing observed data for the validation of local scale emergency response models. Data were gathered during a wind-tunnel flow and dispersion experiment, carried out at the Hamburg University, where a typical European urban site was reproduced. Figure 1a shows the layout of urban structure built for this dataset. In the frame of the COST action two modelling phases were carried out. They consisted in numerically simulating two cases of continuous releases for different source locations (Figure1b), using two wind directions.

a)



b)

Figure 1: Real layout of Michelstadt wind-tunnel experiment (a). Locations of continuous sources releases Sx (dot circles) and sampling points (dot squared) (b).

In the first phase all the dynamical and concentration measurements were made available to the modellers (non blind test), whereas for the second phase, only one wind inflow point and the source characteristics were given (blind test). Sampling points were located within the urban structure to test and verify the spatial extension of the studied accident. The models involved in the modelling exercise range from a simple parametric approach to the large-eddy simulation CFD models. Different numerical models were involved, which were sorted in three categories: type 1 models not resolving the flow, type 2 models resolving the flow between the buildings with simplified equations and type 3 models resolving the flow between the buildings with full equations. Table 3 summarizes the involved models.

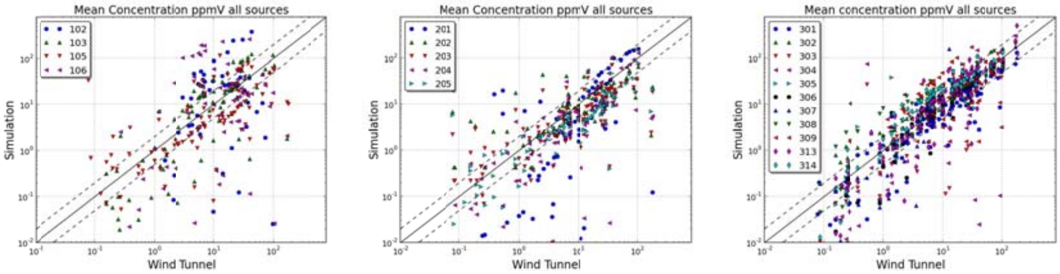
Table 3: models involved in Michelstadt dataset

Modelling approach	Number of models	Remarks	Computational time
Type 1	7	Gaussian – 2 with building parameterization	1 -5 min
Type 2	5	Lagrangian	2 min – 5 hrs
Type 3	10	CFD (8 RANS–3 LES; 1 RANS –Lagrangian)	2 hrs – 4 days

The analyses and comparisons with the experimental results were made according to these three categories rather than specific models. In order to compare the different modelling approach, a dedicated post processing tool was developed in the frame of the Action. The focus is kept on the pollutant concentrations but the tool also allows detailed analyses of the flow field. Grouping the different models according to their categories, the tool produces scatter plots, profiles and 2D projections as well as statistical metrics. Figure 2 shows the scatter plots of simulated vs observed concentrations for each model approach including all results obtained from the available sources in the non blind test. Table 4 shows the values of two indexes of performance (FAC2, FB) obtained for each model approach as an overall evaluation. As expected, results show discrepancies among the model approaches and between model approaches and observations. In general, the better is the description of dispersion phenomena (as in model type 3 which resolves the flow with full equations) the greater are the performances. High discrepancies among the different approaches are also observed in terms of spatial characteristics of concentration maps (not shown), due to the different approaches in reconstructing flow and dispersion.

Table 4: Indexes of performance obtained for the different model types in Michelstadt dataset non blind test. FAC2 (fractions of predictions within a factor 2 of observations). FB (Fractional Bias).

	FAC2			FB	
Modelling approach	min	max	average	min	max
Type 1	14 %	33 %	25 %	-0.24	0.36
Type 2	25 %	46 %	40 %	0.32	0.7
Type 3	25 %	81 %	59 %	-0.43	0.54



a) type 1 b) type 2 c) type 3

Figure 2: Scatter plots of simulated vs measured mean concentrations in Michelstadt dataset for type 1 models (a), type 2 models (b) and type 3 models (c).

Discrepancies among results provided by different modelling approaches were also observed by several authors when obstacles and structures are considered (Gariazzo et.al, 2012; Vianello et al., 2011).

3.6 The catalogue of Threats and Challenges and the Best Practice Guideline.

WG1 is collecting, characterizing and documenting typical and relevant local-scale threats from releases of toxics in populated areas. At the same time WG3 is preparing a document providing guidance in how to apply emergency response dispersion models in order to lower the unavoidable uncertainty in simulation results. This document is expected to supplement the user manual of a typical model by information on the usability, the pros and cons as well as challenges and limitations of different modelling approaches.

4. Conclusions

The COST Action ES1006 was presented. Flow and dispersion modelling, source term characterization, hazardous materials transformation processes during dispersion as well as emergency response management and policy issues have to be considered when evaluating and improving tools and models currently in use. The major outcomes expected from the Action are best-practice recommendations, an up-to-date inventory reviewing the current modelling tools employed in emergency preparedness and response, a comprehensive database of experiments, scientifically and practically qualified, for benchmarking local-scale emergency response models. The Action, although in progress, has produced several documents and results here briefly presented. Of particular relevance are the results provided by the models comparison study carried out using a special developed wind tunnel experiment reproducing an accident in a typical European urban structure. They forms a unique platform to evaluate and validate a wide range of models.

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