AIR QUALITY MANAGEMENT, POLICY AND TOOLS SESSIONS

LOCAL AIR QUALITY MANAGEMENT IN ENGLAND: ISSUES AND CHALLENGES IN CONSULTING STAKEHOLDERS
N.S. Leksmono[1], F. Burnet[1], P. Dorfman[1], D.G. Gibbs[2], J.W.S. Longhurst[1], E.L.C. Weitkamp[1] - [1]Faculty of Applied Sciences, University of the West of England, Bristol, UK, [2]Department of Geography, University of Hull, Hull, UK

ASSESSING ALTERNATIVE TRANSPORT SCENARIOS IN RELATION TO UK AIR QUALITY STRATEGY
M. Valiantis[1], T. Oxley[1], H.M. ApSimon[1] - [1] Centre for Environmental Policy, Imperial College London, London SW7 2AZ, UK

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S. Vogelsang[1], C. Kurz[1], P. Sturm[1], D. Oettl[2] - [1] Institute for Internal Combustion Engines and Thermodynamics, Graz University of Technology, Inffeldgasse 21a, A- 8010 Graz, Austria, [2] Styrian Government, FA 17C Technical Environmental Protection and Safety, Air Quality Control Section, Landhausgasse 7, A-8010 Graz, Austria

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Int Panis, L.[1], Beckx, C. [1,3], Broekx, S. [1], De Vlieger, I. [1], Schrooten, L. [1] - [1] Flemish Institute for Technological Research (VITO), Integrated Environmental Studies, Boeretang 200, B-2400 Mol, Belgium
[3] Instituut voor Mobiliteit (IMOB) Hasselt University, Wetenschapspark 5 bus 6, BE-3590 Diepenbeek, Belgium

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[1] Atmospheric Pollution Unit. Department of Environment. CIEMAT. Avda. Complutense 22, 28040-SPAIN,
[2] Instituto de Tecnología Cerámica (ITC). Universitat Jaume I. Castellón. Spain.

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C. Carnevale, G. Finzi, E. Pisoni, V. Singh and M. Volta - Department of Electronics for Automation, University of Brescia, Via Branze, 38, 25123 Brescia, Italy

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C. Carnevale, G. Finzi, E. Pisoni and M. Volta, Department of Electronics for Automation, University of Brescia, Via Branze, 38, 25123 Brescia, Italy

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F.Costabile, G.Bertoni, F.De Santis, F.Wang, and I.Allegrini - Institute for Atmospheric Pollution, National Research Council, Via Salaria km 29,300 C.P. 10, 00016 Monterotondo Stazione, Rome, Italy

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F. Liguori, S. Pillon, F. Dalan, A. Benassi - ARPA Veneto – Italy.

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A.H. Melkonyan- Armstatehydromet, department of Mathematic Modeling of Hydrometeorology, Adrress: Leo54, Yerevan, Armenia, S. G. Tonapetyan- Armstatehydrome, department of Environment Pollution Research, Adrress: Leo54, Yerevan, Armenia, H.A. Melkonyan – executive of Armstatehydromet, Adrress:Leo54, Yerevan, Armenia

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E. Negrenti[1], A. Agostini[1], P. Mudu[2], A. Parenti[3] - 1) ENEA, Italy; 2) WHO-ECEH, Rome, Italy; 3) ASTRAN s.r.l.Viterbo, Italy

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Tymvios F.[1], Constantinides P.[1], Retalis A.[2], Michaelides S.[1], Paronis D.[3], Evripidou P.[4] and Kleanthous S.[5] - [1] Meteorological Service of Cyprus, [2] National Observatory of Athens, Institute for Environmental Research & Sustainable Development, [3] National Observatory of Athens, Institute for Space Application & Remote Sensing, [4] University of Cyprus, Department of Computer Science, [5] Ministry of Labour and Social Insurance, Department of Labour Inspection, Cyprus

THE USE OF GENERALISED ADDITIVE MODELLING TO INVESTIGATE THE AIR QUALITY IMPACTS OF A BUSY ROAD CLOSURE IN YORK, UK.

E. Westmoreland[1], N. Carslaw[1], D. Carslaw[2], E. Bates[3] - [1]Environment Department, University of York. Heslington, York. YO10 5DD, [2]Institute for Transport Studies, University of Leeds, [3]City of York Council

LOCAL AIR QUALITY MANAGEMENT IN ENGLAND: ISSUES AND CHALLENGES IN CONSULTING STAKEHOLDERS

N.S. Leksmono[1], F. Burnet[1], P. Dorfman[1], D.G. Gibbs[2], J.W.S. Longhurst[1], E.L.C. Weitkamp[1]
[1]Faculty of Applied Sciences, University of the West of England, Bristol, UK
[2]Department of Geography, University of Hull, Hull, UK

ABSTRACT
This paper provides evidence from an intensive 2-year ESRC funded programme aimed to investigate the nature, scope and effectiveness of Local Air Quality Management (LAQM) consultation approaches in England. The Environment Act 1995 (part IV) requires local authorities to review and assess air quality in their area of jurisdictions. The Act also provides the statutory basis for consultation. Results are presented from a questionnaire survey of all English local authorities (n=353) and more in-depth case study research. Case study authorities represented different situations in terms of local air pollution problems, administrative structure, and stages in the LAQM process. The limitation of power to address air pollution problem at a local level and differing levels of stakeholder influence and expertise within the consultation process are identified as issues and challenges faced by local authorities undertaken LAQM consultation.

1. INTRODUCTION
Currently in the UK and across Europe, there is a clear move towards the 'upstream' integration of community participation in environmental and health risk communication process (Abram & Cowell, 2004). The idea is that, by broadening and extending the range of stakeholders directly involved in an environmental risk decision-making process, the likelihood of resolving the problem in the long-term is increased. European Union Directive 2003/35/EC on Public Participation in Environmental Plans and Programmes was adopted on 25 June 2003 by the UK government. The Directive transposed the Public Participation Provisions of the pan-European Aarhus Convention into six existing EU Directives where implementation plans must be prepared and reviewed.

England now has some 10 years experience of Local Air Quality Management (LAQM) process where local authorities are required to consult on their air quality findings with stakeholders. The Environment Act 1995, part IV, requires local authorities to review and assess air quality in their area of jurisdiction and determine locations where concentrations of health-based air quality objectives are likely to be exceeded. The Act has also placed an obligation on local authorities to consult with local stakeholders as part of their LAQM process. Schedule 11 of the 1995 Act (HM Government, 1995) and subsequence Policy Guidance (Defra & National Assembly for Wales, 2003) identify a range of statutory and non-statutory consultees, including the public, where their views should be taken into account in the local authority's LAQM decision-making process.

Local authorities are in the third round of air quality review and assessment and over 200 local authorities across the UK currently have Air Quality Management Area (AQMA), which define an area where an air quality objective is not likely to be met and members of the public are exposed to elevated concentrations of pollutants. The LAQM Policy Guidance (Defra & National Assembly for Wales, 2003) recommends wider involvement through the inclusion of non-statutory consultees such as residents and local businesses in the policy development process. Figure 1 illustrates recommendations prescribed in the Guidance on the approach to LAQM consultation. Although there is no need for a full public consultation at each step of the review and assessment process, local authorities should make their findings available to the public. Details about the process of LAQM are provided by Longhurst *et al* (2006).

2. METHODOLOGY
A combination of two research methods was adopted in this research: a questionnaire survey and case study interviews in 11 English local authorities. A semi-structured questionnaire was developed in 2005 to survey the current practice of LAQM consultation and the communication strategies used for that consultation. Survey included all of the English local authorities (n=353) and specifically addressed to the Chief Environmental Health Officer. Prior to questionnaire distribution, a pilot survey was sent out to local authorities in Scotland and Northern Ireland. Case study authorities were selected to provide a wide-spread geographical distribution throughout England, to represent different administrative structures that exist amongst English authorities (district, London, metropolitan or unitary authorities), and whether the authority is with or without an AQMA.

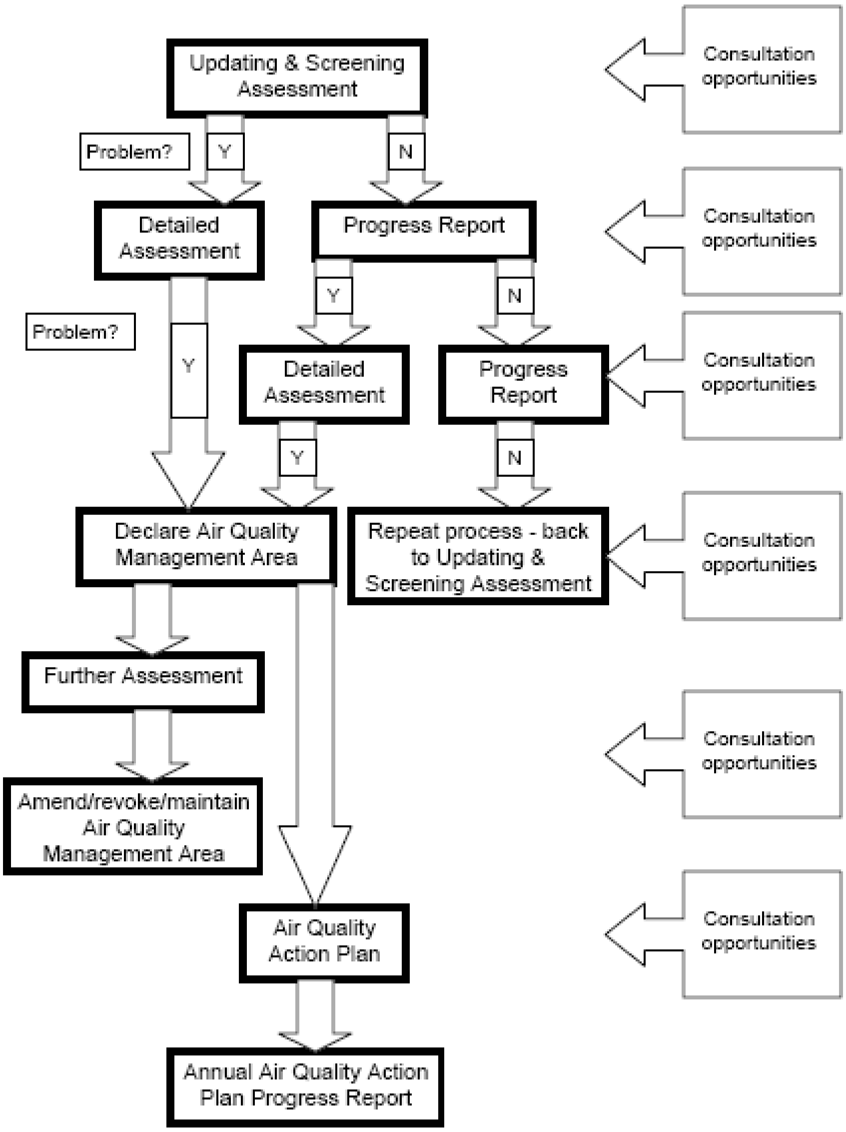

Figure 1. Opportunities for Local Air Quality Management consultation

3. RESULTS AND DISCUSSION

Results suggest that although local authorities were supportive of the idea of greater stakeholder involvement in the LAQM process, the actual process of consultation was generally perceived to be more complex, uncertain and problematic. The outcomes of this research were tested in a series of workshops largely attended by local authorities in England. Workshops participants were in agreement with the outcomes. More information about the workshops can be viewed at www.uwe.ac.uk/aqm/esrc/workshop_outcomes.html.

Of the English authorities, 150 participated in the questionnaire survey achieving a response rate of 42%. The survey showed that LAQM consultation was carried out primarily by environmental health department, on its own (57%) or in partnership with other departments (43%) such as transport and planning departments. A number of issues and challenges faced by local authorities have emerged from both questionnaire and case studies evidence.

Limited power to address air pollution problem at a local level

The vast majority of AQMA declarations in the UK are due to traffic emissions (Longhurst, 2006) and many of the solutions to poor air quality involve reductions in car journeys and consideration of future planning and transport issues. In this context, the effectiveness of intra-organisational working relationships i.e. between the environmental health officers and officers from different departments is critical. Thus, a core feature of enhanced LAQM consultation may be better communication and inter-play of expertise within local authorities. Table 1 provide a list of the most important internal and external stakeholders whom survey participants worked with in carrying out LAQM consultation. The majority of consultation work was undertaken with transport department, followed closely by land-use planners. One case study authority stated that improved communication with planners and transport officers as the most important outcome of undertaking consultation with other departments. Environmental health professionals are increasingly able to advise on planning applications and the development of Local Transport Plan.

Table 1. Stakeholders in Local Air Quality Management consultation

Stakeholders	Percentage
Internal	
Transport	79
Land-use planning	71
Local Agenda 21	33
External	
Regional air pollution groups	74
Neighbouring authorities	70
County council	45

However, measures at a local scale for tackling air pollution are appropriate and cost-effective if air pollution hotspots arise predominantly from a single source, such as an industry and when local authorities are in control of the source (Leksmono, 2005). Otherwise, measures and commitments at a higher level are required. Clear concerns associated with the relative limitation of local authorities in general, and the environmental health department in particular, to address a systemic problem of air pollution at a local level were expressed by participants of the survey and the case study research. A local authority with an AQMA declared to traffic emissions due to motorway networks has limited ability to tackle the air pollution problem. Case study authorities tend to support the suggestion that it may be difficult to fully address systemic problems associated with poor air quality at a local level. Local authorities' efforts for improving air quality must be supported by formal/informal organisations outside the authorities. In the questionnaire, local authorities were asked to identify external stakeholders they had work with in LAQM consultation. Air pollution is a transboundary problem by its nature and data presented in Table 1 highlight the importance of regional collaboration particularly through regional air pollution groups. A case study authority situated in the North West of England organised a workshop event together with other authorities across the region. These authorities declared AQMAs due to vehicle emissions from a busy motorway network.

Differing levels of stakeholder influence and expertise within the consultation process

Schedule 11 of the Environment Act 1995 requires local authorities to carry out consultation with a number of governmental and public bodies such as the Secretary of State for the Environment (Department for Environment, Food and Rural Affairs in England or Defra) and the Environment Agency. The subsequent policy guidance advises consultation with the public, local businesses, and other stakeholders as appropriate.

