Peter Boeker, Peter Schulze Lammers, Oliver Wallenfang, Martin Wittkowski, Bernd Diekmann, Michael Griebel and Frank Koster, Bonn

Tracer measurements for validating odour models

Spread models are computer-based numerical models especially created for the prognosis of the spreading behaviour of materials in natural wind currents. Through the required simplification and additional assumptions, the simulation results must be compared with real data in order to check the validity of the model. Field measurements were made of the spread model NaSt3D. Model calculations and measurements gave a good agreement and confirmed the application suitability of the model NaSt3D for odour spread simulation.

Dr. Peter Boeker is senior engineer at the Institute for Agricultural Engineering of Bonn University, Nussallee 5, 53115 Bonn; e-mail: boeker@uni-bonn.de.
Prof. Peter Schulze Lammers is manager of the Bioprocess Technology Department, Dipl.-Phys. Oliver Wallenfang and Martin Wittowski are members of the scientific staff at the same institute.
Dr. Bernd Diekmann is private reader at the Institute of Physics, University of Bonn.
Prof. Michael Griebel is manager of the Department of Scientific Calculation and Numerical Simulation at the Institute for Applied Mathematics, Dipl.-Math. Frank Koster is a member of the scientific staff there.
This project 74151 was supported by the German Research Society (DFG).

A refereed paper for LANDTECHNIK, the full-length version of which can be accessed under LANDTECHNIK-NET.com

Keywords

Odour model, validating, measurement technology

The modelling method for complex system relationships has developed into a new branch of applied natural science [1]. High available calculation capacities make possible comprehensive analyses of systems and system models which can be applied for the prognosis of real relationships. In this case, the term models is understood to mean computer-based numerical models.

In applied natural science, computer-based models are used in simulations. In this respect, one also speaks of “numerical experimenting”.

The validating of models establishes their suitability for the purpose in question. The validating is carried out with real data the reproduction of which must be performed by the model within the required limits of precision.

Spread models and fluctuations

Spread models are applied to forecast the polluting effect of emitted polluting and odour materials.

The three part-aspects involved in the distribution of a material are known by the terms emission, transmission and effects. Spread models are applied for calculating transmission. So-called Gauß models are distributed and they give an analytic interpretation of the spread under very simplified conditions. Numerical models are in the position to carry out detailed flow and spread calculations but require a high calculation input. Characteristic of all models applied up until now is that they forecast the average polluting effect.

As opposed to pollutant material entries, odours are not completely characterised through the average value of the pollutant concentration. Odour recognition begins only from the odour threshold value below which concentrations do not lead to pollution.

Models of the new generation can now calculate not only the average, but also the timed series, of concentration alterations [2]. Calculation of the flow field and spread are in this case no longer carried out consecutively but simultaneously. The flow calculation is not carried out from a stationary position and this means that a continuous following of the momentarily flow conditions, and of the associated spread, it is possible. A special model matched to the odour spread is the NaSt3D from the Institute for Applied Mathematics, University of Bonn (Work Group: Prof. Michael Griebel).

Validating of spread models

Nature data are required for the validating of spread models. Used as test data applications, these allow the performance of the models to be evaluated. According to the demand and the complexity of the models, various data are required. Spread models for forecasting averages require only measured pollution average values, models for simulating the fluctuations require on the other hand a timed recording of the effects.

In the collection of test data, all meteorological, topographical and data from the emission side which have an influence on the spread occurrence have to be recorded. These data represent the model input in simulation calculations. Complementary to this, the pollution side data which are compared with the results of the simulation calculation, have to be recorded.

Fig. 1: Vehicle for mobile tracer gas measurement; 1. Ultrasonic anemometer; 2. SF6 – tracer gas measurement instrument; 3. GPS position receiver; 4. Data recording and storage; 5. Electricity supply and tracer gas basic instrument.

