AN URBAN SCALE STUDY OF POLLUTANT DISPERSION IN ROME

Andrea Amicarelli[1], Matteo Ferrucci[1], Giovanni Leuzzi[1] and Paolo Monti[1]
[1]Dipartimento di Idraulica, Trasporti e Strade
Università degli Studi di Roma "La Sapienza", Roma, Italia

INTRODUCTION

The growth of population and anthropic activities in many urban areas of the world has produced a progressive deterioration of the air quality. The progress on understanding of urban meteorology and numerical fluid mechanics could furnish a valid aid to improve strategies for environmental management. Numerical tools might be useful to match recent normative on the reduction of air pollution and to provide information extended to the whole urban area rather than to the single locations of monitoring stations. In this contest the authors are trying to develop a forecasting system, that should supply short term forecasting about pollutant concentrations and longer term effects of scenarios changes of vehicular mobility.

In large cities the urban background concentration plays a fundamental role in the whole balance of the pollution. Sometimes background concentration prevails with respect to the concentrations associated to the local emissions and cannot be evaluated by few monitoring stations, because it is not homogeneous within the city. In this paper a preliminary study to evaluate urban background concentrations has been presented. The site studied covers the urban area of Rome and its surroundings. Starting from data on road traffic emissions, the model ADMS-Urban has been applied to the whole city of Rome. The numerical results have been compared against monitoring results.

MODELING APPROACH

The evaluation of the vehicular emissions in a large city is a very hard problem. Starting from some researches on the habits of the Rome inhabitants the Mobility Agency for the City of Rome (STA) estimated the emissions in the Rome area for the peak hour of a typical working day (*Atzori, A.M. et al.*, 2004). The contribution of the single roads was spread on areal sources. Furthermore, a cycle of the mobility factor for a typical working day was derived (Figure 1).

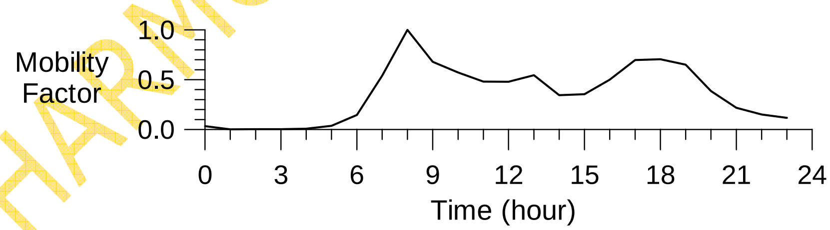

Fig. 16; Mobility factor for a typical working day in the city of Rome.

This factor is defined as the ratio between the number of vehicular displacements in the whole urban area for a generic hour and the peak hour one. In the present paper all the typical working days of the year 2002 have been analysed. In order to discard days with anomalous episodes of vehicular traffic, only Tuesdays, Wednesdays and Thursdays far from not-working days have been considered. Further restrictions have been applied for summer days, rainy days and episodes of low wind speed (< 0.8 m/s). In order to get a complete cycle of emissions for all the sources the peak hour strength of the areal sources has been multiplied by the mobility factor at each hour. For this preliminary study the carbon monoxide (CO) has been chosen as setting pollutant, because of its correlation with road traffic. For the numerical simulation of the pollutant dispersion the model ADMS-Urban has been utilised. This code is a version of the Atmospheric Dispersion Modelling System (ADMS) developed by the Cambridge Environmental Research Consultants (CERC) to evaluate dispersion in complex urban problems (*McHugh, C.A. et al.*, 1997). The model is based on a Gaussian solution of the diffusion equation with point, line, area, volume or grid pollutant sources. In order to calculate dispersion from road traffic sources in urban areas a street canyon model is integrated in the system. Contrary to the other Gaussian models based on the Pasquill stability parameters, ADMS-Urban utilises parametrisations of the boundary layer structure based on the Monin-Obukhov length and the boundary layer height (*Holtslag, A.A.M. and A.P. van Ulden*, 1983; *J.C.R. Hunt*, 1985; *J.C. Weil*, 1985). This approach is defined in terms of measurable physical parameters and generally gives a more accurate prediction of the pollutant diffusion.

