International Congress on Environmental Modelling and Software

2nd International Congress on Environmental Modelling and Software - Osnabrück, Germany - June 2004

Jul 1st, 12:00 AM

Numerical Modelling for Studying the Impact of Urban Air Pollution in Natural Reserves around Setúbal City

C. Gouveia

R. Cerdeira

J. M. Garcia

M. Nogueira

L. M. R. Coelho

Numerical Modelling for Studying the Impact of Urban Air Pollution in Natural Reserves around Setúbal City

C. Gouveia[a], .R. Cerdeira[a], J.M Garcia[a], M. Nogueira[b] and L.M.R. Coelho[a]

[a] *ESCOLA SUPERIOR de TECNOLOGIA de SETÚBAL, Campus do Inst. Politécnico de Setúbal, Estefanilha, 2914-508, Setúbal, Portugal*

[b] *IrRADIARE ENGINEERING & ENVIRONMENT, Lisboa, Portugal*

Abstract: Numerical modelling was used to study the impact of urban air pollution from Setúbal City in two important natural reserves. Setúbal is a city in the middle south Portugal with a large resident population, important industry and intense traffic activities. There is an important harbour, which is responsible for intense heavy vehicle traffic. Setúbal is surrounded by two natural reserves, a mountain (Arrábida) and a river delta (Sado River). There is also an important tourist zone near Setúbal with important beaches and tourist activities. The main pollutants considered in this study were SO_2, Particles, NO_x, CO, and VOC. A range of numerical models there was used to produce results. The AMDS-Urban model was used for the pollutants dispersion, the FLOWSTAR model for the meteorological conditions and the MOBILE 6.0 to estimate traffic emissions. One database was made containing information about industry emissions and other emissions in the city. It was also used a geographic information system. Numerical modelling was done considering all models and information coupled and numerical simulations were produced for different emissions and meteorological conditions.

This numerical approach can be successfully applied to other cases to study the impact of urban air pollution. The tourist zone is the most affected by the urban air pollution but both reverses can also be affected manly depending on the meteorological conditions which are mostly depending on the seasonally.

This work has been developed with the financial support of the Fundação para a Ciência e Tecnologia and FEDER under Sapiens Programme (project nº POCTI/MGS/47247/2002).

Keywords: Air quality modelling; Urban air; Numerical simulation

1. INTRODUCTION

The objective of this paper is to present a study on the impact of urban air pollution from Setúbal City in two important natural reserves.

In recent years urban pollution has received special attention due its negative effects on health and deterioration in living conditions. Its possible to add to this effects, the impacts on natural reserves and on native species.

Serious pollution episodes in urban environment are not only caused by sudden increases in the emission of pollutants, but result from unfavourable meteorological conditions. Many studies were dedicated to the relationship between pollution concentrations and meteorological parameters [Pissimanis et al, 1991, Kallos, 1993, Katsoulis, 1988, Robeson and Stein, 1990, Ziomas et al, 1994].

Setúbal is a city in the middle south Portugal, located in the district of Setúbal, 50km South of Lisbon at the margins of river Sado, with a large resident population (113.937 thousand habitants), important industry and intense traffic activities. There is also an important tourist zone near Setúbal with important beaches and tourist activities and two important natural reserves surrounding the city (Sado Estuary and Arrábida's Natural Park), (Figure 1 and Figure 2).

Serra da Arrábida is a mountain (499 metres high) located at West from Setúbal witch has the only surviving example of primitive Mediterranean vegetation with rare species as

(Quercus faginea). The Arrábida Natural Park was formed in 1976 and covers an area of 10.800 hectares. Among the most important mammal species we can find the wild cat (*Felis silvestris*), the genet (*Genetta genetta*) and the mongoose (*Mungos mungo*), as well as various bat species. Some animals are in extinction risks as goat from mountain (cabra montês - *Capra pyrenaica hispanica*). Bird life finds in Arrabida the most unique habitat, with birds of prey being a particularly important group.

