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Expansion modelling of odours in time-dissolved models

The new odour expansion model presented in this report is based on the program packet NaSt3D and, through special modifications, is matched to odour expansion.
The model makes time-dissolved calculations possible so that the important question of for odour identification of concentration fluctuation can be calculated without auxiliary models. The odour expansion model contains an improved advection-diffusion algorithm with a higher-level approximation and a Lagrange calculation for particle modelling.

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Literature details are available from the publishers under LT 00412 or via Internet at http://www.landwirtschaftsverlag.com/landtech/local/fliteratur.htm.

The measurement and prognosis of emissions in the locality of odour sources poses a special problem. The stress-effect of odour is not defined through an average material damage but instead through the time the odour threshold is exceeded in each case. it is through this that the special difficulty of measurement calculated prognosis is presented in contrast to other gas damage. Integrating or averaging measuring systems do not record the exceeding of the maximum values and standard calculation programs are based on the calculation of average values.

For this reason one is up until now dependent on the human nose, be it through inspections in the area, or via olfactometer. The expansion calculation utilises model concepts which, with help from empirical calculations, depict the variations in average values. This situation is very unsatisfactory in all contested planning or building development permission cases in that substantial changes in model forecasts are associated with the choice of the additional data.

Thus odour expansion models which calculate wind currents in detail, even in complex, built-up locations, as well as carry-out a simultaneous calculation of the local odour concentration at every time period, should be aimed for. A few years ago such aims were only Utopian but with the new computer generations and especially through rapid, parallel calculation-algorithms such an approach has now become possible.

Via examples, this paper will describe the new odour expansion model NaSt3D in the context of the actual state of calculation methods.

Overview of current methods

The basis of the usual expansion prognoses are Gauß-type models. These report on the distribution of a released material in the wind field showing the expansion pattern of the smell. The club-shape is characterised through a Gauß-formed concentration distribution in both lateral directions and from this comes the name "Gauß-model" . The model conditions of the Gauß model are very rigid: uninterrupted spread, absolutely no obstacles in the dispersal area, constant wind direction and velocity. To introduce the Gauß model into real conditions, parameter calculations are necessary for the most different classes of odour expansion. These are achieved through complicated calibration measurements. One advantage of the Gauß models, which has led to their dominating position, is the rapid calculation possibility. The analysis of odour concentration is given directly for every location point, even complete annual prognoses via a wind and expansion class statistic is able to be calculated very quickly.

Especially in the locality of an odour source, it is not possible to aim for reliable results with Gauß models. For this reason Euler expansion models on the basis of numerical grid models are used in such cases. As an example in this case, we take the model MISKAM. MISKAM calculates the wind currents on a calculation grid (typical grid cells 40(40(20) with the Navier-Stokes equations. Wind current obstacles such as buildings and vegetation can be fairly well represented in the grid cells through appropriate settings. The wind current field calculated via MISKAM is stationary, through the chosen surrounding conditions and the limited number of grid cells for every wind direction and speed. Smaller turbulences are, therefore, not taken account of. Only in the second stage does MISKAM calculate the material expansion with an advection-diffusion algorithm. The concentrations finally calculated by MISKAM for every grid cell thus also present average values and for odour prognoses must , just as with the Gauß models, be combined with a calculation to find the frequency with which the odour threshold is exceeded.

Typical formulae for the calculation of odour threshold excess is the Factor 10 model according to TA air [1] and the formula BAGEG [2]. The factor 10 model sets the limit value for a period of time affected by an odour over the threshold via a calculated average value of 0.1 odour units (GE). In practical evaluation, the static Factor 10 is in part altered in the process of an adjustment regarding inspection values. The BAGEG calculation is analytically-based and offers via a parameter the possibility of adjustment to suit the individual case. BAGEG defines a functional association of the average concentration and the associated probability of overstepping the threshold. Through plume inspections the parameter is matched to the individual case.

Out of the associations thus presented it is clear that odour prognoses can be reached over a three-way path: calculation of the flow area, calculation of the expansion of the flow area, calculation of the frequency with which the odour threshold is surpassed. Each of these steps has insecurities and emperic prerequisites. Because of this, a model calculation would be desirable that generally integrates the three calculation steps and thus realises a model especially suitable for depicting odour expansion.

Odour expansion model NaSt3D

The model description NaSt3D [3] is derived from the Navier-Stokes 3-dimensional. Like MISKAM, the model is a grid-based numerical flow and expansion model. An important difference in the program-technical side lies in the parallelisation and object orientation of the calculation code. The paralillisation enables a distribution of the calculations over several processors with associated increase in performance. The object orientation holds the program code open for extensions. NaSt3D also utilises the latest types of rapid numerical solution processes. These program-technical possibilities are complemented through surrounding conditions which are kept free. As opposed to MISKAM, these enable reality-near simulation.