Table 2. Importance of stakeholders in Local Air Quality Management consultation

Stakeholders	Score*
Defra	1.3
County Council	2.1
Residents	2.1
Residents groups	2.2
Neighbouring authorities	2.2
Environment Agency	2.3
Highways Agency	2.3
Transport department	2.3
Local businesses	2.5
Land-use planning department	2.8
Elected Members	2.8

* = 1 = very important and 5 = not important

Although almost all survey participants (94%) had undertaken LAQM consultation with internal and external stakeholders, there exists a contrast concerning the importance of 'expert' consultees to environmental health professionals carrying out LAQM consultation duties. Defra was viewed as the most significant stakeholder in the process. Table 2 illustrates the importance of internal and external stakeholders consulted on LAQM issues. It is clear that external stakeholders were generally perceived to be more important than officers within local authority department. The survey also revealed that formal organisations dominate the consultation process whilst informal 'non-expert' stakeholders, including the public, were considered of less importance.

Case study evidence supported the questionnaire survey results. Local authorities were struggled to get response from non-statutory consultees, even a local authority with AQMA. Although residents were considered as an important stakeholder in the process of LAQM consultation, local authorities may have tended to limit their engagement with non-experts, and sought to expand dialogue with a range of expert stakeholders, either externally or internally, who were perceived to have a better understanding of, and interest in the underlying science and policy issues.

4. CONCLUSIONS

This paper provides evidence on current practice of LAQM consultation in England specifically about stakeholders consulted, worked with, and the importance of each stakeholder. The limitation of power to address air pollution problem at a local level and differing levels of stakeholder influence and expertise within the consultation process have been identified as issues and challenges faced by local authorities undertaken LAQM consultation. In order to undertake meaningful consultation, it is important to ensure that all stakeholders' views are considered and incorporated into the LAQM decision-making process. Throughout the 10 years or so experience of LAQM process in England, it is clear that better intra-authority LAQM consultation practices have evolved. This is evidenced by greater internal engagement with a broad spectrum of relevant local authority departments, especially that land-use planning and transport departments were seen as the key stakeholders in the process. At regional level, collaboration with neighbouring authorities and county councils has also emerged.

5. ACKNOWLEDGEMENTS

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6. REFERENCES

Abram, S. and Cowell, R. 2004. Dilemmas of implementation: integration and participation in Norwegian and Scottish local government. Environment & Planning C: Government and Policy 22 (5), 701-719.

Defra and National Assembly for Wales. 2003. Local Air Quality Management Policy Guidance. LAQM.TG(03). Defra, London.

HM Government. 1995. Environment Act 1995. The Stationery Office, London.

Leksmono, N.S. 2005. Sustainable, proportionate and cost-effective action plans to deliver air quality objectives within air quality management areas. PhD Thesis. University of the West of England, Bristol.

Longhurst, J.W.S., Beattie, C.I., Chatterton, T.J., Hayes, E.T., Leksmono, N.S., and Woodfield, N.K. 2006. Local air quality management as a risk management process: assessing, managing and remediating the risk of exceeding an air quality objective in Great Britain. Environment International 32, 934-947.

ASSESSING ALTERNATIVE TRANSPORT SCENARIOS IN RELATION TO UK AIR QUALITY STRATEGY

M. Valiantis[1,*], T. Oxley[1], H.M. ApSimon[1]

[1] Centre for Environmental Policy, Imperial College London, London SW7 2AZ, UK

ABSTRACT

Integrated assessment modelling aims to bring together information on emissions, atmospheric transport between sources and exposed areas or populations, criteria for environmental protection, and potential emission control measures in order to explore effective abatement measures. These abatement measures have become increasingly significant in order to meet current policy targets creating the need for integrated assessment modelling to understand and capture changes in behaviour resulting from them.

Focusing upon urban air quality (PM_{10} and NO_2), this work will reflect modelling of emissions from road transport in a manner which allow us to capture some of the dynamics resulting from non-technical measures, such as low emission zones (LEZs), as well as from technical abatement measures such as the use of low emission vehicles (LEVs) - hybrids. The measures are implemented upon the basis of emission factors which are aggregated to provide generic emissions factors for a specified vehicle mix thus providing a tool for implementing certain behavioural changes (such as uptake of LEVs), whereas the derived flow for each road link can capture changes in activity.

1. INTRODUCTION

Many countries are having difficulties in complying with the European Commission's legislation on air quality, particularly for PM_{10} and NO_2. In assessing strategies for future improvement, modelling tools are required for estimating future concentrations resulting from both technical and non-technical abatement measures. These abatement measures have become increasingly significant in order to meet current policy targets creating the need for integrated assessment modelling to understand and capture changes in behaviour resulting from them. The Air Quality Expert Group [AQEG, 2006] also notes these linkages with behaviour, with examples of the effects of aircraft fuel pricing on travel patterns, of fiscal incentives for petrol-diesel switches on technology uptake rates, and of congestion charging and low emission zones on daily activity patterns.

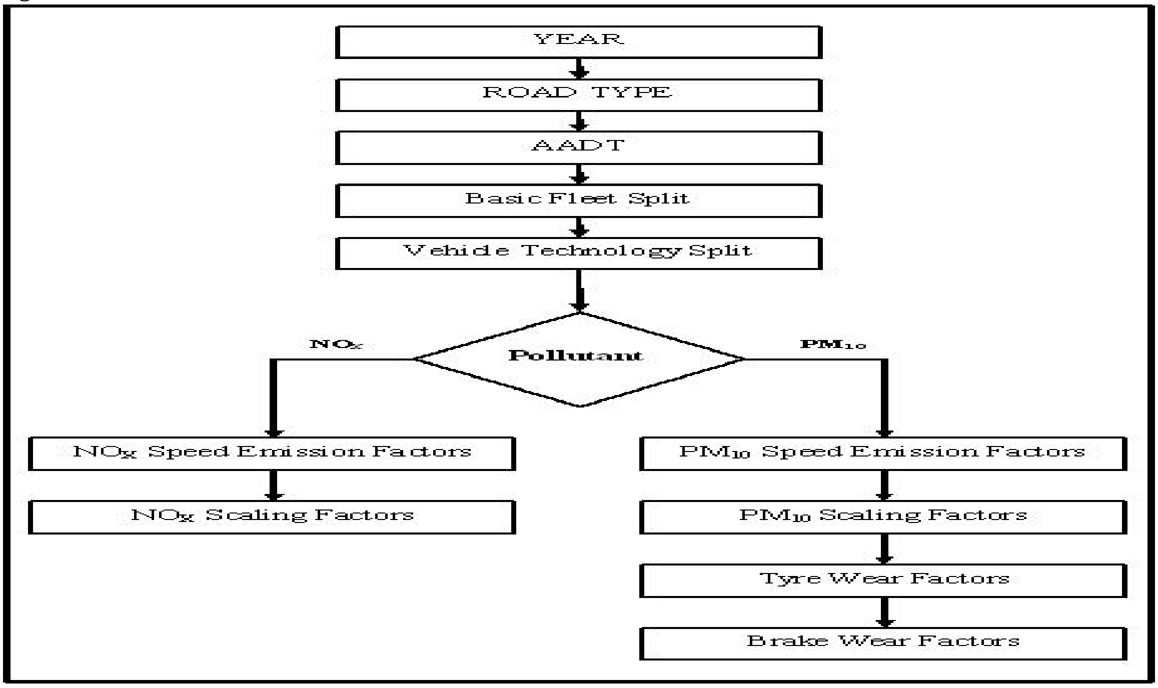
The research on which this paper is based on reflects modelling of emissions from road transport in a manner which allows us to capture some of the dynamics resulting from non-technical abatement measures such as low emission zones and congestion charging, as well as from technical abatement measures such as retrofitting diesel particulate filters and using low emission vehicles – hybrids. The technical abatement measures are implemented upon the basis of emissions factors which are then aggregated to provide generic emission factors for a specified vehicle mix [Valiantis, 2007]. This vehicle mix provides a tool for implementing certain behavioural changes (such as uptake of hybrid vehicles) whereas the derived flow for each road link can capture changes in activity. With ASAM and the UKIAM nested to provide the relevant background data [Oxley & ApSimon, 2007], this work shows how integrated assessment modelling can capture the dynamics of technical and non-technical measures and behavioural responses at the local scale whilst maintaining the linkages to national and transboundary dynamics.

2. METHODOLOGY

To capture the dynamics resulting from the abatement measures, a transport emissions tool has been developed that calculates emissions from transport in great detail. *Integrated Modelling of Vehicle Emissions* (iMOVE), is designed as a tool to assess current and future vehicle emissions and to investigate a variety of potential emission reduction strategies to reduce air pollution both at a local or national scale. It brings together information on air quality, population numbers, traffic data, vehicle emission inventories, technical and non-technical measures for transport emission reduction, and GIS mapping techniques.

The model calculates emissions using data provided by Netcen and is based on the same methodology used in the National Atmospheric Emissions Inventory in the UK [NAEI website]. Depending upon the road type, year in question, and traffic data, iMOVE splits the basic fleet into 7 vehicle categories and the vehicle technology (Euro Standards) mix into 4 categories. Then, depending upon the pollutant, iMOVE applies different emission factors to calculate total emissions [Figure1]. The model calculates emissions for both PM_{10} and NO_X, for each vehicle category, Euro standard, and engine size when applicable. The model also calculates no-exhaust emissions for PM_{10} for each vehicle category.

Figure 1. iMOVE emissions calculation flowchart



The calculations are made using data provided by Netcen and applying the following equation:

$$Emissions_{x,y}^{PM_{10}} = (Flow_{x,y}^{roadtype} * ((EF_{mix}^{PM_{10}} * SF_{mix}^{PM_{10}}) + Tyre_{roadtype,mix}^{PM_{10}} + Brake_{roadtype,mix}^{PM_{10}}))$$

where:
Flow is the vehicle flow in the road link
roadtype is the type of road in terms of urban, rural, or motorway
mix is the vehicle mix applicable to road link (x,y) and year in question
EF is the speed emission factor for each vehicle category and Euro standard
SF is the scaling factor for each vehicle category and Euro standard
Tyre is the tyre wear emission factor for each vehicle type for each road type
Brake is the brake wear emission factor for each vehicle for each road type

NO_X emissions are calculated similarly with exception that there is no tyre and brake wear.

$$Emissions_{x,y}^{NOx} = (Flow_{x,y}^{roadtype} * (EF_{mix}^{NOx} * SF_{mix}^{NOx}))$$

Emissions produced by iMOVE are linked to the BRUTAL model in order to calculate the concentrations. The BRUTAL model has been developed as a high resolution (1km) module of the UK Integrated Assessment Model [Oxley *et al.,* 2003] that is able to capture the transient road-side concentrations of air pollutants in urban street canyons [Oxley *et al.*, 2007]. By modelling local roadside concentrations, and superimposing these upon background concentrations calculated by the UKIAM and ASAM, it was possible to model the peak local concentrations in urban street canyons which contribute to exceedance of urban air quality Limit Values. Nesting BRUTAL within the UKIAM (and thus ASAM) enable us to assess the significance of different pollutant sources (controlled by policies applied at different spatial and temporal scales) towards exceedance of air quality Limit Values and to address the abatement measures in integrated assessment modelling which can influence air quality through affecting traffic flows.

3. RESULTS AND DISCUSSION

Six transport scenarios comprising of technical and non-technical measures have been applied as a means to abate air pollution. The technical measures included fitting diesel particulate filters (DPFs) on all diesel LGVs, HGVs, and Buses, early uptake of Euro V and VI (high intensity – 100% passenger cars and LGVs -> EuroV, 75% HGVs and Buses -> EuroV, and 25% of HGVs and Buses -> Euro VI), increase uptake of hybrids (50% passenger cars) in urban areas, and introduction and uptake of hydrogen fuel cell vehicles

(HFCVs) in urban areas (50% passenger cars). Low emission zones (LEZs) (keeping traffic flow same while requiring all articulate HGVs and Buses entering the zone to be EuroV) and congestion charging schemes (15% reduction in traffic) were the two non-technical measures applied.

Looking at Table 1 it quickly becomes apparent the significance of tyre and brake wear in relation to exhaust emissions. Tyre and brake wear emissions remain unchanged for all the scenarios apart from the congestion charge scenario. This is because tyre and brake wear emissions depend mainly on the number of vehicles. Since the traffic count is kept the same in all the other scenarios then there will be no change in non-exhaust emissions of PM_{10}. This is very important because it reduces the emissions abatement performance of each scenario.

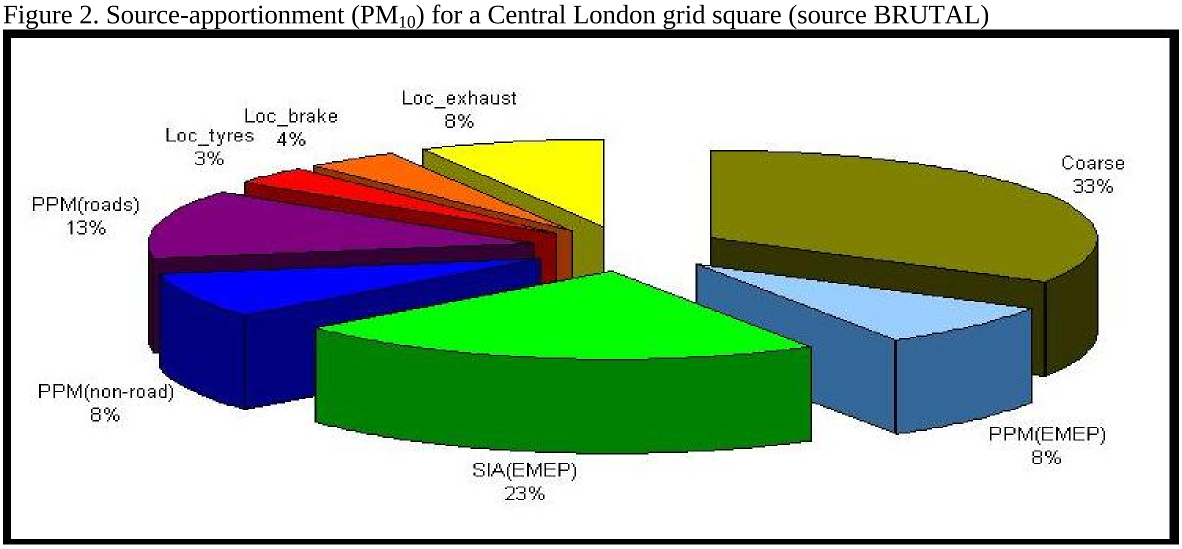
Table 1. Performance of emissions abatement measures in relation to BAU scenarios

NO	Description & Year in Effect	Emissions Abatement Performance (% Annual Reduction)				
		PM_{10}				NO_X
		Exhaust	Tyre Wear	Brake Wear	Combined	Exhaust
1	DPFs (2010)	58.42%	0%	0%	23.54%	-
2	Uptake Euro V/VI (2010)	76.59%	0%	0%	30.86%	58.44%
3	Hybrid-LEVs (2020)	17.26%	0%	0%	5.92%	12.93%
4	HFCV (2020)	23.59%	0%	0%	8.09%	21.42%
5	LEZ (2010)	11%	0%	0%	4.43%	8.29%
6	Congestion Charge (2010)	15%	15%	15%	15%	15%

The dominance of secondary inorganic aerosols contributing to total PM_{10} concentrations, with total non-road contribution reaching close to 70%, is also very important. Although different abatement technologies are applied, since tyre and brake wear remain unchanged, and exhaust emissions contributing as little as 10% of the total concentrations [Figure 2], the small reductions in the total PM_{10} concentrations from transport scenarios are understandable. With probably as little as 20% of the source contribution which can be captured by local policy, the national and transboundary contributions become more important with regards to abatement policy.