In the present study the urban area of Rome and some neighbouring zones have been considered. According to the ADMS-Urban requirements the areal sources have been subdivided into quadrilateral parts. The meteorological data have been obtained from the station of Rome-Ciampino airport, that represents the urban area better than other airport stations located within the Roman area (*Leuzzi, G.*, 2002). At each hour of the selected days wind velocity (intensity and direction), temperature and cloud cover have been entered into the model. For a further site characterisation a surface roughness of 1m and a minimum Monin-Obukhov length of 100 m have been specified.

RESULTS

The model has been run starting at 00 LST of each selected day with the corresponding meteo data file. In Figure 2 are reported the CO concentrations calculated at 3 m above ground level in the whole studied domain on 12 March 2002. On this day a breeze event occurred. At 08 LST (Figure 2a) the land breeze advects the pollutant toward south-west suburban areas. In such conditions the wind is thermally stable and cannot efficacy diffuse the emissions, that are at the peak level. Subsequently the sea breeze grows until the hottest hours of the day. At this time the pollutant concentration decreases, because of the increase of wind speed, convective turbulence and of the emission reduction. In the afternoon the sea breeze drops until the evening, in the meanwhile the emissions increase again, reaching another peak level less pronounced of the previous one. The concentration values are reported in Figure 2b, the plume of pollutant is oriented toward north, advected by the residual sea breeze.

The computed concentrations have been compared with the values measured by the monitoring stations of Rome Municipality. As stressed by *Hanna, S. R.* (1971) and *Berkovicz, R.* (2000), the spreading of road traffic emissions on areal sources is suitable to evaluate urban background concentrations, but cannot takes account of the pollution due to local traffic. Therefore ADMS-Urban, with the adopted set-up, evaluates urban background concentrations. On the contrary the monitoring stations take account of both background and local traffic contributions. If a station is located on the side of a heavy traffic road, the local contribution will prevail on the background one. Starting from a preliminary analysis based on the measurements of all the monitoring stations during hours without emissions, an average concentrations of 0.5 mg/m^3 has been calculated. This value has been considered as a regional background concentration and has been added to all the concentrations calculated by ADMS-Urban. For a less approximate approach an unsteady model should be adopted. In Figure 3 the comparisons between computed and measured concentrations for some of the selected days are depicted. The considered stations was grouped in categories from A to C, according to greater or less exposure to local traffic. The examples in Figure 3 are referred to days with different weather conditions, ranging from breeze events to strong synoptic winds. In almost all the cases two maxima of concentration are present, one in the early morning and the other in the late afternoon. The agreement between calculated and observed concentrations is quite satisfactory for the stations not exposed directly to traffic emissions (Figures 3a-d). A very good agreement is verified with the Cinecittà station (Figures 3a-b), probably because of its vicinity with the Ciampino airport. As foreseen, because of the source settings, the model cannot predict the concentrations at stations located near heavy traffic roads (Figures 3e-f). The discrepancies should quantify the local traffic contribution. A further confirmation of these conclusions can be deduced analysing the errors of the 8 hour averages for all the selected cases (Figure 4). The best agreement is verified with the Villa Ada Station, that is a background station (A category). The agreement is still sufficient for the stations of Arenula, Cinecittà and Preneste (B category), while at the stations of Fermi, Montezemolo and Tiburtina (C category) the model underestimates the concentrations. An exception occurs for the stations Libia and Magna Grecia, that seem to follow a behaviour contrary to their assignation category (respectively C and B).

