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Modelling the driving mechanisms of pollutant dispersion in urban street canyons

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Air pollutrion is a major concern for people living in urban areas and local authorities dealing with its assessment. The scenarios causing greater concern are those associated with calm wind conditions and high traffic volumes. Operational dispersion models, such as ADMS-Urban and WinOSPM, are increasingly employed to assess the impact of traffic pollution within urban streets, and to help identify appropriate abatement strategies because of their low running cost. However, urban dispersion models perform relatively poorly under low wind speed conditions. This may be partly due to the lack of accurate parameterisations of traffic producing turbulence (TPT) in the models. Under low wind speed conditions, TPT may outweigh the contribution of the wind field in diluting traffic-related pollutants. This justifies the need to accurately study and quantify such a process using experimental and computational techniques. However, field experiments cannot isolate the contribution of traffic producing turbulence from other sources of mechanically induced turbulence within the street. Wind tunnel experiment, though very usefull for model validation, have certain limitation related to scaling and other practical constraints. For that reason, Computational Fluid Dynamics (CFD) is adopted in this study in order to improve our understanding of the dispersion processes in urban streets. CFD has proved to be a useful tool in characterising the driving mechanisms of pollutant dispersion within urban street canyons, also providing high resolution flow-details that can hardly be captured in field experiments.

The aim of this study is to provide useful operational parameterisations for the turbulence processes governing the dispersion of pollutants within urban street canyons,

which can be included within operational dispersion models for assessing urban air quality. To this scope, a CFD-based methodology for studying the combined effects of atmospheric wind and vehicle movement in an urban street canyon was developed. In particular, the interaction of the two flow fields induced by ambient wind and moving vehicles was studied and the development of organised flow in the wake of vehicles was analysed. In particular, significant transport of TPT to the leeward side of the canyon was detected. This is likely to have a significant impact on the spatial distribution of pollutants emitted in the wake of vehicles, and thus on the concentration detected by the receptors on the road sides, especially under low wind conditions.

Further study was carried out for the parameterisation of TPT in terms of vehicle density and velocity. The results showed that the turbulence generated in the wake of moving vehicles increases linearly with the square of the vehicle velocity, but has a more complex behaviour as a function of the vehicle density. In fact, the TPT rises linearly with vehicle density in the range of 0.02–0.04 m^{-1} and approaches a threshold value (that depends on the vehicle and street dimensions) when the vehicle density is larger than 0.1 m^{-1}. These features are not currently handled by operational dispersion models, which simply account for a linear growth of TPT with traffic density. The new TPT schemes were implemented in the WinOSPM dispersion model. Results for three independent datasets of roadside concentrations have confirmed that for low wind speed and large traffic density scenarios, the new TPT formulations improve the model performance, allowing more reliable predictions.