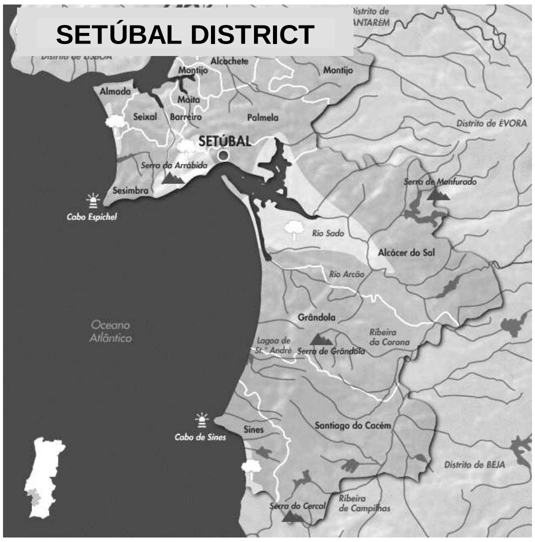

Figure 1. Location of Setúbal (black dot) and Natural Reserves (light grey)

The Natural Reserve of the Sado Estuary was created in 1980 and covers an area of 23.971 hectares. This Natural Reserve is located at South and East from Setúbal and includes important salt marsh areas, commercial fish farms, rice fields and the dunes of Troia with significant examples of flora. Some important mammals such as otters (*Lutra longicaudis*), dolphins (*Tursiops truncatus*), civets (*Arctogalidia trivirgata)*, badgers (Meles meles) and foxes (*Vulpes vulpes*) can also be found. Sado Estuary is also very important for bird migration, the most common of which are white storks (*Ciconia ciconia)*, black-winged stilts (*Himantopus himantopus*), water-hens (*Rallus aquaticus*), kingfishers (*Alcedinidae*) among other species.

The main pollutant sources are traffic, industrial and urban activities. Important traffic fluxes crossing city centre to reach the motorway which links Setúbal to Lisbon or to reach the industrial area. The motorway finishes near the city centre and serves other destinations. Important amount of heavy vehicles move near the city centre to reach the industrial area and the river harbour.

The industrial area is mainly located at East of Setúbal city and the main industries are one fuel oil fired power station (4*250 MW_e), one paper mill industry and a cement industry which is located at West of Setúbal city.
Therefore to assure the ecological equilibrium of this region it is important to preserve these two natural reserves maintaining the equilibrium between the city live, tourist activity and nature live.

The main pollutants considered in this study were SO_2, NO_x, CO, VOC and Particles.

Due the absence of the background data the option was to consider only the primary emissions for calculated PM10.

A range of numerical models were used to produce results. The AMDS-Urban model was used for the pollutants dispersion, the FLOWSTAR model was used for the meteorological conditions and the MOBILE 6.0 model was used to estimate traffic emissions. These models have been extensively validated in several works presented in the literature [CERC 2001, Carruthers et al., 1998]. In the present work due to the absence of background data the main objective is to evaluate qualitatively the impact of pollutant sources in the natural reserves for different scenarios based in same approach.
One database was made containing information about industry emissions and other emissions in the city. It was also used a geographic information system. Numerical modelling was done considering all models and information coupled and numerical simulations were produced for different pollutant emissions and meteorological conditions.

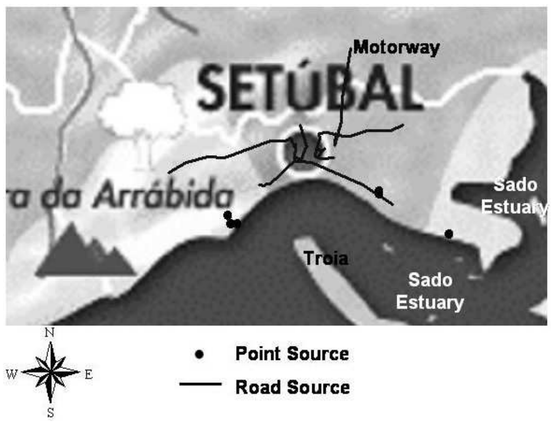

Figure 2. Location of considered sources

2. NUMERICAL MODELLING

2.1 Pollutant emissions

The sources of pollutant emissions were divided in three different kinds, point, line and area sources (Figure 2).

The point sources represent the main industries considered, the line sources the main traffic roads and the area sources representing remain sources as the residential and rural activities, others smaller traffic roads and industries.

