17th International Conference on
Harmonisation within Atmospheric Dispersion Modelling for Regulatory Purposes
9-12 May 2016, Budapest, Hungary

EFFECTS FROM URBAN STRUCTURES TO ATMOSPHERIC DISPERSION MODELS IN DECISION SUPPORT SYSTEMS FOR NUCLEAR EMERGENCIES

Hartmut Walter and Gerhard Heinrich

Federal Office for Radiation Protection, Munich, Germany

Abstract: In present times, even no more than in the past, there is a fear that terrorists might thread population or a state to enforce illegal demands. An often-discussed possibility is to disperse explosive material combined with radioactive substances somewhere in public areas (dirty bomb- or RDD- (radiological dispersive device) scenario). These public areas consist generally of urban structures, from smaller buildings like housing areas to complex buildings like areas in the centre of big cities.

A decision support model (LASAIR) has been developed to assist in such a case providing quick and basic information on the radiation exposure. The paper gives an overview of the model and especially on the influence of simple urban structures to the dispersion of radioactive substances and related radiation exposure.

Key words: *Urban structures, malevolent attacks, dirty bomb, Lagrangian- Particle-Model, decision support***.**

INTRODUCTION

In present times there still is a fear that terrorists might aim with an act of violence against population in an urban environment to enforce illegal demands. An often-discussed possibility is to disperse explosive material combined with radioactive substances somewhere in public areas. This is called a dirty bomb- or RDD- (Radiological Dispersive Device) scenario.

In such a case, it is essential to get as quickly as possible a clear picture of the potential threat. This means that the possible radioactive concentration in surrounding areas and the contribution to the pathways that lead to the exposure of the population are assessed and counter measures are recommended.

THE DECISION SUPPORT SYSTEM LASAIR

An existing system program LASAT, (Janicke, L., 1983, 1985) based on Lagrangian particle simulation has been adapted to meet the requirements of a dirty bomb scenario. Conducted by the German Federal Office for Radiation Protection (BfS) and under the direction of the German Federal Ministry for Environment, Nature Preservation, Building and Reactor Safety (BMUB) the program LASAIR (Walter, H. and G. Heinrich, 2011, Walter, H. and G. Heinrich, 2014)) has been developed which is able to give a first and rapid overview of atmospheric dispersion, ground activity, deposition and different exposition pathways (inhalation, ground- and cloud shine) after an instantaneous release of radioactive material.

The program can be used by radiation emergency authorities that are responsible for emergencies within the different German Federal States (Bundesländer). The program was developed in the year 2000 and has been continuously upgraded since then.

The model LASAIR (Lagrangian Simulation of the Dispersion and Inhalation of Radionuclides) in its latest version is able to simulate an explosion of an RDD with additional radioactive material and computes the dispersion in the planetary boundary layer. In order to assess the dose to the population, the inhalation, ground- and cloud shine doses to individuals can be computed. The model has been introduced as a rapid decision support system within the Federal Office for Radiation Protection and authorities in Federal States in Germany. LASAIR has been used within model comparisons for dispersion models especially used for radioactive substances and herein proved its ability (von Arx et al., 2016, Thiessen et al 2011).

FEATURES OF THE DECISION SUPPORT SYSTEM LASAIR

Special attention has been directed to the usage of the program in emergency cases. The program can be run on a laptop, is extremely easy to handle and allows the user only a strictly straight forward step by step usage in order to grant a maximum security feeding the program with input data.
To model just needs basic necessary meteorological input as

- wind speed and wind direction
- stability class,
- precipitation
- roughness length
- source term (single point, area, volume, with momentum)
- amount of explosives
- radionuclide and activity

Outputs of the model are activity concentration, deposition, ground shine, cloud shine, inhalation dose and time dependant information (activity, dose) in different scales.