The opposite happens in the case of NO_2, where the dominance of traffic contribution in relation to non-road and background concentrations is evident. Findings in the same grid square in Central London as in figure 2 suggest that up to 50% of the road-side concentrations may be a direct result of the local traffic, whereas only 20% comes from non-road sources. With the annual limit values being more stringent, policy will tend to be aimed towards meeting national emissions ceilings with perceived benefits from urban air quality. NO_2 concentrations are complicated further by the influence of localised O_3 and other (transboundary) pollutant concentrations and variations in meteorological conditions, requiring policy action even more distant from local pollution 'episodes'. In order to model such episodes we must also take into consideration how, and the extent to which, the NO_2:NO_X ratio is increasing in urban areas, and how this ratio is affected by global NO_X and O_3 dynamics.

Figure 2. Source-apportionment (PM_{10}) for a Central London grid square (source BRUTAL)



4. CONCLUSIONS

Many countries are having difficulties in complying with the European Commission's legislation on air quality, particularly for PM_{10} and NO_2. In assessing strategies for future improvement, modelling tools are required for estimating future concentrations resulting from both technical and non-technical abatement measures. These abatement measures have become increasingly significant in order to meet current policy targets creating the need for integrated assessment modelling to understand and capture changes in behaviour resulting from them. iMOVE has been designed as a tool to assess current and future vehicle emissions and to investigate a variety of potential emission reduction strategies to reduce air pollution both at a local or national scale. Emissions produced by iMOVE were linked with the BRUTAL model, a high resolution (1km) module of the UKIAM that is able to capture the transient road-side concentrations of air pollutants in urban street canyons. By modelling local roadside concentrations, and superimposing these upon background concentrations calculated by the UKIAM and ASAM, it was possible to model the peak local concentrations in urban street canyons which contribute to exceedance of urban air quality Limit Values. While NO_2 concentrations are dominated by the local emissions (possibly more than 50%), PM_{10} emissions from traffic may contribute less than 20% of total concentrations indicating the dominance of secondary inorganic aerosols contributing to total PM_{10} concentrations, with total non-road contribution reaching close to 70%. This work provides the framework for potential integration with local, high resolution, meteorological models to enable us to begin assessing effects of pollution episodes upon the exposure and health of vulnerable urban populations within the overall framework of integrated assessment modelling.

5. ACKNOWLEDGMENTS

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6. REFERENCES

ApSimon, H. M., Gonzalez del Campo, T. & Adams, H. S., 2001, Modelling long-range transport of primary particulate material over Europe. Atmospheric. Environment, 35, pp343-352.

ApSimon, H. & Oxley, T. (eds.), 2004, Comparison of the EMEP model and other models for the UK region, Report to DEFRA, Imperial College London

ApSimon, H., Oxley, T. & Valiantis, M., 2006, Scenario Q/P: Results from the UKIAM, Report to DEFRA (EPG1/3/167), Imperial College London, February 2006.

ApSimon, H., Warren, R. & Wilson, J., 1994, The Abatement Strategies Assessment Model: Applications to reductions of SO_2 emissions in Europe, Atmospheric Environment, 24(4), pp649-663

AQEG, 2004, Nitrogen Dioxide in the United Kingdom, Report to DEFRA by the Air Quality Expert Group, http://www.defra.gov.uk/environment/airquality/aqeg/

AQEG, 2006, Air Quality and Climate Change: A UK perspective, Draft report to DEFRA by the Air Quality Expert Group, http://www.defra.gov.uk/environment/airquality/aqeg/

Gonzalez del Campo, T., 2003, Integrated Assessment of Abatement Strategies for Primary Particulates, PhD Thesis, Imperial College London

National Atmospheric Emissions Inventory Website: http://www.naei.co.uk

Oxley, T. & ApSimon, H.M., 2007, Space, Time and nesting Integrated Assessment Models, Environmental Modelling & Software (in press)

Oxley, T., ApSimon, H., Dore, A., Sutton, M., Hall, J., Heywood, E., Gonzales del Campo T., & Warren, R., 2003, The UK Integrated Assessment Model, UKIAM: A national scale approach to the analysis of strategies for abatement of atmospheric pollutants under the Convention on Long-Range Transboundary Air Pollution, Integrated Assessment, 4(4), pp 236-249

Oxley, T., Valiantis, M. & ApSimon, H., 2007, Background Road and Urban Transport modelling of Air quality Limit values (The BRUTAL model), (in prep.)

Valiantis, M., 2007, Assessing Alternative Future Scenarios in Relation to Air Quality, PhD Thesis, Imperial College London (to be submitted April 2007)

Valiantis, M., Oxley, T. & ApSimon, H., 2007, Integrated Modelling of Vehicle Emissions (The iMOVE model), (in prep.)

EVALUATION OF MEASURES FOR REDUCING PM_{10}-CONCENTRATIONS IN URBAN AREAS

S. Vogelsang[1], C. Kurz[1], P. Sturm[1], D. Oettl[2]
[1] Institute for Internal Combustion Engines and Thermodynamics, Graz University of Technology, Inffeldgasse 21a, A- 8010 Graz, Austria (vogelsang@vkmb.tugraz.at)
[2] Styrian Government, FA 17C Technical Environmental Protection and Safety, Air Quality Control Section, Landhausgasse 7, A-8010 Graz, Austria

ABSTRACT

High urban concentrations of PM_{10} are a well-known problem in many European countries. PM monitoring stations in Austria show very high concentrations of PM_{10} especially in alpine basins. The PM10 daily mean threshold value (50 µg/m³) is frequently exceeded. Hence, there is a need for introducing measures in order to reduce PM_{10} concentrations in urban areas.
Based on detailed emission inventories dispersion modelling was carried out for the Lavanttal region, a basin south of the Alps with rather unfavourable dispersion conditions. The results provide important information about the source attribution of PM_{10} concentrations. Compared to measured concentrations the simulated total PM_{10} load agrees within +/- 2,5 µg/m³. In addition the results give an idea how effective measures should be formulated.

1. INTRODUCTION

The EU directive 1999/30/EC defines the standards for air quality in the European Community. The Immissionsschutzgesetz Luft (IG-L) is the realisation of this EU-directive into national law. In 2001 threshold values for PM_{10} were implemented. Austria chose to implement more stringent threshold values than given in the EU directive. While the threshold for the annual mean value (40 µg/m³) and the daily mean value (50 µg/m³) remains the same, the acceptable number of days with violations of the threshold for the daily mean value has been reduced from 35 (EU) to 30 and shall decrease further to 25 starting in 2010.
Measurements indicate that the permissible number of days with threshold violations is exceeded by far those of 30/25 throughout Austria. In particular, unfavourable meteorological conditions at the south side of the Alps result in the fact that even in small urban agglomerations PM_{10} is a major problem in air pollution.
In the year 2005 the threshold value for the annual mean value was exceeded in Austria on two locations only, whereas the daily mean value was exceeded more often than the allowed 30 times on 58 of the 111 PM_{10} monitoring stations in Austria. Not only urban areas are concerned, violations occur even in rural areas.
The reasons for the high PM_{10} burden are various. Local and regional emissions combined with unfavourable dispersion conditions are of importance in some regions while in others the transboundary pollution mainly from easterly and south-easterly directions is the crucial factor. Especially the basins in the central Alps as well as on the south side of the Alps are affected by unfavourable dispersion conditions with low winds, strong inversions during wintertime and little precipitation.
This high number of violations of the air quality (AQ) standard calls for an action plan with massive restrictions in order to achieve the limit values given.
As PM_{10} emissions have various sources the impact of all these possible sources have to be considered within an abatement programme. Therefore, all sources have to be known and represented in a good emissions inventory, which is the basis for dispersion simulation with an adequate model.

2. METHODOLOGY

The approach for evaluating the impact of different sources on the air quality and for quantifying the effects of some abatement measures is based on the application of a high level emission inventory combined with a dispersion model.

Emission inventory

The emission inventory is the basis for all quantification activities. Hence, it is imperative that a high quality in source description is required. The high quality concerns quantification as well as temporal and special allocation.

Traffic exhaust emissions are calculated by the Network Emission Model (NEMO), which combines a detailed simulation of the fleet composition and emission factors for various engine types and engine load conditions depending on the traffic situation, fleet composition and the road network (Rexeis et al. 2005).

Dispersion modelling

GRAL (Lagrangian dispersion model, Oettl et al. 2003a and Oettl et al. 2003b) is a combined model system for the calculation of prognostic steady-state wind fields and dispersion. It was developed especially for the application to dispersion situations with low wind speeds in complex terrain. In the following paragraph the basics of the wind field simulation and of the algorithm used for dealing with low wind conditions in GRAL are briefly described.

For the flow field modelling a meteorological approach based on wind statistics and stability is used. First, a pre-processing of local meteorological measurements, of about one year is carried out. Thereafter a statistical classification of flow situations into wind sectors J, wind speed categories K and stability classes L (usually 3) from a single point observation in the domain is carried out. Finally, J x K x L = N steady state simulations with wind field model GRAMM (Graz Mesoscale Model, see Almbauer et al. 2000 and Oettl 2000 for more details) are carried out. Main features of GRAMM are prognostic non-hydrostatic wind fields, terrain following grid (tetrahedronal grid), implicit time integration, parameterizations to account for low wind conditions, constant surface cooling in stable conditions (10 W/m²), spatial variable surface heat flux in convective conditions (shadowing effects of topography).

The dispersion calculations are carried out with GRAL using the calculated flow fields. During low wind speed conditions large horizontal atmospheric motions develop (so called meandering), which influence the dispersion process significantly. The Lagrangian model used applies an algorithm accounting for the effect of stronger turbulences in low-wind weather situations.

The input data from the emission inventory consists of different source types with different release characteristics. As a consequence it is necessary to simulate these different kinds of sources like line sources, point sources and tunnel portals, simultaneously. GRAL fulfils these requirements and the following parameters are taken into account for the individual source types:

- Point sources: location (3D): Source strengths, exit velocity, temperature differences, source diameter.
- Line sources: location (3D, also bridges): Widths, source strengths, heights of noise barriers.
- Area sources: Same as line sources.
- Tunnel portals: Location (3D), source strengths, exit velocity, temperature differences, traffic influence on tunnel jet (Oettl et al. 2002).

The formation of secondary organic and inorganic aerosol as well as long-range transboundary PM is currently not considered in the model simulations.

Quality assurance

Quality assurance of the modelling system GRAL is guaranteed by permanent validation activities using data from field experiments. Currently 18 different data sets for tunnel portals, point sources, line sources and built-up area are used for the model evaluation, such as Prairie Grass, Indianapolis, INEL, Elimaeki, Goettingerstrasse, Hornsgatan, etc. Model development and modelling results have been published frequently in peer-reviewed journals (e.g. Oettl et al. 2001, Oettl et al. 2003a/b).

3. RESULTS AND DISCUSSION

An intensive study was carried out to determine the share of different PM_{10} emission sources in the region of Klagenfurt (in the framework of the EU-Life project KAPA-GS (http://www.kapags.at)) and in the Lavanttal. Measurements were combined with numerical simulations and partly also with chemical analyses.

The numerical simulations - based on emission inventories and dispersion calculations - enable a clear distinction between the different sources. PM_{10} measurements and some available chemical analyses of PM_{10} samples were used for a validation of the model system. This approach has been applied to the city of Klagenfurt and to the Lavanttal. The main results from the latter are briefly presented here.

The Lavanttal region is a basin with an extension of 30 x 20 km² surrounded by mountains 1400 m – 1800 m higher than the valley floor. Major emitters in that region are a paper and pulp mill, the small city of Wolfsberg (pop. 26000 / 57000 with suburbs and commuters) and agricultural activities. Traffic is dominated by a highway and some minor roads.

Besides the two big industrial facilities (pulp and paper mill and wood industry) this region is mainly dominated by small enterprises and agricultural activities. Nevertheless, PM_{10} is a problem concerning the AQ standard for the 50 µg/m³ threshold for the daily mean value. The PM_{10} AQ standard (50 µg/m³) is exceeded 35 – 68 days per year. Therefore, a detailed emission analysis was carried out. In contrast to urban locations in this case emissions from farming play an important role. On the basis of the available data only emissions from land cultivation (e.g. ploughing, harrowing) were taken into consideration, emissions from life stock were excluded.

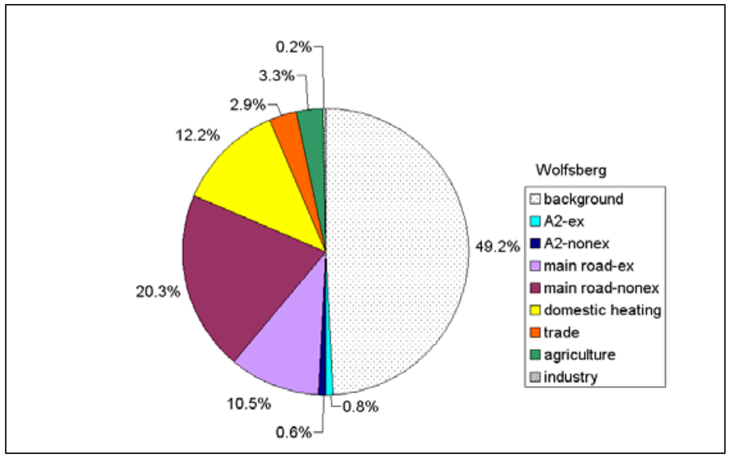

Figure 1: Contribution of the different sources to the PM10 emissions in Wolfsberg, Lavanttal.

Figure 1 shows the contributions of the different source categories in Wolfsberg. Traffic exhaust and non-exhaust are dominating, industry and trade also have a remarkably share. Domestic heating also has a relatively high share as in the rural areas wood is still a major energy source. During wintertime traffic non-exhaust is three to four times more important than traffic exhaust.