The data base of pollutant emissions was created based in values furnished by each industry, and it was considered the mean values for each pollutant [Garcia et al, 2002]. The sources from traffic were based in a study furnished by Setúbal municipality.

MOBILE 6.0 model from EPA (Environmental Protection Agency) was used to estimate traffic emissions.

Area sources were estimated based on the UK emission Factors Database [DETR, 1999], and had considered the main kind of activity of the considered areas (urban, rural and industrial).

The boundary conditions are set to zero. All main pollutant sources in the region are inside the domain considered. All important sources outside the domain as industrial and urban sources are relatively far from Setubal city, so the influence of other sources is considered negligible

2.2 Meteorology characterization

The meteorological data considered in this study were supplied by the Portuguese Meteorological Institute, using climatic acquisition station located in Setúbal, and considering meteorological data covering the period of 1974-1988. Different meteorological conditions were considered and combined with the emission data. The meteorological variables considered were wind speed and direction. Concerning these variables we considered four different scenarios:

- Two most common circulation scenarios: wind from North for: Winter, (scenario A) and Summer (scenario B).
- Unusual circulations from NE: for Winter time with low intensity (scenario C).
- Unusual circulations from NW: for Spring time with high intensity (scenario D).

First two scenarios are the most frequents in Continental Portugal and in this region too and the last two scenarios are chosen due the possible influence on reserves areas (Table 1).

Table 1. Scenarios Frequency

Scenario	*Wind Prob.*
A	31%
B	36%
C	8%
D	17%

These four scenarios were combined with information about atmospheric stability, namely the Monin-Obukhov length. It was considered three typical values for this length; those correspond to the possible situations of atmospheric stability: unstable, stable and neutral. For Setúbal meteorological station, those categories have the following annual mean occurrence (Domingos et al., 1980):

- Unstable: 16%
- Neutral: 47%
- Stable: 7%

The total of possible scenarios in terms of meteorology data was twelve.

2.3 Topography characterization

The topographic data considered in this study were supplied by the Portuguese Geography Army Institute and was computed for the present study using ArcView Software. The selected area is presented in Figure 2 and represents an area de 22kmx15km with the Gauss coordinates represented in Table 2. The grid is regular, with 400 m of spacing in both directions and the topography data was obtained from a grid with 100m spacing.

Table 2. Gauss Coordinates for the study area.

	Min (m)	*Max (m)*
X	-77 000	-55 000
Y	-135 000	-120 000

2.4 Numerical Models

ADMS-Urban 2.0 is a comprehensive PC-based model developed by CERC, of dispersion in the atmosphere of pollutants released from industrial, domestic and road traffic sources in urban areas. ADMS-Urban models these using point, line, area, volume and grid source models. [CERC, 2003].

FLOWSTAR 7.1 is a model developed by CERC to calculate air flow and turbulence over complex

terrain, including the effects of stratification and variable surface roughness. [CERC, 2004]
MOBILE 6.0 is a software application program developed by EPA that provides estimates of current and future emissions from motor vehicles [EPA, 2002].

3 Results

It is observed that for unstable category some particle concentration appears few meters around the chimneys, due to the rising thermals that create stronger vertical motions than horizontal motions. For neutral category the turbulence is isotropic and it is found also some particle concentration near the chimneys. Figure 3 shows particle concentration (PM10) from industries and traffic for scenario B, stable category. The height chimney of the power plant avoids the contamination of the studies areas by particles and SO2 for any scenario and for any atmospheric stability.
Particles from the cement industry affect Arrábida in scenario C and Troia for scenario D but only for stable categories for both. Figure 4 shows particle concentration (PM10) from industries and traffic for scenario D, stable category.
Particles from the centre of the city affect Troia for scenarios A and B but only for stable category. However the values in Troia and Sado river in front of the city are not high. Under scenario C stable category, Arrábida is affected by the plume, although the obtained values for particles (PM10) concentrations are below the limit value referred in legislation. Note that is due to the influence from cement industry and city centre activities together. Under scenario D stable category, a large area of Sado estuary is affected by the plume. However these two scenarios are not very frequent (Table 1).
NO_x concentrations from industries in the studied areas are negligible comparing with the city centre activities. NOx from the city centre in scenarios A and B, stable conditions, affects mainly Troia and the River estuary in front of the city, but with very low concentrations. Arrábida is also affected under scenario C, stable and the River estuary is affected under scenario D, stable.
Important concentrations of CO and VOC appear only in the city centre and are manly due to its activities, for all the scenarios. On the other hand, SO_2 from other sources and for different scenarios do not affect significantly the studied areas.
Traffic sources are important for some pollutant but affect only areas near the roads, comparing with other sources, so it is possible to say that the centre of the city is mainly affected by its own activity.