The latest version of LASAIR (Version 4.0.5, April 2014) includes the following features additionally:

- actual turbulence parameterisation (harmonized in Germany),
- verification according to radioactive dispersion experiments with Tc-99m,
- worldwide orography and individual topography,
- rapid online integration of urban structures,
- use of Open Street Maps for EU or worldwide operation.

ACTUAL TURBULENCE PARAMETERISATION (HARMONIZED IN GERMANY)

Investigating literature one will find a huge amount of different atmospheric dispersion models. They have been developed according to different demands and applications. It is one aim of the HARMO-Organisation to provide harmonisation for the dispersion models in such a way that the application of different models e.g. in an emergency, will lead to similar results.

In Germany, the VDI (Verein Deutscher Ingenieure, Association of German Engineers) supports strongly the idea of harmonisation in different aspects. One of it is to develop state of the art standards for the turbulence parameterisation in mesoscale dispersion models. In the course of 2014 the basic work for a new turbulence parameterisation based on measurements at a weather mast close to the city of Hamburg in the northern part of Germany will be completed. This parameterisation will end in a guideline that is applicable for all modelers (VDI 3783, Blatt 8; 2014 Gründruck/ 2016 Weißdruck) and shall set a standard in Germany but as well in other countries.

The new turbulence parameterisation will be implemented in LASAT and therefore in LASAIR making sure that the scientific improvement will be available for the model users.

USAGE OF LASAIR WITHIN URBAN STRUCTURES

The application of LASAIR especially for dirty bomb scenarios requires the consideration of urban structures. Special windfield models therefore have been examined to be implemented in Decision Support Systems. Complex wind field models are available however require detailed input information that is not available in general during a real emergency. Alternatively less complex windfield models based on a diagnostic approach have been taken into account.

Following the development of the windfield model TALDia (Janicke, U. and L. Janicke, 2004) it was demonstrated, that for long term dispersion calculations and ground based releases the differences between complex (nonhydrostatic) windfield models and TALDia is less than 30 %. This level might be higher for short term or instantaneous releases. However as the computation time for complex windfield models is significantly higher than that for diagnostic windfield modes it was judged that the advantages are on the diagnostic windfield side and therefore a combination of the basic dispersion model (LASAT) and the diagnostic windfield model similar to TALDia (Lprwnd, three dimensional, divergence free windfield model) was implemented in LASAIR.

To demonstrate the abilities of Lprwnd several dispersion calculations with different urban structures from very simple to complex has been conducted.

Description of the urban scenarios that have been investigated:

- simple building, basic dimensions 30 m x 20 m x 20 m
- building block with courtyard, basic dimensions 110 m x 8 0 m x 20 m (see Figure 1)
- several building blocks, basic dimensions 350 m x 8 0 m x 20 m (see Figure 2)
- simple building, dimensions see above, building is upwind of the source
- simple building, dimensions see above, building is downwind to the source
- simple building, dimensions see above, building is upwind to the source
- two simple buildings, dimensions see above, source is between the buildings

Some results for wind fields (Lprwnd) and exposition from LASAIR are depicted in the following figures:

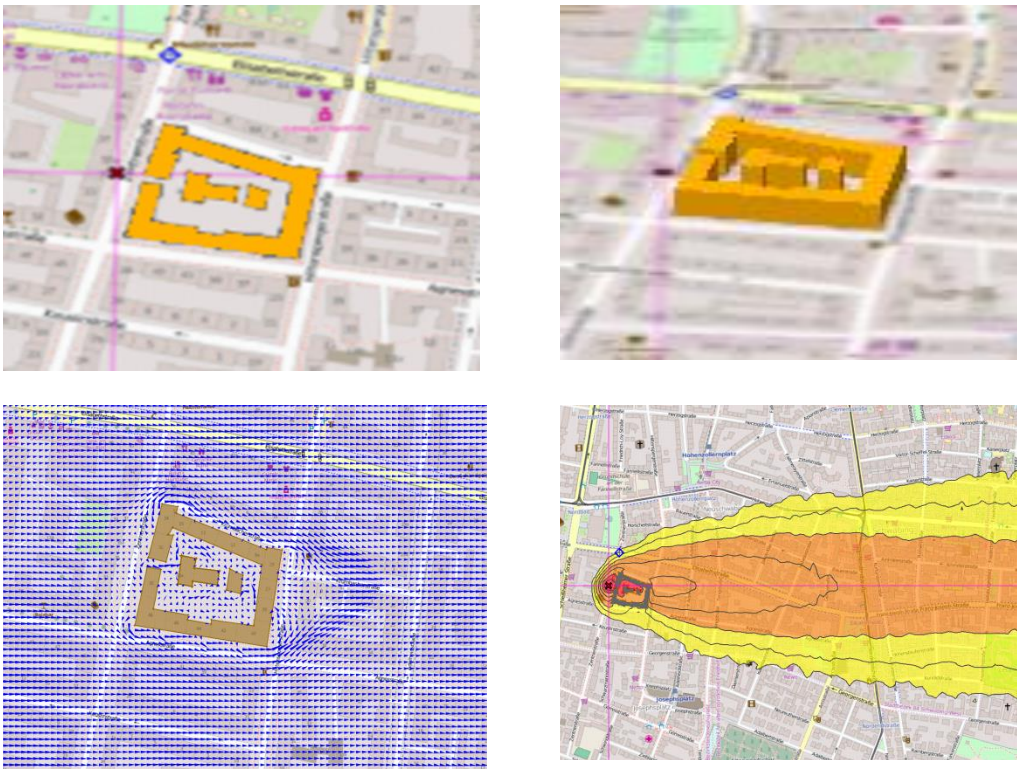

Figure 1. a, b, c, d. Scenario building block. Figures show 2 d- and 3 d- sight (top left, top right), windfield (wind direction 270°) and inhalation dose for an arbitrary radionuclide and activity (bottom left, bottom right).