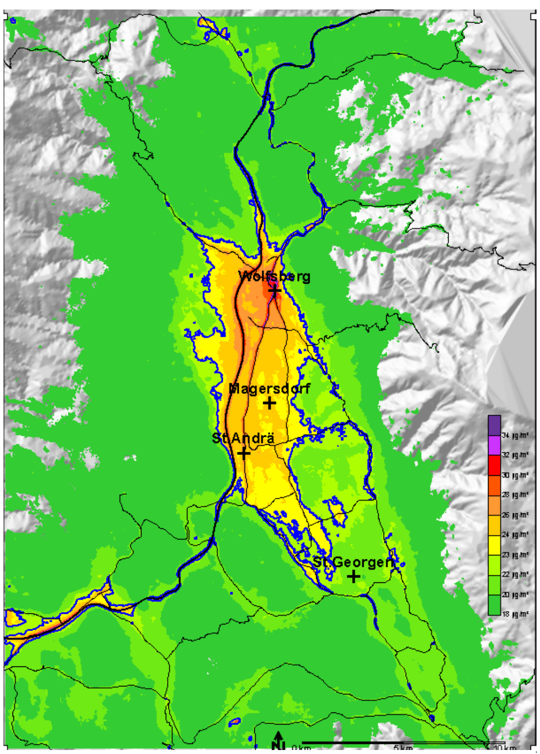

Figure 2: PM10 concentrations [µg/m³], all sources, annual mean value.

The background accounts for about 50 % of PM_{10} within this analysis. In this case background was determined by measurements taken from a monitoring station within the calculation domain, but at a higher altitude location. The annual mean value at that station amounts to 17 µg/m³. Adding this value to the calculated ones results in a good agreement between calculation and measurement at the remaining three monitoring locations.

We attribute secondary formed PM and transport on larger scales as the major source processes to explain the background. In (almost) all environmental assessment studies made at our institute the background is between 17 and 24 µg/m³. In contrast, simulations of NO_x are traffic dominated and show a residuum of less than 15 %.

In Figure 2 the annual mean value of PM_{10} (including background) in the Lavanttal is shown. The area inside the thick blue line depicts the region in which the Austrian PM10 standard for 2010 (25 days threshold value exceeded) would be violated. Such areas have to be declared as PM_{10} non-attainment zones. In such zones abatement measures have to be set by law.

The potential of several measures for the reduction of the PM10 concentrations, which were considered as feasibly by the local authorities, was investigated. These measures were defined as follows:

- Scenario 1: Improvements in winter service due to enforcement of de-icing instead of sanding
- Scenario 2: Reduction of domestic heating emissions by 50% due to usage of district heating

- Scenario 3: Retrofitting of all diesel cars with PM filters with an efficiency of 90%

An improvement in winter service (scenario 1) helps to reduce the PM emissions by more than 10 tons per year. However, the area with threshold violations would be reduced by 5% only. A reduction in domestic heating emissions (scenario 2) by 50% (i.e. by almost 47 tons) would result in a reduction of almost 43% in the area concerned. The retrofitting of diesel cars with PM filters would minimise the PM emissions by approximately 6 tons per year. However, the effect on the area concerned is almost negligible.
It has to be mentioned that even a combination of possible measures (reduction in emissions from domestic heating, winter service and retrofitting of diesel cars with PM filters) would not ensure that the air quality goals can be met.

4. CONCLUSIONS

Dispersion simulation with the model system GRAL offers the possibility to calculate differentiated air quality inventories on the basis of detailed emission inventories. As many different source types with their special emission characteristics are simulated simultaneously, their contributions to the total PM_{10} load can be determined. The analysis in the Lavanttal showed that in rural areas domestic heating and agricultural emissions are dominating, whereas even in small cities traffic exhaust and non exhaust emissions have more influence. Nevertheless, the background concentration accounts for up to 50 % of the measured concentrations. The calculated results were compared with observed concentrations and an agreement within +/- 10 % was found.
The calculated results show that in a large region the Austrian PM_{10} standard for 2010 (25 days with threshold value exceeded) would be violated. Therefore it is necessary to introduce PM_{10} source abatement measures. Short term measures (concerning traffic) show rather little effect, as they often lead to a relocation of traffic emissions instead of reducing them. Reducing emissions of domestic heating by 50 % would reduce the area affected by violations of the AQ standards by almost 45 %.
Before introducing any abatement measure in regions, which do not reach the Austrian AQ standards it is important to identify the source contribution of the total PM load. Especially in South alpine basins the complex terrain and the often occurring low wind conditions state a challenge for dispersion modelling. Nevertheless, the model system GRAL is a useful tool for defining effective measures.

5. ACKNOWLEDGEMENTS

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6. REFERENCES

Almbauer, R. A., D. Oettl, M. Bacher and P. J. Sturm (2000): Simulation of the air quality during a field study for the city of Graz, Atmos. Environ., 34, pp. 4581-4594

Immissionsschutzgesetz Luft IG-L, 1997

Oettl, D. (2000): Weiterentwicklung, Validierung und Anwendung eines Mesoskaligen Modells. Diss., Institut für Geographie Universität Graz. p. 155

Oettl, D., J. Kukkonen, R. A. Almbauer, P. J. Sturm, M. Pohjola and J. Härkönen (2001): Evaluation of a Gaussian and a Lagrangian model against a roadside dataset, with focus on low wind speed conditions. Atmos. Environ., **35**, 2123-2132

Oettl, D., P. J. Sturm P, M. Bacher, G. Pretterhofer, R. A. Almbauer (2002): A simple model for the dispersion of pollutants from a road tunnel portal. Atmos. Environ., **36**, 2943-2953

Oettl, D., P. J. Sturm, G. Pretterhofer, M. Bacher, J. Rodler, R. A. Almbauer (2003a): Lagrangian dispersion modeling of vehicular emissions from a highway in complex terrain. Journal of the Air and Waste Management Association, **53**, 1233-1240

Oettl, D., R. A. Almbauer, P. J. Sturm, and G. Pretterhofer (2003b): Dispersion modelling of air pollution caused by road traffic using a Markov Chain - Monte Carlo model. Stochastic Environmental Research and Risk Assessment, 58-75.

Rexeis M., S. Hausberger (2005): Calculation of Vehicle Emissions in Road Networks with the model “NEMO”; Proceedings Transport&Airpollution Conference; ISBN: 3-902465-16-6, Graz

CAN WE ESTIMATE PM-EMISSION REDUCTIONS FROM SPEED MANAGEMENT POLICIES ?

Int Panis, L.[1, 2], *Beckx, C.* [1, 3], *Broekx, S.* [1], *De Vlieger, I.* [1], *Schrooten, L.* [1]
[1] *Flemish Institute for Technological Research (VITO), Integrated Environmental Studies*
Boeretang 200, B-2400 Mol, Belgium
[2] *Corresponding author: luc.intpanis@vito.be, Tel. 0032 14 33 58 87*
[3] *Instituut voor Mobiliteit (IMOB) Hasselt University,*
Wetenschapspark 5 bus 6, BE-3590 Diepenbeek, Belgium

ABSTRACT
Speed reduction measures are commonly introduced to increase traffic safety. Recently many urban streets or entire districts were converted into 30 km/h zones and in many European countries the maximum speed of lorries is under discussion. Reducing the maximum speed is seen as beneficial to the environment because of reduced fuel consumption and lower emissions. These claims however are often unsubstantiated. We calculated emissions for specific vehicles with a microscopic model using real-life driving cycles and compared the results with those from MEET. Although emissions of most classic pollutants should not be expected to rise or fall dramatically, the conclusion for PM could be different. The effects of speed reduction schemes on PM emissions from trucks on highways are ambiguous, but detailed modelling results indicate that the PM exhaust from diesel passenger cars may show a significant decrease in urban areas converted to 30 km/h zones.

1. INTRODUCTION
In June 2005 the Flemish transport Minister proposed to lower maximum speed for trucks on highways from 90 to 80 km/h. This resulted in a wave of critique from stakeholders. Reference was made to time and economic losses and doubts were cast over the assumed environmental and safety benefits. Unfortunately scientific analysis was either ignored or unavailable in the discussion. Similarly, low speed zones (30 km/h) around schools and residential areas, intended to increase traffic safety, are vigorously opposed by people claiming that this will exponentially increase exhaust emissions.

2. METHODOLOGY
To shed some light on the problem we calculated emissions with the microscopic VeTESS-tool using real-life driving cycles and compared the results with those obtained using MEET-like methodologies. VeTESS was developed within the European project Decade as a vehicle level tool for the simulation of fuel consumption and emissions for real traffic transient vehicle operation. It is specifically designed to calculate dynamic emissions, and thereby reaching higher accuracy than traditional emission simulation models including those using steady state engine maps. The calculations in this vehicle simulation tool are based on a detailed calculation of the engine power required to drive a given vehicle over any particular route. This includes the rapidly changing (transient) demands placed on the engine. We used this model to calculate emissions and fuel consumption on a second-by-second basis for specific vehicles on a given speed profile. Urban driving cycles were recorded during on-the-road emission measurements in the cities of Mol (Belgium) and Barcelona (Spain), using three different vehicles: VW Polo (Euro 4, petrol), Skoda Octavia (Euro 3, diesel) and a Citroen Jumper (Euro 3, diesel) light commercial vehicle. We believe these vehicles are representative for an important fraction of current car sales in Belgium. We refer to Pelkmans et al. (2004) for a detailed technical description of the VeTESS-model, the vehicles and set-up of the test cycles.
From each of the 6 different urban driving cycles we derived a modified version in which the top speed was limited to 30 km/h without changing the acceleration or deceleration. The length of time driven at the new top speed was elongated where appropriate to preserve the original cycle distance. The effect on the average speed however is limited. For trucks the VeTESS model was run with a compilation of speed profiles measured on Flemish highways in normal traffic. The maximum speed is legally limited to 90 km/h and the average real speed is approximately 86 km/h. Small variations that occur between 85 and 90 km/h can be attributed to the presence of other vehicles. The measured speed profiles were converted to lower speeds to reflect a change in the legal speed limit. The speed variation was left unchanged whereas the average speed was decreased to 77 km/h.

3. RESULTS AND DISCUSSION
The emissions of each of the three light vehicles were modelled with each of the 6 available urban driving cycles, resulting in 18 emission estimates for a reduction of the top speed from 50 km/h to 30 km/h. Overall results are summarized in Figure 1. Positive values indicate that emissions go up when the new speed limit is implemented. Negative values indicate that pollutant emissions decrease. Results for CO and HC differ widely between

vehicles and cycles. Because emissions of these pollutants are very low in modern cars, we believe that they are not modelled with sufficient accuracy to lend credibility to the relative changes shown in the graph. (Even a 100% increase represents only a tiny amount of pollutants emitted, close to the smallest amount that can be measured; Pelkmans, pers. comm., 2005.) For the emissions of CO_2 and hence fuel consumption it was found that the change to the driving cycle only had a limited impact, either positive or negative, on the emission. Emissions decreased for both cars, but increased for the LGV. For the emissions of NO_x the LGV mostly showed a small increase whereas the results for the cars indicate moderate to important decreases of the emission. Both diesel vehicles (Octavia and Jumper) showed a moderate or large decrease in the modelled emissions of PM in each of the cycles. No PM emissions can be modelled with VeTESS for petrol fuelled vehicles (i.e the VW Polo).

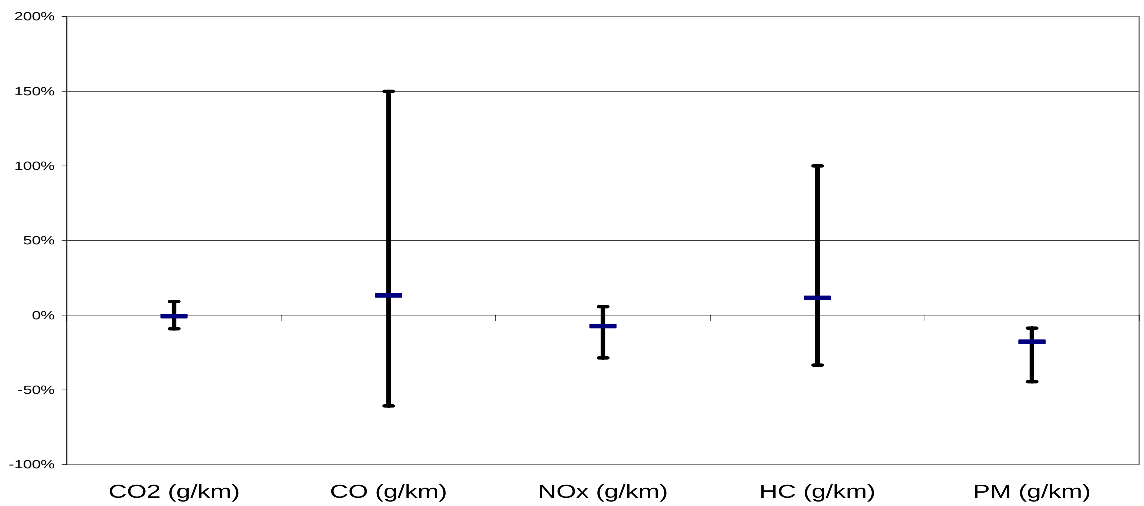

Figure 1 Estimated relative change in emission for 5 pollutants. Average and range for 18 estimates.