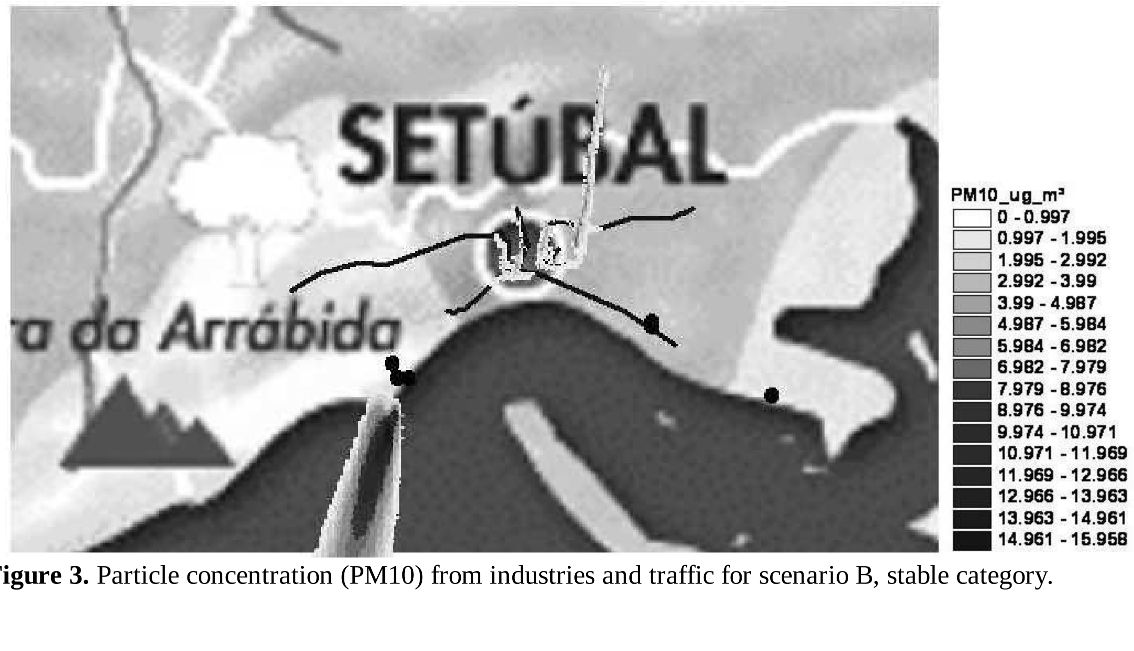

Figure 3. Particle concentration (PM10) from industries and traffic for scenario B, stable category.