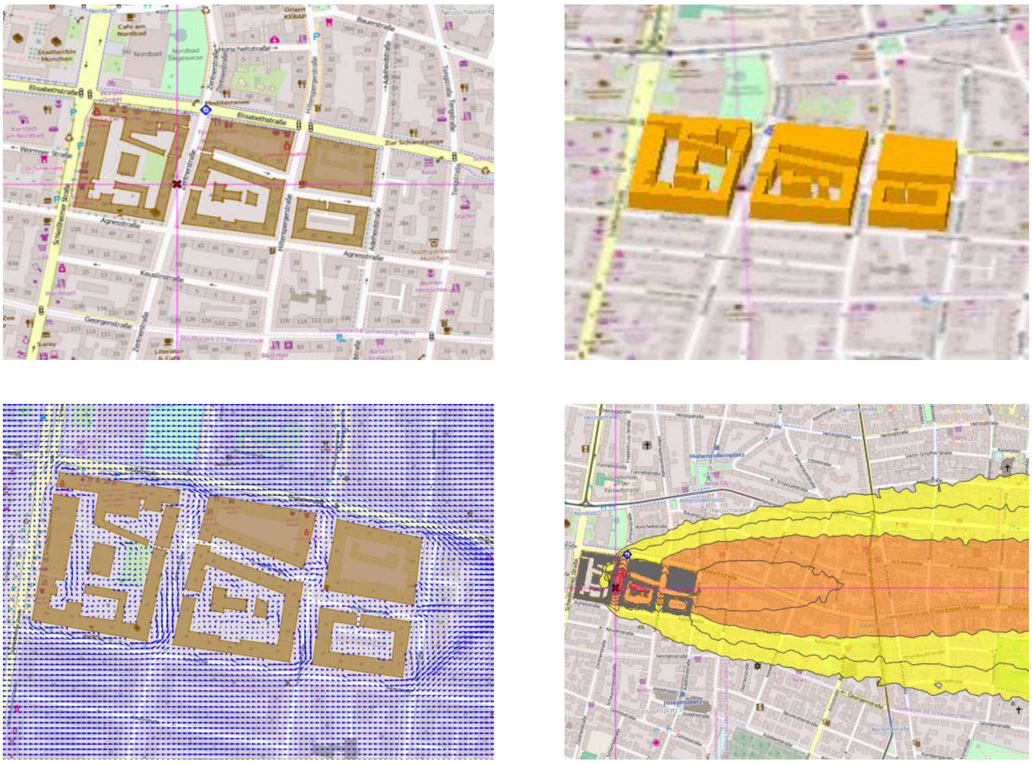

Figure 2. a, b, c, d. Scenario several building blocks. Figures show 2 d- and 3 d- sight (top left, top right), windfield (wind direction 270°) and inhalation dose for an arbitrary radionuclide and activity (bottom left, bottom right).

The following Figure 3 shows the inhalation dose inhalation dose [mSv] of an arbitrary radionuclide and activity in six different building scenarios compared to the flat scenario (without buildings). It can be seen, that the building effects reach a distance downwind of minimum 200 m from the source. From these scenarios it can be assumed, that for a realistic urban scenario the downwind distance will significantly exceed the distance as shown here.

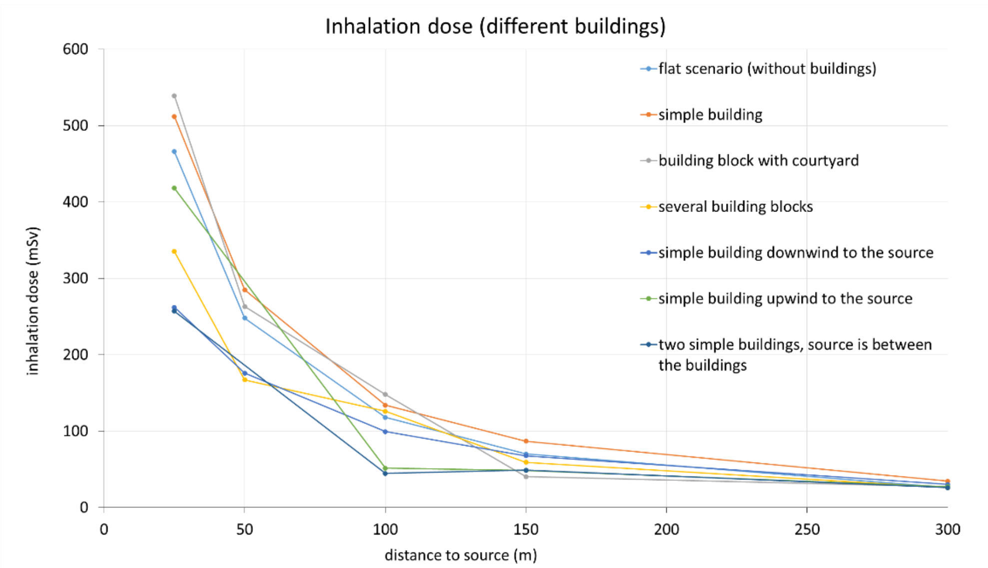

Figure 3. Overview for the inhalation dose [mSv] of an arbitrary radionuclide and activity in six different building scenarios compared to the flat scenario (without buildings).

SUMMARY

The Decision Support Model LASAIR has proven to be a quick and easy to handle tool for operational use within microscale nuclear emergency scenarios and has been applied successfully within exercises and model intercomparisons.