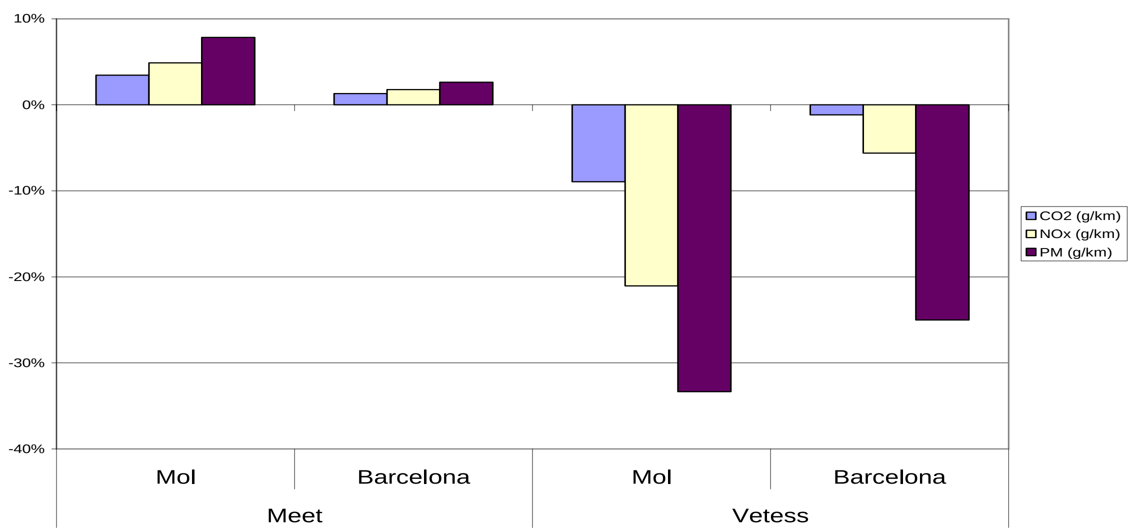

Figure 2 Relative change between two normal urban drive cycles (up to 50km/h) and drive cycles limited at 30 km/h (Skoda Octavia; Cycle 4: 25.2->22.7 km/h in Mol, Cycle 1: 14.8->13.9 km/h in Barcelona)

In Figure 2 we present the detailed results for the Skoda Octavia for one representative cycle in each city. The emissions estimates were made with the relevant MEET functions based on average trip speed and with VeTESS on the full speed profile respectively. Results for most other vehicle/cycle combinations yield similar results. Not surprisingly, the MEET methodology results in a slightly higher estimate for the emissions. The small difference can be attributed to the fact that although the derived driving cycle may seem very different the resulting change in average speed is quite limited. The results from the VeTESS model runs are less straightforward to interpret or explain because a large number of factors contribute and interact. Nevertheless it is clear that emissions of CO_2, NO_x and PM decrease in each situation for this specific vehicle. This is the combined result of lower top speeds, longer driving periods at 30 km/h and extended driving to reach the end of the cycle. Emissions of CO_2 are marginally smaller and NO_x emission factors are also lower. The largest reduction however is found for emissions of PM which decrease in most cases by approximately one third. The result of detailed emission modelling for the delivery van agrees well with the simpler MEET calculation for CO_2 emissions. Both fuel consumption and CO_2 emissions are projected to increase slightly (~3-5%). Results for NO_x emissions are mixed because the small increase evident from the MEET functions is not reproduced by VeTESS which indicates insignificant changes. For the PM emissions, this vehicle would show an important decrease (although smaller than for the passenger cars) under the speed-limited driving cycle.

Table 1. Relative emissions for different trucks (VeTESS results)

90 km h-1 → 80 km h-1	CO_2	NO_X	PM
IVECO Eurocargo 7500 kg	84%	71%	84%
IVECO Eurocargo 12,000 kg	86%	72%	100%
MAN 30,000 kg	91%	89%	103%
Scania 30,000 kg	90%	85%	n.a.

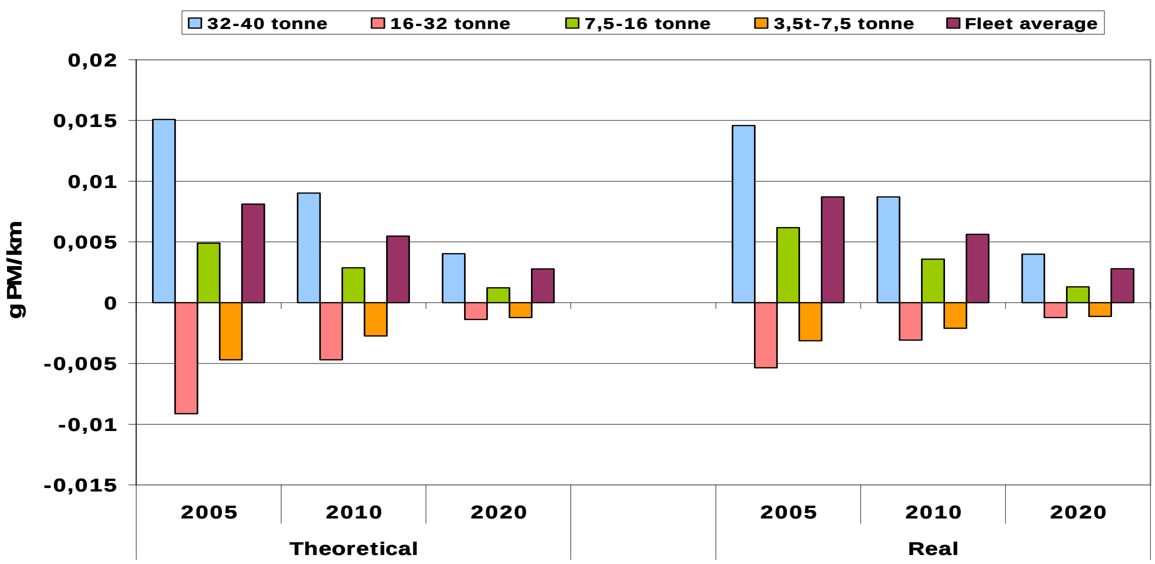

Figure 3. Absolute difference in the PM fleet emission factors for the 3.5-32 tonne trucks, 90 km/h compared to 80 km/h (Theoretical) and 86km/h to 77 km/h (Real) (VITO TEMAT model, 2006)

Summarizing the results for trucks we can say that the total CO2 emission would decrease by approximately 10 %, a trend that is consistent for all weight classes and years (Table 1). Results from the Belgian MEET-based TEMAT model confirm the results for CO2 which makes the results more credible. In absolute numbers the CO2 emission factors would on average drop by approximately 100 g/km if the policy resulted in a decrease from 90 to 80 km/h. Using more realistic estimates of the impact of the policy on real traffic speeds yields a reduction of only 50 to 70 g/km. Emission factors of NOx show a decrease for all types of trucks available in VeTESS (Table 1). In sharp contrast the Belgian MEET-based TEMAT model simulates an increased emission for the heaviest trucks (32-40 tonnes, +0.2 – 0.5 g km-1) even resulting an increased fleet averaged emission factor. The results for PM are even more confusing (Figure 3). PM emission factors decrease for the 3.5-7.5 and 16-32 tonnes weight classes and increase for the 7.5-16 and 32-40 tonnes weight classes. All changes (increases and decreases) become smaller in the future. Because of the dominance of the largest trucks the fleet average emission factor also increases. A high R^2 was reported in MEET for this emission function, indicating it was based on a small sample. The lack of consistency between the effects for the different classes indicates a large uncertainty.

The results presented here demonstrate that estimating emissions from vehicles is a complex endeavour. Estimating the impact of policies on emissions is even more difficult (Int Panis et al, 2005). In the case of a severe decrease of the urban speed limit, neither the naïve assumption that emissions will decrease nor the straightforward (but methodologically unjustified) application of the MEET methodology seem to be correct. The use of the detailed microscopic emission model has the obvious disadvantage that the necessary engine and vehicle data is only available for a limited number of vehicles. Nevertheless the detailed analysis of the behaviour of these vehicles emissions' is relevant for two reasons. First the available data used for this study are from quite popular vehicles that represent analogous models from other brands as well as other cars with similar engines. Secondly the engines and after treatment technology of these modern cars is a fair proxy to what may become the average fleet in the near future. This being said, there are some important aspects which we have not taken into account. We have not made any changes to the acceleration and deceleration behaviour in the selected driving cycles. This is an implicit assumption that needs to be validated. Unfortunately we cannot take this into account in this study because detailed (i.e. measured) data are currently lacking. A large scale monitoring programme will start later in 2007 (Broekx, pers. comm., 2006). Theoretically this problem can be circumvented by using microscopic traffic simulation models that generate instantaneous speed estimates (and hence also acceleration) for individual vehicles. Unfortunately detailed as the models may seem at first glance the acceleration estimates are largely based on very rough estimates that have never been validated (Joumard, pers. comm., 2005, Int Panis et.al, 2006, Beckx et al, 2006).
Considering highway speed reduction for trucks, we find that emissions of CO_2 decrease but emissions of NO_x and PM could increase, which is consistent with the results from other studies. The choice of gear features among the most prominent changes to the driving pattern and is likely to be influenced by changes to the speed limit. Although this may be more important in urban locations than on highways. The VeTESS model was therefore used to study the effect of different gear shifting strategies in connection with different speed limits. Our conclusions were confirmed for any gear shifting strategy for any speed reduction down to 80 km/h. These results were presented to and discussed with both individual manufacturers and the ACEA expert group. It is clear that they design and build long distance haulage trucks to minimize fuel consumption at the most prevailing speed limits in Europe (80 km/h on highways). The optimum is between 80 and 85 km/h which confirms our findings.

4. CONCLUSIONS

It is unlikely that strict speed limits in urban areas have a significant influence on emissions of NO_x or CO_2. Concerning the impact on emissions of PM VeTESS results indicate that the exhaust from the diesel vehicles may show a significant decrease, whereas MEET functions assume a moderate increase. The effect on emissions of PM should be confirmed by further research, also focusing on the impact of acceleration or gear shifting behaviour. All results for trucks consistently indicate that lower maximum speeds for trucks on motorways result in lower emissions of CO_2. Results for NO_x and PM are not consistent.Estimating impacts of speed management policies on emissions will remain very complex even when second order effects are ignored.

5. ACKNOWLEDGEMENTS

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6. REFERENCES

Beckx, C., Int Panis, L., De Vlieger, I. and Wets, G. 2006. Influence of gear changing behaviour on fuel-use and vehicular exhaust emissions. In: Proceedings of the 8th International Symposium on Highways and the Urban Environment. Rauch S. & Morrisson G. (eds.), Chalmers University. (in press)

Int Panis, L., Cosemans, G., Torfs, R., Liekens, I., De Nocker, L., Broekx, S. and Beckx, C., 2005. Mobilee: effect of a local traffic plan on exposure to local air pollution. VKM-THD Mitteilungen, Heft/Volume 85/II, pp.13-21.

Int Panis, L., Broekx, S., Liu, R. 2006. Modelling instantaneous traffic emission and the influence of traffic speed limits. Science of the Total Environment 371(1-3), 270-285

Int Panis, L., De Vlieger, I., Pelkmans, L., Schrooten, L. 2006. Effect of speed reduction on fuel consumption and emissions of heavy duty lorries in Belgium. In: Proceedings of the 8th International Symposium on Highways and the Urban Environment. Rauch S. & Morrisson G. (eds.), Chalmers University. (in press)

Pelkmans, L., Debal, P., Hood, T., Hauser, G., Delgado, M. R. 2004. Development of a simulation tool to calculate fuel consumption and emis-sions of vehicles operating in dynamic conditions. SAE 2004 Spring Fuels & Lubricants, 2004-01(1873), SAE Int., Warrendale, PA, (USA).

AIRBORNE PARTICULATES AND TRAFFIC RELATED POLLUTANTS DURING CAR-FREE DAYS IN THE BRUSSELS URBAN AREA

P. Vanderstraeten[1], Y. Lénelle[1], A. Meurrens[1], D. Carati[2], L. Brenig[2], Z.Y. Offer[3]

(1) Brussels Institute for Environmental Management
(2) ULB, Université Libre de Bruxelles – (3) BGU Ben-Gurion University, Beersheba

ABSTRACT

Road traffic is often indicated as an important contributor to the PM10 concentration, especially in a city environment. Although traffic may be one of the most important sources for the health related components, there are several indications that direct traffic emissions are probably not the dominant source in the total PM10 mass concentration. Relative high PM10 concentrations have been observed at some of the official holidays, as was the case for the carnival period and Eastern Monday in the year 2005. The car free day of 2003, on a dry and hot Sunday of September, showed PM10 levels exceeding those of an average Sunday during the dry and hot summer period of 2003. At that car free Sunday, during the traffic ban hours no significant decrease in PM10 concentration was observed as it was the case for other traffic related pollutants (NO, NO_2, CO and CO_2).

The results of the car free Sunday of 2006 show even more spectacular results. The PM10 and PM2,5 concentration during the traffic ban hours are about three times higher than on an average Sunday or working day during the period May – September 2006. Moreover in all measuring stations of the Brussels Capital Region, the daily average PM10 and PM2,5 values of this car free Sunday did exceed the 50 µg/m^3 limit value set for the daily PM10 concentration.

1. INTRODUCTION

The Brussels Capital Region has a population of about 1 million and a surface of about 160 km^2. The Brussels telemetric network has eleven fixed stations for controlling the ambient air quality and two road tunnel stations. Compliance with the EC quality objectives is still problematic for the NO_2 limit value of 40 µg/m^3 as the annual average concentration to be met by 2010 and for the 50 µg/m^3 daily PM10 limit value, not to be exceeded more than 35 times per year (since 2005). Reducing every day emissions to the average weekend level will not be sufficient to respect these quality objectives in all Brussels measuring sites.

The PM10 concentration is monitored at six different sites. Over the past years the PM10 annual average at different sites in the Brussels area ranged from about 27 to 30 µg/m^3 at a city background and suburban site to hardly less than 40 µg/m^3 in the city centre and up to 50 µg/m^3 at an industrial site. Although there was no clear tendency observed over the past years the highest annual average was observed for the year 2003, with its dry and hot summer period. In 2005 the EU limit value of 40 µg/m^3 for the annual average was respected in all six sites. At two of the sites the EU limit value for the daily average concentration, not more than 35 days with a daily concentration higher than 50 µg/m^3, was not respected (Vanderstraeten et al., 2006C). Days with dry weather conditions and prevailing winds coming from the continent (large sector east) are well represented amongst the days with PM10 levels exceeding the limit value of 50 µg/m^3 as the daily average concentration. On the other hand at several occasions some very high PM10 results have been obtained under conditions with a relative high humidity. In these cases practically 80 to 90% of the PM10 mass concentration consisted of PM2,5 particles.

2. METHODOLOGY

Measurements to obtain PM10 concentrations by means of R&P TEOM 1400Ab continuous instruments have been started up during the period 1996-1999 at six different sites in the Brussels Capital Region. Three of the sites are representative of the general activities in the city (traffic, domestic heating, business and commercial activities), a fourth one is situated in an industrial area (city naval port) and two of the sites are more typical for a city residential environment (Vanderstraeten et al., 2006C). In the period up to 2003, in order to obtain PM10 data comparable to the EC gravimetric reference method, the raw measured data from TEOM-analyzers in Belgium are multiplied by a factor 1,47 (*VMM-study 2003*). From 2004 on all TEOM PM10 analyzers are equipped with a FDMS module (Filter Dynamics Measurement System). The PM10-FDMS results obtained are, by measurement, more directly comparable to the gravimetric reference method. Since January 2006 at four sites PM2,5-FDMS is measured along with PM10.

