# Pollutant Dispersion in the Vicinity of Tunnel Portals

A contribution to subproject SATURN

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## Summary

During the year 2001 the research work of the group was mainly dedicated to the investigation of the particular dispersion conditions in the vicinity of road tunnel portals. $SF_6$-tracer tests were performed in the vicinity of a road tunnel portal in Austria, and theoretical work was done to develop a suitable dispersion model for road tunnel portals. Seven tracer experiments on two days formed the basis for the model development. The main results that could be drawn from the field measurements were a strong dependency of the jet stream from the tunnel portal on the ambient wind field. This specific effect was found to be more important than the diffusion due to shear stresses along the surface between the jet stream and the ambient wind field. A rather simple dispersion model could be developed, which is based on a Lagrangian formulation of the dispersion process. The model is able to treat the momentum of the jet stream, buoyancy effects due to temperature differences between the jet stream and the ambient air, and the influence of changing wind directions of the ambient flow on the position of the jet stream. It is

the first time, that the latter process is considered in a dispersion model for road tunnel portals.

## Introduction

Increasing road traffic, especially in and around cities, demands for practical solutions to avoid major congestions and to keep away the noise and air pollution from residential areas. Roadway tunnels become more and more the solution for all these problems, but they also may cause high pollution concentrations in the vicinity of the portals, when a tunnel is ventilated longitudinally. This is mostly the case in one-way roadway tunnels, because the thrust of cars inside the tunnel then supports the ventilation and thus, saves running costs.

There is a strong need for air quality models, which can treat the special dispersion conditions from tunnel portals and in addition, which are suitable for environmental assessment studies. Hence, they should require a minimum of computation time on conventional personal computers. From that point of view, Eulerian microscale models (Large eddy simulation, Reynolds averaged Navier-Stokes equations) are not a proper choice for that purpose, since they are not easy to handle, and still consume much CPU-time, if run on a PC. Therefore, such models can mainly be applied for single case studies and their applicability to calculate statistical concentration values (percentiles, annual mean) is rather limited. In addition, the computational domain has to be kept small, and it is not always possible to calculate an adjacent street network or other sources (point, area) simultaneously.

## Activities

Activities during 2001 were the set up and implementation of seven $SF_6$-tracer tests in the vicinity of a road tunnel portal situated in an inneralpine basin in Austria. Approximately 25 receptors were mounted 1 m above ground level around the portal up to distances of 200 m. Meteorology was observed by means of three sonic anemometers, one installed 10 m a.g.l. to capture the ambient wind flow, and the others installed at street level to allow for turbulence measurements of the jet stream. Two tracer tests were performed at the southern portal of the Katschberg tunnel in Austria, which is situated in highly complex terrain. In the course of the year a simple dispersion model could be developed and tested against all tracer tests.

## Results

One important process found in the investigations of the tracer experiments conducted, was the influence of the changing ambient wind field direction (meandering) on the position of the jet stream of the tunnel portal. The position changes are of the order of decameters, while the characteristic length scales of eddies evolving at the surface between the jet stream and the ambient wind field are of the order of some meters. To the best of the authors knowledge it is the first time that this effect is being described and included in a dispersion model. The model is based on a Lagrangian formulation, i.e. single particles are tracked, whose velocities are determined by the prevailing ambient wind field and the features of the jet stream (exit velocity, temperature difference between the jet stream and the ambient wind field). Buoyancy effects are accounted for in the model in following the suggestions of Van Doop (1992) for point source releases. The computation of the shape of the jet stream is largely based on Bernoullis equation. For instance, it is assumed that the ambient wind causes a pressure upon the jet stream, which changes the direction of the jet stream and slows it down or accelerates it depending on the wind speed differences between ambient wind and jet stream. After a certain time the jet stream owns the same wind speed and direction as does the ambient wind field. The subsequent calculations are then implemented with the dispersion model GRAL (Oettl et al. 2001a, Oettl et al. 2001b).

Fig. 1 shows one example of calculated concentrations with the new model for one SF6-tracer tests.

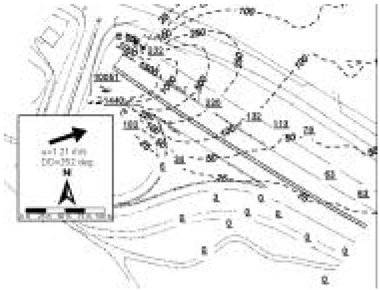

**Figure 1.** Modelled (Italic numbers, dashed lines) and observed (underlined) concentration distributions for test 1 of the tracer experiments near a motorway road tunnel in Austria.

It can be seen, that there is a fairly good agreement between observed concentrations and modelled ones. Observations were also compared to simulations with a microscale Eulerian model, which does not account for the particular dispersion process as described above. The Eulerian model, which uses a k-å turbulence model, overestimates concentrations at the centre line of the jet stream by about a factor of ten. The reason is most probably the neglecting of the changing wind directions of the ambient wind field and the resulting changes in the position of the jet stream.

## References

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## List of publications in 2001 and aims for next year (i.e. 2002)

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## Aim for the coming year

It is planned to perform additional tracer tests at other tunnel sites to generate data sets for the validation of the new model. A national research project regarding dispersion during low wind speeds is being proposed to further investigate the particular problems in such situations (meandering, non-stationary flows, etc.).