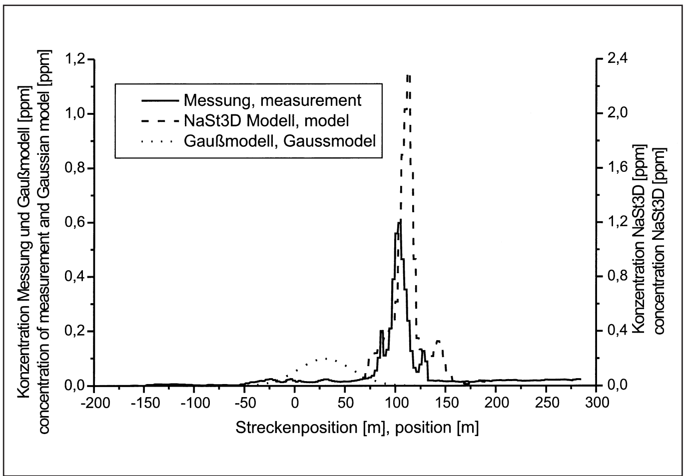

Fig. 2: Measurement and simulation of the tracer concentration across the plume

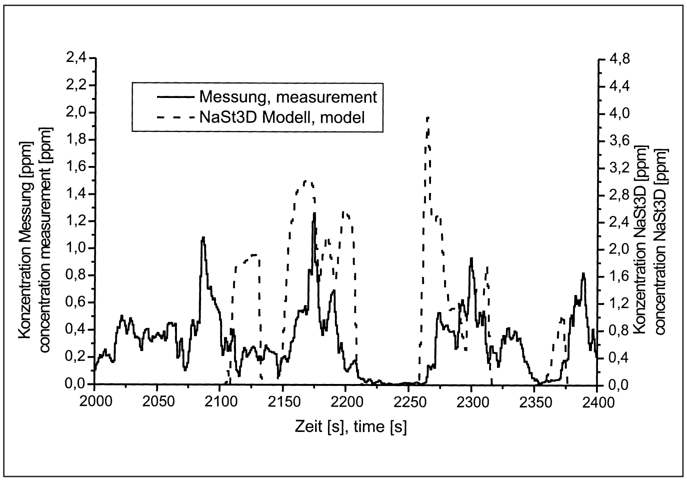

Fig. 3: Stationary measurement and simulation of the tracer concentration

Tracer measurement technology

Odour measurements which are direct and highly resolved according to time have been impossible up until now. Electronic noses which carry out a type of odour measurement are not yet sensitive enough for a direct measurement and so far not applicable for field measurements. Thus the method requires substitute measurement parameters. Instead of odour materials, other gases which can be measured sensitively and over a period of time are set free at the emission point.

A few requirements are needed for tracer gases:

- Non-toxic with no negative effects on the environment
- Low background concentration
- Reaction inertia and minimal solubility
- Easy and sensitive traceability

Able to be used as tracer gases can be krypton [3], propane [4] and the gas applied in this case, sulphur hexafluoride (SF_6) [5]. Radioactive krypton (^{85}Kr) can be measured sensitively and rapidly with Geiger-Müller Count Pipes, but its use, however, requires a special permit. Because of the importance of protection against explosions at the emission point, propane is not unproblematic as tracer and is also difficult to measure selectively. Sulphur hexafluoride offers all the properties required of a tracer and because of this was used in the study presented here.

The measurement of the tracer took place with a modified leak search instrument. The instrument worked with an ECD (Electron Capture Detector).

Measuring method

Tracer emission

Estimates of the amount of SF_6 emitted and the expected pollution concentration were required for the recording. The Gauss model was applied for these estimations because, as a validated model, this allowed an estimation on the 'safe side'. The emission took place out of a 10 kg pressure bottle with self-constructed instrumentation comprising pressure minimiser, manometer, suspended material measuring instrument and control valve.

The mobile measurement system

The pollution was measured with a mobile test vehicle because recording from a fixed point in the variable wind conditions would have meant the instrumentation having to be adjusted often or measurement from a number of points. The basis of the measurement vehicle was a four wheel drive cross country machine with a platform for the measurement equipment (*fig. 1*).

In addition to measurement of tracer gas, local wind conditions were recorded with an ultra-sonic anemometer. Position was established to a precision of around 1 m by GPS receiver. The data was synchronised via notebook and recorded at a measurement rate of 1 sec.

Results of the validating measurements

Two variants were measured for the validation of the spread model NaSt3D. For establishing the form of the spread plume, drives were carried out across the plume. For determination of the fluctuations, local measurements were recorded. The driving through the odour plume enabled the balancing-out of the turbulent diffusion parameters from the breadth of the adjustable size in the model NaSt3D. According to this size, the material either split up more or less. The result of a plume cross drive is presented in *figure 2*. For comparison, it is calculated according to the Gauß model, the measured, and the NaSt3D simulated, concentration development given. As expected, the averages according to the Gauß model are considerably lower that the momentary values of a concentration plume. The additionally presented simulation shows a comparable breadth of plume but, because of the current stage of model development (non- inclusion of thermal effect), still manages to overcalculate the value by a factor of four.

Figure 3 shows the measuring and the simulation comparison with stationary recording featuring different plume transmissions and intermittent phases (phases without pollution effects).

Summary and outlook

The recording of validation data is necessary, especially for models with integrated calculation of the fluctuation because little respective data is available. The use of the tracer gas sulphur hexafluoride outdoors, in combination with a modified leak seeking instrument, revealed itself as a practical method. The flexible installation of the measurement instrumentation onto a mobile recording vehicle enabled very efficient measurement operations with minimum material expenditure.

Literature

[1] *Schweber, S.* and *M. Waechter*: Complex Systems, Modelling and Simulation. Studies in History and Philosophy of Science Part B: Studies in History and Philosophy of Modern Physics (2000), No. 4, pp. 583-609

[2] *Boeker, P., O. Wallenfang, F. Koster, R. Croce, B. Diekmann, M. Gabriel* und *P. Schulze Lammers*: The modelling of odour dispersion with time-resolved models. Agrartechnische Forschung 6 (2000), H 4, S. 84-89

[3] *Lung, T., H.-J. Müller, M. Gläser* und *B. Möller*: Messung und Modellierung von Konzentrationsfluktuationen für Gerüche. KTBL Sonderveröffentlichung zum KTBL/FAL-Fachgespräch, 24./25.10.2000, Braunschweig, 2000, Nr. 031 52-59

[4] *Mejer, G.-J.*: Messungen zur Ausbreitung luftfremder Stoffe im Bereich bodennaher Punktquellen. Grundlagen der Landtechnik 37 (1987), H.6, S. 221-227

[5] *Zenger, A., A. Ruhling, W. Bachlin* und *A. Lohmeyer*: Tracergasuntersuchungen zur naturgetreuen Simulation von atmosphärischen Transport- und Mischvorgängen im Rahmen von Umweltverträglichkeitsprüfungen, Staub. Reinhaltung der Luft 54 (1994), S. 51-54