Nitrogen oxides, NO and NO_2, are measured at all 11 ambient stations and at the two tunnel stations, carbon monoxide at 8 surface stations and at the tunnel stations, ozone at 7 and carbon dioxide at 4 ambient stations.

3. RESULTS AND DISCUSSION

On Sunday 17 September 2006 and already for the fifth time since 2002, a car free Sunday was organized by the Brussels Authorities. From 7:00 till 17:00 UT (9 to 19 h local time) nearly all motorized traffic was banned from the entire surface of the Brussels Capital Region. The use of Public transport was free and besides the busses from the Brussels Public transport company exceptions were given to a limited number of taxis, to emergency services and, on request, to a few thousands individuals. The day was characterized by mild meteorological conditions: no temperature inversion close to the surface in the morning nor in the evening, a relative high but decreasing humidity (90 to 70%), a medium wind velocity (2-3 m/s) and a temperature from 19°C in the morning to about 22°C in the afternoon, winds coming from the West and a cloud cover during the whole day. With an exception for PM the concentration levels of different pollutants were low in the early morning.

The effect of the traffic ban hours is best seen in a road tunnel where the influence of the meteorological conditions on the concentration is rather limited. Immediately after the beginning of the traffic ban period a sharp and sudden decrease of the concentrations can be observed. By the end of that period when the traffic returns, a sudden increase of the concentrations can be seen. Similar, but less spectacular observations can be made for the traffic related pollutants at traffic oriented measuring stations at the surface. Since the ambient concentrations at one particular day can be strongly dependent on the meteorological conditions of the moment it is more appropriate to represent the average situation over all five car free Sundays (2002-2006) organized so far and compare it to the average situation of all Sundays and all working days during the months May – September of the years 2002 till 2006. Figure 1 is represents the results for NO obtained in a traffic station.

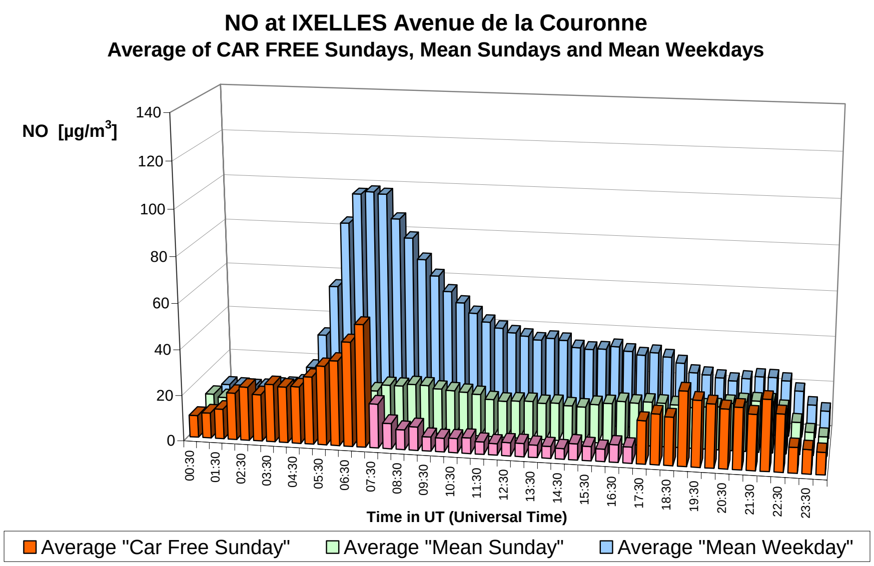

Figure 1 : Traffic station NO – Average of all five car free Sundays (2002-2006), average Sunday and average working day during May – September 2002-2006

At the beginning and at the end of the traffic ban period a sharp and sudden concentration change can be observed. During the traffic ban hours the average concentration level is lower than on an average Sunday or working day. Similar observations can be made for NO_2, CO and CO_2. During the traffic ban hours of the car free Sundays a decrease of the NO_2 concentration is observed in all measuring sites, also in the suburban and urban background sites. This observation makes clear that the NO_2 problem can be solved at the condition that traffic NO_X emissions can be reduced permanently by a similar amount but on a much larger spatial scale.
The PM10 and PM2,5 concentrations on the car free Sunday of 17 September 2006 were about three times higher than on an average Sunday or average working day during the period May – September 2006.

Figure 2 represents the PM10 results for the Molenbeek site for an average Sunday, an average working day and the car free Sunday of 2006. The same picture is obtained in all Brussels sites measuring PM10 or PM2,5. Daily PM10 values ranged between 75 and 92 µg/m^3 and daily PM2,5 values between 70 and 78 µg/m^3. The EU limit value of 50 µg/m^3 for the daily PM10 concentration was exceeded in all Brussels measuring sites.

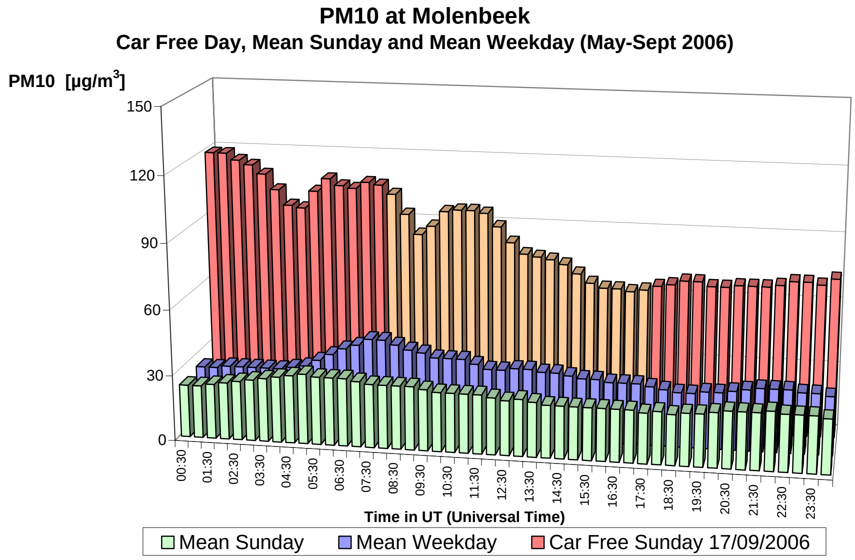

Figure 2 : PM10 at Molenbeek – Average Sunday, average working day and car free Sunday 2006

PM10 and PM2,5 concentrations were already high at the beginning of the car free day. A concentration build up has taken place from Friday 15 September in the afternoon and it continued on Saturday 16 during the whole day. Although the PM concentrations decreased during the car free day (17 September), they remained quite high. At the beginning nor at the end of the car free period one cannot observe a sharp or sudden concentration change as it is the case for NO, NO_2, CO or CO_2 in traffic related stations. The average PM10 concentration computed for all five car free Sundays (2002-2006) organized so far is also higher than or at least of the same order of the average concentration on all Sundays or all working days from the periods May – September 2002-2006.

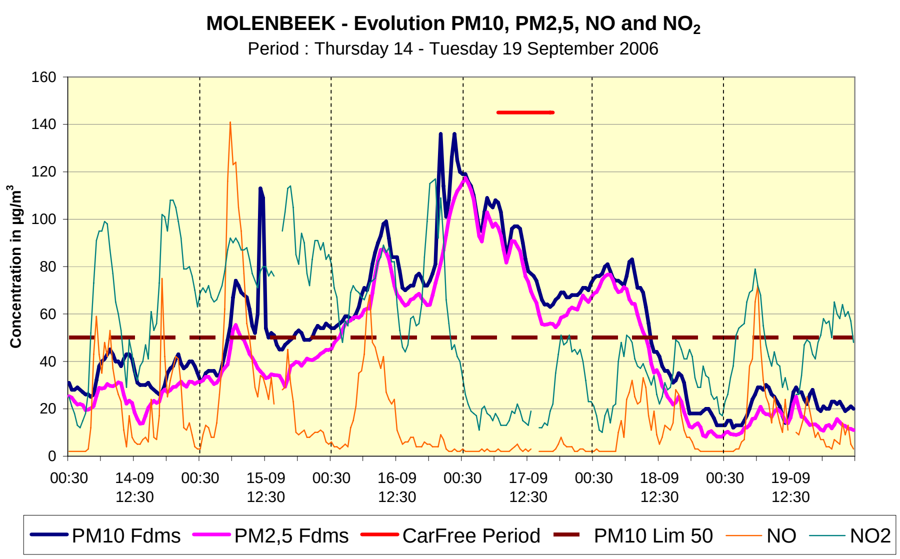

Figure 3 : Molenbeek – Evolution hourly values for PM10, PM2,5, NO and NO_2 – Period 14-19 Sept 2006

The graphs in figure 3 represent, for the period 14-19 September 2006, the evolution of the hourly values for PM10, PM2,5, NO and NO_2 at the Molenbeek site, close to the city centre (habitation) and situated along the commercial and industrial axis of the Brussels Capital Region. It can be seen that 80 to 90% of the total PM10 mass concentration consists of PM2,5. The dynamic evolution of the PM10 and PM2,5 concentration seems not to have much in common with the evolution of the NO and NO_2 concentration. Analysis of PM sampled on additional filters showed that 35 to 40% of the collected mass consisted of (secondary) sulphates and nitrates.

4. CONCLUSIONS

For the organization of the different car free Sundays the Brussels Authorities achieved the maximum possible for banning the motorized traffic out of the entire Brussels Capital Region. During the interdiction hours, the concentration of traffic related pollutants (NO, NO_2, CO, CO_2) is decreasing significantly in road tunnels and in traffic oriented measuring stations at the surface. Sharp and sudden concentration changes are observed at the beginning and at the end of the traffic ban hours. On all car free Sundays organized so far, the NO_2 concentration decreased at all measuring sites of the Brussels Capital Region, in traffic stations as well as in suburban and background stations. This important observation points out that drastic emission reductions will enable to be compliant in the future with the EU limit value for the annual average NO_2 concentration.

At the car free Sunday of 17 September 2006 very high PM10 and PM2,5 concentrations have been observed in the Brussels Region. The concentrations were three times higher than those of an average Sunday or working day and they exceeded the 50 $\mu g/m^3$ level of the EU limit value for the daily PM10 concentration. The absence of a sharp and sudden concentration change at the beginning and at the end of the traffic interdiction period seems to indicate that direct traffic emissions contribute only little to the total PM10 or PM2,5 mass concentration.

The presence of high PM concentrations on this car free day, with practically no traffic and no domestic heating (~20°C) and with only a limited contribution of the commercial and industrial activities (Sunday), do accentuate the complexity of the PM problematic. Over the past few years, on at least four different occasions with similar conditions (restricted traffic, no domestic heating and few industrial activity) and with relative low concentrations for traffic related pollutants (NO, NO_2, CO), daily PM10 concentrations exceeding the EU limit value have been observed. At these occasions additional intervention by the local authorities seems to be very limited.

The average PM10 concentration computed for the five car free Sundays (2002-2006) is also higher than or at least of the same order of the average concentration on all Sundays or all working days from the periods May – September 2002-2006.

5. REFERENCES

Brenig L and Offer Z.Y. 1995. Dust dynamics: experiments and models. The Neuman Memorial Symposium on Mesoscale Models and Climate History. Jerusalem p.192-193

Offer Z.Y. 2002. Airborne particle dynamics in the Brussels environment. Research in Brussels Action Report

Vanderstraeten P., Lénelle Y., Meurrens A., Carati D., Brenig L. Offer Z.Y. 2005. Granulometry and micro morphology of airborne particles in the Brussels urban environment. Journal of Chemistry and Environment. ICCE Proceedings, 549-553

Vanderstraeten P., Lénelle Y., Meurrens A., Carati D., Brenig L. Offer Z.Y. 2006A. Temporal variations of airborne particles concentrations in the Brussels environment. Environmental Monitoring and Assessment. Online first 16.12.2006

Vanderstraeten P., Lénelle Y., Meurrens A., Carati D., Brenig L. Offer Z.Y. 2006B. Airborne particle Granulometry and micro morphology during working and not working days in the Brussels Environment. WIT*Press* Air Pollution XIV, 287-295.

Vanderstraeten P., Lénelle Y., Meurrens A. Air Quality in the Brussels Capital Region 2003-2005. 2006C. Report IBGE-BIM (www.ibgebim.be only in Dutch or French)

VMM Study – Comparison of PM10 measurements methods. 2003

Proceedings of the 6th International Conference on Urban Air Quality
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ESTIMATES OF THE IMPACTS OF DIFFERENT ABATEMENT STRATEGIES FOR CERAMIC INDUSTRIES IN THE PM10 CONCENTRATIONS IN CASTELLÓN (SPAIN).

[1]De Pascual, A., [1]Aceña, B., [1]Palomino, I., [1]Martín, F., [2]Celades, I., [2]Sanfelix, V., [2]Gomar, S., [2]Monfort, E.

1) Atmospheric Pollution Unit. Department of Environment. CIEMAT. Avda. Complutense 22, 28040-SPAIN. E-mail:a.depascual@ciemat.es

2) Instituto de Tecnología Cerámica (ITC). Universitat Jaume I. Castellón. Spain.

ABSTRACT

The study presented shows a methodology for estimating the effectiveness of different strategies for reducing the PM10 concentration in an industrial cluster focused on ceramic manufacturing products. In order to estimate the emission rates, four kinds of industrial plants that are associated with ceramic industry (producers of ceramic tiles, spray-dried granules, frits and pigments) were taken into account. These industries release particles to the atmosphere from channelled emissions (stacks) as well as fugitive emissions from areas where dusty materials are stored, handled or transported. According to the emission factors given by ITC (channelled emissions) and by EPA-AP42 (fugitive emissions), PM10 total emission was calculated for every single industry taking into account the production of each plant. Several technological abatement scenarios has been set up based on combining the use of the best available techniques (BAT) to channelled and diffuse sources of particles.

The MM5/CALMET meteorological model and the MELPUFF dispersion model were used to simulate the PM10 dispersion in several meteorological and technological scenarios. The modelling results enable analysing the effect of different strategies for improving air quality concerning PM10 concentrations.

1. INTRODUCTION

Castellón is located in Eastern coast of Iberian Peninsula, it is characterized by a very complex topography, a Mediterranean climate and a strong influence of mesoscale flows induced by radiative heating such as sea breezes or anabatic and katabatic flows (Salvador, 1999). Castellón has over 200 ceramic industries located in an area of around 400 Km^2 and producing around 650 10^6 m^2/year of ceramic tiles. Due to clays are the main raw material manipulated by ceramic industry, it releases important amounts of particles to atmosphere from stacks (channelled emissions) and from storing areas, trucks transport by road and mining activities (diffuse or fugitive sources).