The separation between flow calculations and expansion calculations is removed by NaSt3D. The numerical calculation takes place in (very small) time steps. In each step the development of the flow is calculated through the Navier-Stokes equation, and the associated expansion through an expansion model. As a rule, therefore, an NaSt3D calculation will never be completely stationary (which is the breaking-off criterium with MISKAM). Instead, fluctuations created by turbulence are reproduced. Through the simultaneous calculation of material expansion in the flows is calculated thereby also the concentration fluctuations over time. With these time series the frequency distribution of the odour values is available directly, without a model extension such as with the Factor 10 model.

Through the simultaneous flow and expansion calculation NaSt3D can additionally calculate under varying single flow conditions. Variations in the wind direction result in a meandering of the odour plume and, with this, a strong variation in the odour stress values when such a meandering plume moves over the source locality. With models used up until now, this meandering could not be reproduced.

Two different expansion models are available for NaSt3D, an improved advection-diffusion calculation and a Lagrange calculation which is described below in more detail.

Lagrange particle calculation

The expansion calculation with the Lagrange Particle model is especially suitable for odours. Simultaneously to the calculation of the flow, the movement curve of virtual particles is followed in each case with free definable mass. In order to be able to use the particle number density for calculating once again the concentrations, a large number of particles (several 100,000) must be calculated. Through the interpolation of the flow area in the grid cells there appears no effects comparable with numerical division – only controllable with Euler models via high numerical effort. The expansion calculation is therefore independent of the grid orientation. The Legrange model has further advantages for odour problems. The behaviour of odour material bound to dust can be better simulated over freely-choosable mass. As opposed to the case with gases, the sedimentation is thus reproducible. Chemical alterations can be recorded over the individual ages of the particles, e.g. the oxidation of odour materials.

Application of NaSt3D in expansion calculations

In combination with the Lagrange particle model, the NaSt3D is capable of delivering very detailed information. The flow preliminary stages in the near vicinity of buildings and other flow obstacles are especially problematical and cannot be calculated with normal Gauß models. The different expansions from a high source and a low source are presented by an illustration in *fig. 1*. While the high source created a plume with reduced distribution, through the wash-down effect of the emissions from a lower source behind the building, there resulted emissions partly distributed and partly accumulated in a backflow area.

The meandering of the expansion plume is shown in *fig. 2*. The calculation was carried out with wind data measured during a tracer expansion experiment. The varying wind directions and speeds were used as starting data in the calculation. The formation of a meandering plume is clearly to be seen.

Summary and Outlook

NaSt3D means a new prognosis program especially suited to odour expansion is now

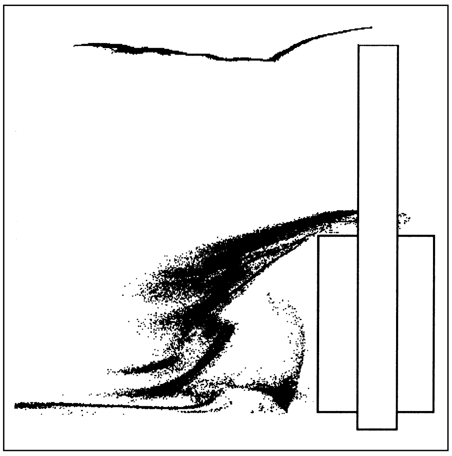

Fig. 1: Dispersion behind a low and a high emission source

available. The program integrates the flow and the expansion models and the model for the threshold surpassing probability. At the moment, work is being done on the calibration of the model NaSt3D through tracer experiments in order to determine the influence of the dissipation energy. In order to increase user-friendliness, the enter interface for topologies and source configurations, and a program for annual odour damage prognosis is being developed.

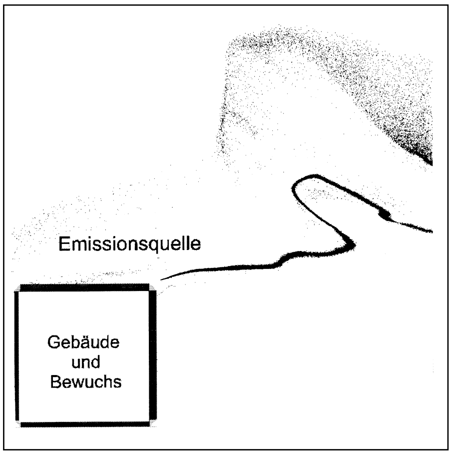

Fig. 2: Meandering odour plume in model NaSt3D