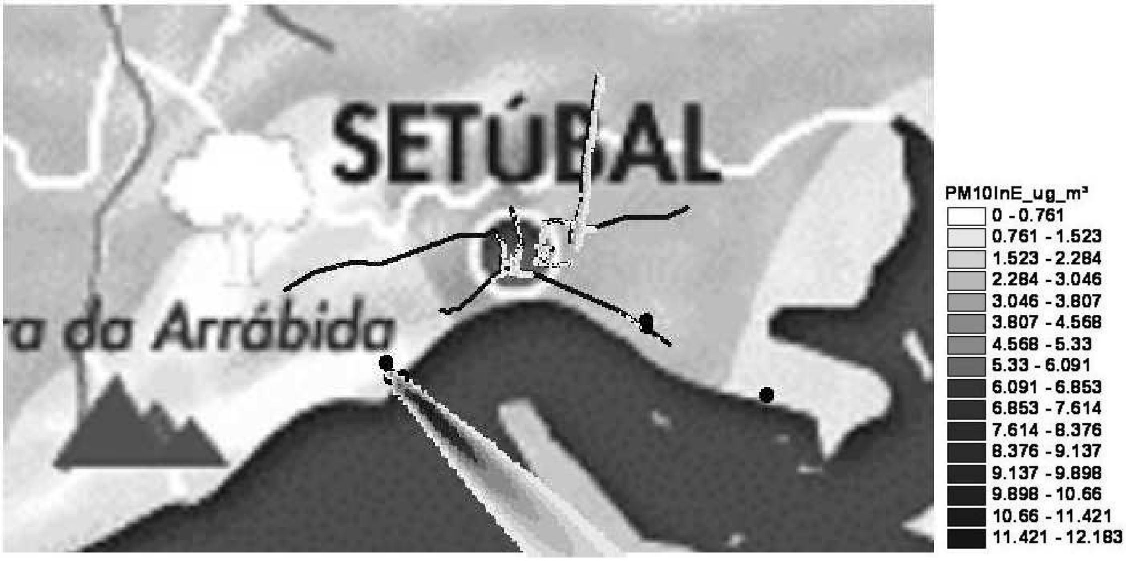

Figure 4. Particle concentration (PM10) from industries and traffic for scenario D, stable category.

4 CONCLUSIONS

The main common meteorology scenarios do not produce any heavy negative impacts in the two natural reserves. The main affected zone is the tourist area (Troia) and the city centre.

The sources considered (industry, traffic and residual urban activities) do not affect significantly the natural reserves for the majority of considered scenarios, due the high frequency of North wind.

Sado is only affected in vicinity of Setúbal, under some particular scenarios, but with no severe impact on the protected area. The most affected zone is Troia, namely by the city centre activities. However, the low frequency of this episodes do not compromise the development of tourist activities.

5 ACKNOWLEDGEMENTS

This work has been performed in the framework of the POCTI program financed by the FCT (Fundação para a Ciencia e Tecnologia of Portugal) and FEDER program, this project has the reference POCTI/MGS/47247/2002. The authors also wish to acknowledge CCDR-LVT by the information provided.

6 REFERENCES

Carruthers, D.J., Edmunds, H.A., Lester, A.E., McHugh, C.A. and Singles, R.J., Use and Validation of ADMS-Urban in Contrasting Urban and Industrial Locations, *Intl. J. Environment and Pollution,* 14, 364-374, 1998.

CERC, Validation of ADMS-Urban and ADMS-Roads Against M4 and M25 Motorway Data, Cambridge Environmental Research Consultants Ltd, 2001

CERC, ADMS-Urban User Guide, Version 2.0, 2003

CERC, Flowstar User Guide, Version 7.0, 2004.

DETR, UK Emission Factors Database, Department Of Environment Transport and Regions, 1999.

Domingos, J.J.D., Pinto, M.F., Pontes, M.T., Ocorrência media anual no território Português das classes de estabilidade atmosférica Pasquill-Guiford. *Técnica*. No 460, Vol XLII, 27-42, 1980.

Garcia, J.M., Coelho L.M.R., Ribeirete, A, Nogueira, M., Machado, P., Magalhães R., Air Quality Analysis in the city of Setúbal – Scenarios generation to support municipality decisions, *Proceedings of Eight International Conference on Harmonisation Within Atmospheric Dispersion Modelling for Regulatory Purposes*. Sofia 14-17 October, 468-473, 2002.

Kalos, G., Kassomenos P., Pielke R.A., Synoptic and mesoscale weathr conditions during air pollution episodes in Athens. *Boundary-Layer Met.* 62, 163-184, 1993.

Katsoulis, B.D., Some meteorological aspects of air pollution in Athens. *Met. Atmos. Phys.* 39, 203-212, 1988.

Pissimanis, D.K., Karras G.S., Notaridou V.A., On the meteorological conditions during some strong smoke episodes in Athens.

Atmospheric Environment. 25B, 193-202, 1991.

Robeson, S.M., Stein D.G., Evaluation and comparison of statistical forecast models for daily maximum ozone concentrations. *Atmospheric Environment*. 24B, 303-312, 1990.

Ziomas, I.C., Melas D., Zerefos, C.S., Bais, A.F., Forecasting peak pollutant levels from meteorological variables, *Atmospheric Environment*. Vol. 29, No 24, 1995.