The goals of this paper are to assess the air quality in the area to determine the zones with probable exceedances of the EU air quality standards due to the ceramic industry, and how PM_{10} concentrations can be reduced applying different abatement strategies.

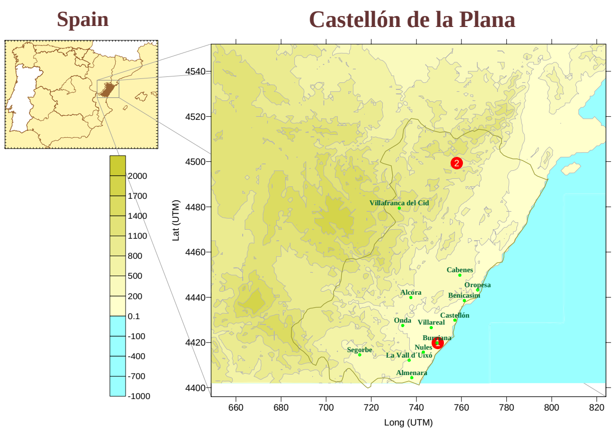

Figure 1: Location and topography of Castellón province. Two red dots show where are located meteorological stations. 1 for Burriana estation and 2 at Vallibona's meteorological station.

2. METHODOLOGY

In order to obtain a set of days that statistically represents meteorological variability of the area taking as reference the year 2003, a K-means clustering analysis has been done attending to wind direction and temperature at 850 hPa, temperature gradient, surface pressure and precipitation variables. Data included in this analysis are from 0.2ºx0.2º-resolution HIRLAM reanalysis (Instituto Nacional de Meteorología). A set of 38 days was obtained whose meteorological behaviour is considered representative for year 2003 (Table 1).

Table 1: Dates of selected days representing every meteorological scenarios and percentage of cases in 2003

Wind Direction at 850 hPa															
N		NE		E		SE		S		SW		W		NW	
06/03	0.8	03/07	3.0	24/02	0.6	07/04	3.3	27/04	2.5	07/03	6.0	10/04	3.0	11/09	3.8
03/04	2.5	17/09	1.9	23/03	2.7	14/05	3.0	30/05	3.6	06/06	1.4	01/07	4.4	26/11	4.9
13/05	2.7	17/11	1.9	09/08	2.5	21/08	1.4	01/06	2.5	25/06	4.4	25/07	4.9	19/12	4.9
18/10	1.6	25/11	1.6	25/10	2.2	05/11	1.1	02/06	2.5	22/10	0.3	29/10	1.9	29/12	3.6
24/12	2.5	08/12	1.9			04/12	0.8	26/10	1.4	31/10	3.6	14/11	2.5		

Atmospheric flows during these days were simulated using the MM5 (Dudhia, 2001) and CALMET (Scire, 1990) models. Boundary conditions are from 0.2ºx0.2º-resolution HIRLAM reanalysis. A two step downscaling process has been done using MM5/CALMET meteorological models to obtain 1 Km resolution meteorological fields. Resulting meteorological fields was compared with observational meteorological data for two stations, one in the coast and other one several tens of km inland (Fig. 1). The modelled results fits quite well with the observations including the sea breeze cycle (fig. 2).

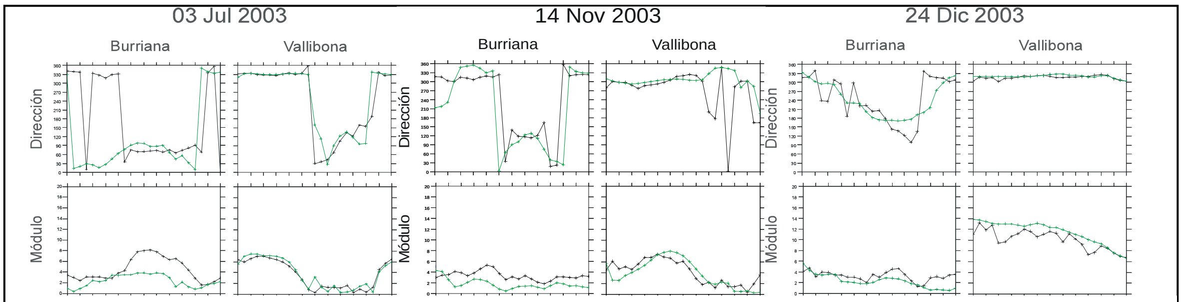

Fig 2: Comparison of observational data (black) and model results (green) for wind at 10 m in tree different days

PM10 emission rates has been assessed applying AP42 emission factors taking into account technical characteristics of each industrial plant related with ceramic production (ceramic tiles, spray-dried granules, frits and pigments). These industries release particles to the atmosphere from stacks and areas where dusty materials are stored, handled or transported. According to a set of emission factors given by ITC (Blasco et al, 1992; Monfort et al, 2006a; Monfort et al, 2006b) and EPA-AP42, PM10 emission were calculated for every industry knowing the production of each plant. For technological scenarios simulations, as well as for meteorological data, year 2003 is considered as reference.

Therefore five technological scenarios have been set up considering different abatement strategies based on technical aspects of each type of particles sources:

- Scenario 1. Reference technological scenario considering the BAT implementation state at 2003.
- Scenario 2.1. Taking the reference scenario but considering that the spray-driers implement Venturi-type wet scrubbers for removing particles (95% theoretical efficiency).
- Scenario 2.2. Taking the reference scenario but considering that the spray-driers implement bag filters for removing particles (99% theoretical efficiency).
- Scenario 2.3. Taking the reference scenario but considering the implementation of BAT in particle diffuses emissions, in particular overall enclosure of raw material storing and handling areas (99% theoretical efficiency for particles removal).
- Scenario 3. Implementation of high efficiency BAT for channelled (bag filters) and diffuses sources (enclosure of storing areas) in the ceramic industry.

The atmospheric dispersion of PM10 was simulated for the 38 meteorological scenarios combined with the 5 technological scenarios by using the MELPUFF model (Martín et al, 2002). It is a Lagrangian puff model that simulates dispersion of pollutants estimating advection processes of Gaussian puffs that, in this work, has been emitted each minute. It has parameterizations to calculate puffs dispersion based on turbulence parameter generated by CALMET model, a specific module for particles dry deposition of pollutants (Zhang et al, 2001), wet deposition, plume rise, etc. Results of the MELPUFF simulations shows the time evolution and spatial distribution of PM10 released from ceramic industries. These results were compared with European Union limit values for PM10 (50 μg/m^3 for daily average and 40 μg/m^3 for annual mean).

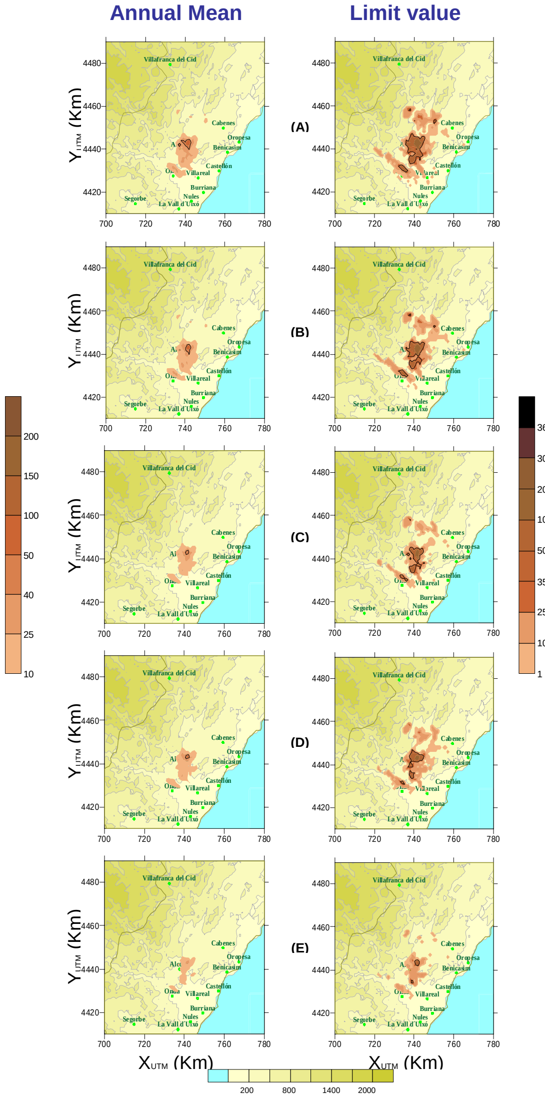

Fig. 3: PM_{10} inmision levels originated by emissions from ceramic industry of Castellón province. Rows A, B, C, D, and E shows results for scenarios 1, 2.1, 2.2, 2.3, and 3, respectively. Left column corresponds to annual mean, black line shows the area where annual limit value (40 μg PM_{10} / m^3) is exceeded. Right column shows number of daily exceedances/year, black line is rounding the area with more than allowed exceedances (currently 35 exceedances).

3. RESULTS AND DISCUSSION

Figure 3 shows statistical results from MELPUFF simulations carried out under different technological scenarios including only emission from ceramic industries. The base scenario shows us than the most affected area by PM_{10} emissions from the ceramic industry seems to be close to L'Alcora town and his Eastward and Northeastward vicinity with annual mean concentrations higher than the limit value and a wide area with more than 35 exceedances of the daily limit value. These results must be considered with some caution because of the high uncertainty in the emission from diffuse sources.

The size of overcoming thresholds areas of scenarios 2.2 and 2.3 are similar and slightly smaller than the area in the scenario 2.1. Therefore the reduction of PM10 levels applying abatement strategies to diffuse emissions seem to be similar to reductions obtained by applying strategies for channelled or stacks emissions.

It can be seen that areas exceeding legislated levels are always wider for daily limit value than in annual mean limit value. In addition, in scenario 3, there are not areas exceeding the annual limit value but a relatively small area with daily limit value exceedances remains. These findings agree with previous studies conducted in the area (Querol et al., 2004), which concluded that the current legislative daily PM_{10} limit value is more demanding than the annual limit value.

4. CONCLUSIONS

This study is a first approximation to how to estimate the impact of air particles abatement strategies applied in an area with high density of ceramic industries. However, this study based on modelling techniques has yet some aspects to improve. One of them is the high uncertainty in the PM10 emission from diffuse sources. Other one is the study must be extended to all the emission sectors. It can provide the estimates of relative contribution of each specific sector, specially the ceramic industry, to the ambient PM10 concentrations in the studied area. In addition, the use of all emission data would allow to calibrate the dispersion model in the area in spite of the MELPUFF model has shown its skill for simulating the air pollution level in several areas of Spain (Martin et al, 2002). Then, the results and conclusions of this work are quite preliminary and they could be the following:

- The most affected area by PM10 emissions from the ceramic industry could be close to L'Alcora town and his Eastward and Northeastward vicinity.
- The reduction of PM10 levels applying abatement strategies to diffuse emissions seem to be similar to reductions obtained by applying strategies for channelled or stacks emissions.
- Even in the most restrictive technological scenario (3) there are some relatively small areas with exceedances of the daily limit values caused only by the ceramic industries. Hence, the abatement strategies must be extended to other pollutants sector besides ceramic industry, such as, traffic, refineries, power plants, etc, in order to not exceed the daily limit values.

Presently, we are carrying out a more complete study including all sources, validation of MELPUFF model with measured data from Castellon stations, estimates of relative contribution of each pollutant sector and impact of abatement strategies. More complete results will be presented in the oral presentation.

5. ACKNOWLEDGEMENTS

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6. REFERENCES

Blasco A., Escardino A., Busani G., Monfort E., Amorós J.L., Enrique J., Beltrán V., Negre P., 1992. Tratamiento de emisiones gaseosas, efluentes líquidos y residuos sólidos de la Industria Cerámica. Castellón: Instituto de Tecnología Cerámica; AICE.

Dudhia J. et al., 2001. PSU/NCAR Mesoscale Modelling System. Tutorial Class Notes and User's Guide. Mesoscale and Microscale Meteorology Division. National Center for Atmospheric Research. USA.

Martín F., C. González, A. Bailador, E. Sánchez, I. Palomino, M. Palacios, S.N. Crespí and C. Gorostiza, 2002. SICAH: An automatic system for control and prevention of air pollution in Huelva (Spain). International Journal of Environment and Pollution, 16, 1-6

Monfort E., Celades I., Gomar S., Rueda F., Quereda F., Sanfelix V., Minguillón M.C., 2006a. Determinación de las fracciones PMX/PST en emisiones canalizadas de la industria cerámica. QUALICER 2006. Castellón.

Monfort E. Celades I., Gomar S., Sanfelix, V., 2006b. Control y estimación de emisiones difusas de material particulado en operaciones al aire libre. PROMA-X Congreso de Ingeniería Ambiental, Bilbao, 3-5 octubre 2006.

Querol X., Alastuey A., Ruiz C.R., Artiñano B., Hansson H.C., Harrison R.M., Buringh E., Ten Brink H.M., Lutz M., Brumann P., Strael P., Schneider J., 2004. Speciation and origin of PM_{10} and $PM_{2.5}$ in selected European cities. Atmospheric Environment 38, 6547-6555.

Salvador, R., 1999. Análisis y modelización de los procesos atmosféricos durante condiciones de brisa en la costa mediterránea occidental: zona de Castellón. Ph.D. Thesis, Universitat Politécnica de Catalunya,

Scire, J.S., Insley and R.J. Yamartino, 1990. Model formulation and user's guide for the CLAMET meteorological model. Sigma Research Corp., Concord, MA.

Zhang L., Gong S., Padro J. and Barrie L., 2001. A size-segregated particle dry deposition scheme for an atmospheric aerosol module. Atmospheric Environment 35, 549-560.

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NEURO-FUZZY AND NEURAL NETWORK SYSTEMS FOR AIR QUALITY CONTROL

C. Carnevale*, G. Finzi, E. Pisoni, V. Singh and M. Volta
Department of Electronics for Automation, University of Brescia
Via Branze, 38, 25123 Brescia, Italy
*email: carneval@ing.unibs.it

ABSTRACT
Regional Authorities need tools to assess both the impact of emission reduction strategies on pollution indexes and the costs of such emission reduction in order to define suitable air quality plans. The problem can be formalized as a multi-objective mathematical program, integrating pollutant-precursor models and the estimate of emission reduction costs. Both aspects present several complex elements. In particular the source-receptor models, describing transport phenomena and chemical non linear dynamics, require deterministic complex modelling systems with high computational costs. In this paper we suggest to identify simplified source-receptor statistical models (neural network and neuro-fuzzy models) processing the simulations of a multi-phase modelling system (GAMES) is presented. The methodology has been applied to Lombardia region (Northern Italy) PM10 pollution control.