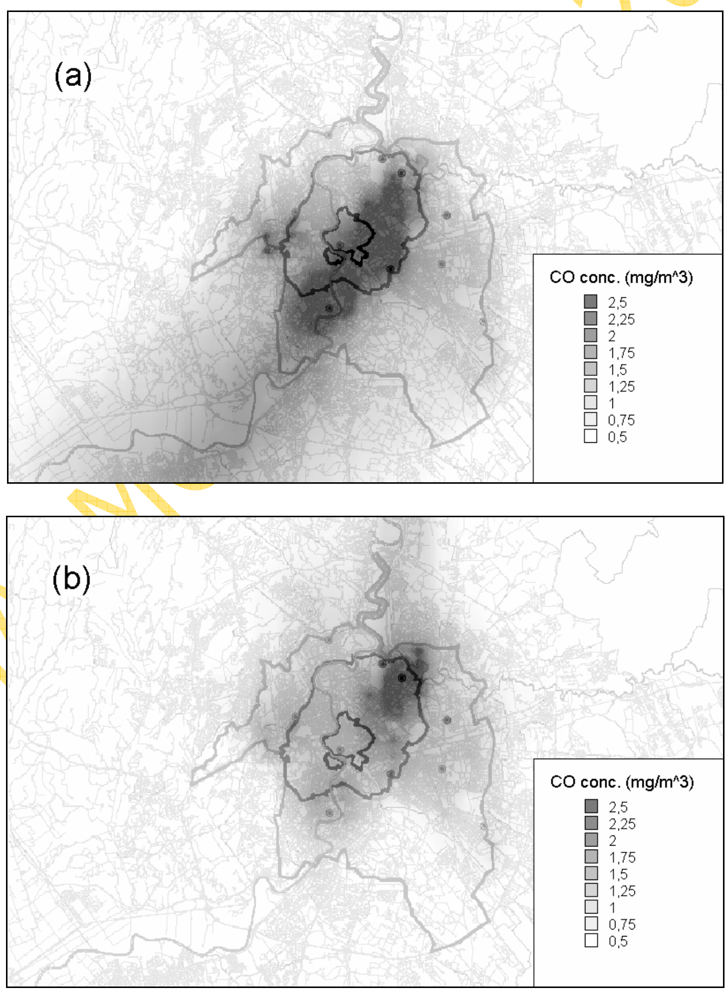

Fig. 2; CO concentrations calculated by ADMS-Urban at 3 m above ground level at 08 LST (a) and at 18 LST (b) on 12.03.2002.

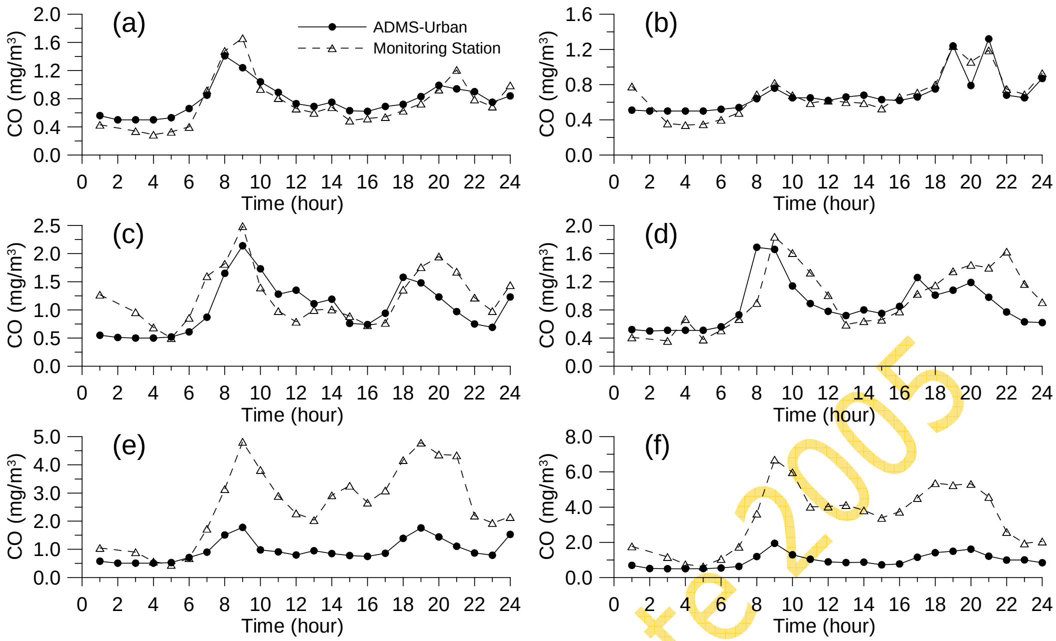

Fig. 3; Comparisons between CO concentrations calculated by ADMS-Urban and measured by monitoring stations of Cinecittà (10 April (a) and 22 October (b)), Preneste (12 March (c)), villa Ada (19 November (d)), Montezemolo (12 March (e)) and Fermi (23 October (f)).