A special feature of LASAIR is the consideration of building effects within a city based on a simple mass consistent flow model Lprwnd. It can be seen from cases studies that depending on the kind of building scenario the inhalation dose can be higher or lower according to either the mechanical induced turbulence or due to downwind turbulent wake effects. As for this, it seems obvious that the building wake effects should be taken into account if ever possible in such an emergency situation. The downwind distance of the effects from buildings in this study reaches up to 200 m away from the end of the building and might reach even further as the buildings dimensions used in this study had only a limited range. Further studies (not listed here due to constraints of page number) showed that the influence of building blocks perpendicular or with an angle close to 90° is able to shift significantly the main dispersion lateral and downwind.

The Decision Support Models used in such situations therefor should have the possibility to consider buildings and implement the building situation as quick as possible into the model in order not to spend too much time during the emergency itself. LASAIR provides the possibility to define the actual buildings within a few minutes. However this feature will be improved in future as there is a chance to load building scenarios at least for main cities automatically via the internet into the program.

REFERENCES

von Arx, C., Glaab, H., Grimm, Chr., Martens, R., Päsler-Sauer, J., Scheuermann, W., Schnadt, H. , Schumacher, P., Torchiani, S., Walter, H., Wilbois, T.: Vergleich aktuell eingesetzter Modelle zur Beschreibung der atmosphärischen Ausbreitung radioaktiver Stoffe. Abschlussbericht zum Arbeitspaket AP5500 im Projekt A510 der Strahlenschutzkommission, Bundesamt für Strahlenschutz (BfS), BfS-SCHR-58/16, 2016.

Janicke, L., 1983: Particle Simulation of Inhomogeneous Turbulent Diffusion. Air Pollution Modelling and its Application, (ed. Weber). Plenum Press, N.Y., 527-535.

Janicke, L., 1985: Particle simulation of Dust Transport and Deposition and Comparison with Conven-tional Models. Air Pollution Modelling and its Application, IV, (ed. C. de Wispelaere). Plenum Press, N.Y., 759-769.

Janicke, U, Janicke, L., Weiterentwicklung eines diagnostischen Windfeldmodells für den anlagenbezogenen Immissionsschutz (TA Luft), Umweltforschungsplan des Bundesministeriums für Umwelt, Naturschutz und Reaktorsicherheit, Anlagenbezogener Immissionsschutz, Förderkennzeichen (UFOPLAN) 203 43 256, Oktober 2004

Prouza, Z:, V. Beckova, I. Cespirova, J. Helebrant, J. Hulka, P. Kuca, V. Michalek, P. Rulik, J. Skrkal and J. Hovorka, 2010: Field Tests using radioactive matter, Radiation Protection Dosimetry (2010), pp. 1–13.

VDI-Richtlinie 3783, Blatt 8, 2014: Umweltmeteorologie, Messwertgestützte Turbulenzparametrisierung für Ausbreitungsmodelle, Environmental meteorology – Turbulence parameters for dispersion models supported by measurement data, 15. Vorentwurf, 2014-06-03, to be published in 2016..

Thiessen, K.M., K.G. Andersson, V. Berkovskyy, T.W. Charnock, S.L. Chouhan, G. de With6, J. Ďúran, V. Fuka, J. Helebrant, J. Hůlka, W.T. Hwang, P. Kuča, F. Mancini, E. Navarro, R. Periáñez, Z. Prouza, G. Sdouz, J. Tomás, D. Trifunović, L. Urso, and H. Walter: Assessing emergency situations and their aftermath in urban areas: The EMRAS II Urban Areas Working Group International Conference on Radioecology & Environmental Radioactivity (ICRER 2011), Hamilton , Canada.

Walter, H. and G. Heinrich, 2014: The Decision Support System LASAIR: New features for evaluating Dirty Bomb scenarios in: Proceedings of the 16th International Conference on Harmonisation within Atmospheric Dispersion Modelling for Regulatory Purposes, Varna, Bulgaria, 8th – 11th September 2014.

Walter H. and, G. Heinrich, 2011: Quick and clean: Dirty bomb scenarios evaluated with the decision support system LASAIR. ICRER 2011, Hamilton, Canada.