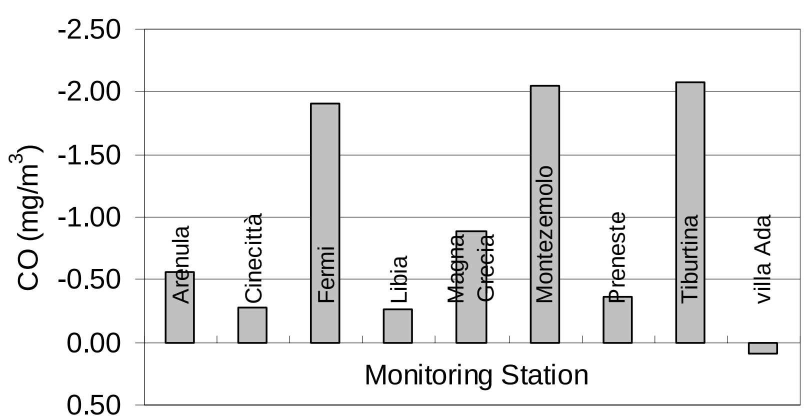

Fig. 4; Errors calculated on 8 hour averages of the CO concentrations for all the selected days and monitoring stations.

CONCLUSIONS

The model ADMS-Urban has been utilised to evaluate the diffusion of pollutant emitted by the road traffic in the city of Rome, during the typical working days of 2002. The emission data of areal sources have been furnished by the STA (Mobility Agency for the City of Rome). The meteo data have been measured at Rome-Ciampino airport. The computed concentrations have been compared with data measured by monitoring stations of the Rome

Municipality. The computed concentrations are in sufficient agreement with measurements taken at locations far from road traffic emissions (station categories A and B). As foreseen, because of the source setting, a systematic underestimation occurs for heavy traffic zones. ADMS-Urban with the adopted set-up seems to give a satisfactory estimation of the urban background concentration.

ACKNOWLEDGEMENTS

The authors are grateful to Drs. F. Nussio and A. M. Atzori of the STA, and to Dr. S. Anselmi of the Rome Municipality for providing respectively the emissions and the monitoring station data.

REFERENCES

Atzori, A.M., E. Donato, F. Nussio, V. Ancidei and A. Bacino, 2004: Valutazione delle emissioni inquinanti prodotte dal traffico veicolare e dei provvedimenti adottati dall'Amministrazione Comunale. Technical Report STA.

Berkovicz, R., 2000: A simple model for urban background pollution. *Envir. Monit. and Ass.*, **65**, 259-267.

Hanna, S.R., 1971: A simple method of calculating dispersion from urban area sources. *J. Air Poll. Control Ass.*, **21**, 774-777.

Holtslag A.A.M and A.P. van Ulden, 1983: A simple scheme for daytime estimates of the surface fluxes from routine weather data. *J. Clim. Appl. Met.*, **22**, 517-529.

Hunt J.C.R., 1985: Turbulent diffusion from sources in complex flows. *Ann. Rev. Fluid Mech.*, **17**, 447-458.

Leuzzi G., 2002: A sensitivity analysis of ADMS-Urban, proceedings of the 8th International Conference on Harmonisation within Atmospheric Dispersion Modelling for Regulatory Purposes, Sofia, Bulgaria, 14-17 October 2002.

McHugh C.A., Carruthers D.J. and H.A. Edmunds, 1997: ADMS-Urban: an air quality management system for traffic, domestic and industrial pollution. *Int. J. of Environment and Pollutution*, **8**, 437-440.

Weil J.C., 1985: Updating applied diffusion models. *J. Clim. Appl. Met.*, **24**, 1111-1130.