1. INTRODUCTION

The air quality control problem can be generally formalized as a multi-objective problem where the air quality and the emission abatement costs are considered (Finzi and Guariso, 1992, Friederich and Reis, 2000). The cause-effect relations between secondary pollution and its precursors (primary PM10, VOC, NOx, NH3, SOx) are numerous and non linear, so the computation of the air quality index requires complex deterministic 3D models. Therefore, these models, describing transport and chemical phenomena, have so high computational costs that they are not of practical use in a multi-objective mathematical program. For this reason, the identification of simplified models synthesizing the relationship between the precursor emissions and secondary pollutant concentrations is required. In literature, reduced form models to describe the source-receptor relationship between gas pollutant (typical ozone) and its precursors have been presented. These reduced models can be classified in: (1) simplified photochemical models, obtained by adopting semi empirical relations calibrated with experimental data (Venkatram et al., 1994), (2) statistical models identified by processing the results of complex 3D transport-chemical models (Carnevale et al., 2007, Guariso et al., 2004, Friederich and Reis, 2000, Volta, 2003). As for precursor-PM10 relationship, Amann et al. (2004) have identified linear models by processing the EMEP 3D modelling system simulations.
This work focuses on the identification of neural networks and neuro-fuzzy models processing long term simulations of GAMES multi-phase modelling system (Volta and Finzi, 2003) in order to compute a PM10 exposure indicator.

2. METHODOLOGY

GAMES long term simulations

Ground level PM10 concentrations have been simulated by the GAMES modeling system consisting of: (a) the multiphase eulerian 3D photochemical model TCAM (Carnevale et al, 2005); (b) the meteorological pre-processor CALMET (Scire et al., 1990); the emission processor POEM-PM (Carnevale et al., 2006).
The modeling system has been run over Northern Italy (Figure 1), in the frame of CityDelta-CAFE project. The domain (300 x 300 km^2) has been horizontally subdivided into 60 x 60 cells, with a resolution of 5x5 km^2 each. Vertical domain extends up to 3900 m a.g.l., subdivided into 11 layers of growing thickness. Simulations have been performed getting initial and boundary conditions by a nesting procedure from the results of the EMEP Unified Model working at European scale. Assuming the actual meteorology, emission patterns and boundary conditions of that period, the simulation has been performed for the entire 1999 year (base case simulation), supplying pollutant hourly concentration fields. The results has been validated in the frame of the CityDelta-CAFE project (Carnevale et al., 2005). The run of such a simulation takes about 23 days of CPU time (Pentium IV, 3.8 Ghz) and this explains why GAMES cannot be directly integrated in an optimization procedure that should process hundreds of model runs. Keeping the same meteorology in input and applying two different emission control strategies (CLE - current legislation and MFR - most feasible reduction, http://www.iiasa.ac.at) reducing PM10 precursor emissions (Table 1), two alternative scenarios have been simulated in the frame of CityDelta-CAFE EU Project. Starting from the 5x5 km^2 resolution results of the GAMES yearly simulations, one neural network and one neuro-fuzzy model have been been identified for each group of 2x2 (10x10 km^2) domain cells using as input data the daily emission of primary PM10, NOx, VOC, NH3 and SOx estimated for each cell group. The inputs are pre-processed by means of a normalization procedure.

Table 1: PM10 precursor emission variation (%) for CLE and MFR scenarios.

Scenario	NOx	VOC	SOx	NH3	Primary PM10
CLE	-29.79	-38.16	-77.49	0.51	-39.65
MFR	-44.50	-58.74	-90.64	-35.12	-77.19

The target data are the PM10 daily mean concentrations computed by the GAMES system. The validation set (Nval) has been yielded extracting, from the simulation pattern, the third week of each month (7x12x3, i.e. 252 patterns). The identification set (Ntr) includes the remaining 843 patterns.

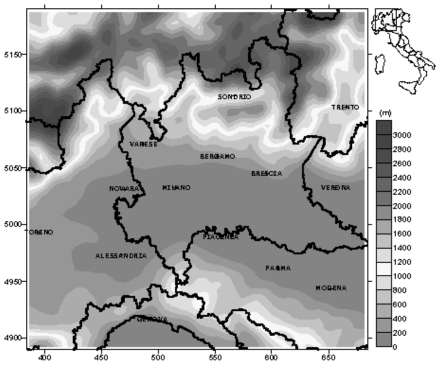

Figure 1: The selected domain with main cities, Lombardia Region boundaries and orography.

Neural Network simplified models

Several network structures have been considering. The best fitting architecture is the Elman Neural Network (Elman, 1990), i.e. a vector function $f : R^Q \rightarrow R^L$, where Q and L are the dimensions of the input and output vectors of the net respectively; the *l-th* element of the vector function f for the n-th pattern $v^n \in \Re^Q$ is defined as (M is the number of the neurons in the hidden layer):

$$f_l(v^n) = \sum_{m=1}^{M} (OW_{l,m} \cdot a_m^n) + g_l$$

where

$$a_m^n = \tan sig(\sum_{q=1}^{Q} (IW_{m,q} \cdot v_q^n) + \sum_{w=1}^{M} (FW_{m,w} \cdot a_w^{n-1}) + b_m) \quad \text{and} \qquad \tan sig(x) = \frac{2}{1+\exp(-2x)} - 1$$

The matrices IW (M×Q), OW (L×M), and FW (M×M) are the input, output and feedback weight matrix respectively, and b (M×1) and g (L×1) vectors are the bias terms. Neural networks weights (IW, OW, FW, b and g) are tuned on a training dataset by means of a back-propagation algorithm.

Neuro-fuzzy simplified models

In neuro-fuzzy systems, neural networks are used to tune the membership functions of the fuzzy system, and to extract fuzzy rules from numerical data (Shing and Jang, 1993). In this work, a 4 layer neuro-fuzzy network has been considered. The first layer compute the value of the membership function $\mu_{A_{h,d}}(v_d, \alpha_{h,d}, \beta_{h,d})$ (where the dependence to parameter $\alpha_{h,d}$ and $\beta_{h,d}$ to be identified during the training process is stressed) of each component of the input vector $v \in \Re^D$, where $A_{h,d}$ is the $h-th$ linguistic variable of the $d-th$ input vector component. In the second layer, the antecedent of each of the Z rules has been computed by means of a T-norm function and normalized:

$$\overline{w}_z = \frac{w_z}{\sum_{z=1}^{Z} w_z}, \text{ where } w_z = T(\mu_{A_{h,d}}(v_d)) \qquad \forall \mathrm{A}_{h,d} \in Ant_z$$

where T is the chosen T-norm function (min, and), Ant_z is the set of antecedents of the z-th rule, $Z=H^D$ is the number of fuzzy rules in the second layer and $\overline{w}_z$ is the normalized antecedent of the z-th rule.

The third layer performs the computation of consequent parameter of the rules, following the Takagi-Sugeno approach:

$$g_z = w_z \cdot \left(\sum_{q=1}^{Q} (p_{q,z} \cdot v_q + r_z)\right)$$

Finally, the overall output is computed has weighted mean of the output membership functions g_z:

$$f(v) = \sum_{z=1}^{Z} \overline{w}_z \cdot g_z$$

During the learning process the membership function parameters $\alpha_{h,d}$, $\beta_{h,d}$, pd,z and r_z are tuned, using a backpropagation algorithm.

3. RESULTS AND DISCUSSION

The performance of the simplified source-receptor models are assessed on the validation dataset in terms of spatial correlation and mean error between the network and neuro-fuzzy systems and the GAMES output (Figure 2, 3, 4).

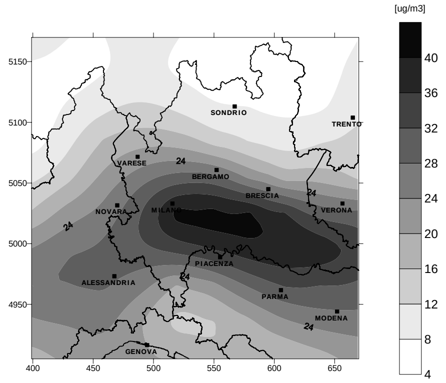

Figure 2: PM10 mean concentration (μg/m³) simulated by TCAM model for the validation dataset.

The mean error maps (Figure 3) highlight that both the systems are able to correctly reproduce the mean concentration over the domain. The two patterns are very similar, with a maximum overestimation of 5 μg/m³ in the west of the domain.

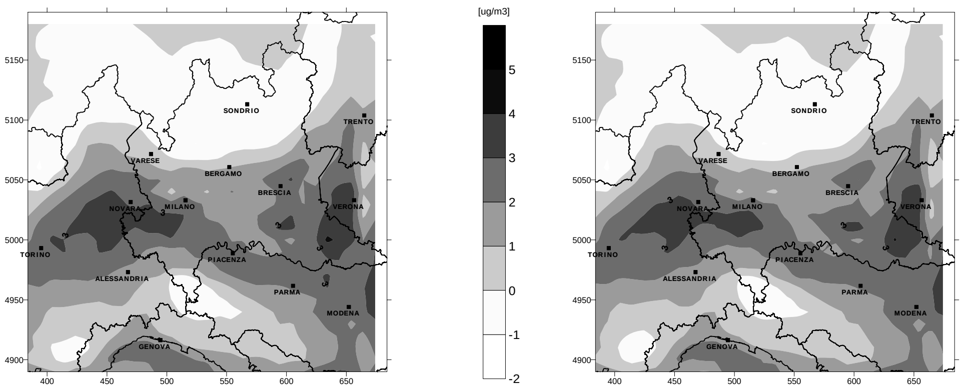

Figure 3: Difference (μg/m³) between PM10 mean concentration simulated by neural network system and GAMES modelling system (left) and between neuro-fuzzy system and GAMES (right).

The scatter plots (Figure 4) confirms that the two models have very similar behaviour, with all points very close to the bisecting line, even if the identified networks slightly overestimate concentrations higher than 30 μg/m³.

The two systems have been implemented on a Pentium IV - 3.8 GHz, with 1 GB RAM; a yearly simulation runs in 150 seconds, with respect to the 23 days required by GAMES modelling system.

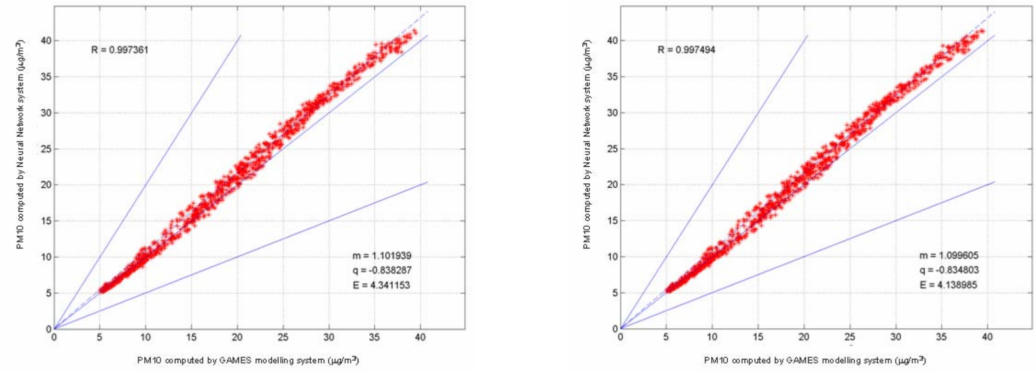

Figure 4: Neural network (left) and neuro-fuzzy versus GAMES PM10 mean concentration computed in each point of the domain.

4. CONCLUSIONS

A procedure to formulate source-receptor models aimed to support PM10 pollution control has been presented. The methodology has been applied over Northern Italy domain, often affected by high PM10 levels. The procedure implements Elman neural networks and neuro-fuzzy models tuned processing the outputs of the GAMES modelling system for three different yearly simulations (a base case and two alternative emission scenarios obtained varying the PM10 precursors emission). The comparison between the two source-receptor systems and GAMES results highlights the high capability of the simplified models to reproduce the deterministic simulations, in terms both of mean values and spatial correlation coefficient. Thanks to the low computational costs, the identified source-receptor models will be integrated in a two objective optimization problem considering both the effectiveness of emission reduction policies and their costs.

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REFERENCES

Amann, M., Cofala, J., Heyes, C., Klimont, Z., Mechler, R., Posch, M., Schopp, W., 2004. The RAINS model. documentation of the model approach prepared for the RAINS peer review 2004," tech. rep., IIASA, Laxenburg, (AU).

Carnevale, C., Finzi, G., Volta, M., 2005. Design and validation of a multiphase 3D model to simulate tropospheric pollution, 44th IEEE Conference on Decision and Control and European Control Conference 2005, Seville (E).

Carnevale, C., Gabusi, V., Volta, M., 2006. POEM-PM: an emission model for secondary pollution control scenarios. Environmental Modelling and Software, 21, 320–329.

Carnevale, C., Pisoni, E., Volta, M., 2007. Selecting effective ozone exposure control policies solvine a two-objective problem. Ecological Modelling, doi: 10.1016/j.ecolmodel.2006.12.036.

Elman, J., 1990. Finding structure in time. Cognitive Science, 14, 179–211.

Finzi, G., Guariso, G., 1992. Optimal air pollution control strategies: a case study. Ecological Modelling, 64, 221–239.

Friedrich R., Reis, S., 2000. Tropospheric ozone abatement. Springer-Verlag.

Guariso, G., Pirovano, G., Volta, M., 2004. Multi-objective analysis of round-level ozone concentration control. Journal of Environment Management, 71, 25-33.

Scire, J.S., Insley, E.M., Yamartino, R.J., 1990. Model formulation and User's Guide for the CALMET meteorological model," Tech. Rep. A025-1, California Air Resources Board , Sacramento , CA.

Venkatram, A., Karamchandani, P., Pai, P., Goldstein, R., 1994. The development and application of a simplified ozone modeling system (SOMS). Atmospheric Environment, 28, 3665–3678.

Volta, M., Finzi, G., 2006. GAMES, a comprehensive Gas Aerosol Modelling Evaluation System.
Environmental Modelling and Software 21, 587–594.

Shing, J. and Jang, R., 1993. ANFIS: Adaptive-Network-based Fuzzy Inference System," IEEE trans. on System, Man and Cybernetics, 23, 665–683.

INTEGRATED MODELLING SYSTEM TO ASSESS PARTICULATE MATTER CONTROL POLICIES

C. Carnevale, G. Finzi, E. Pisoni* and M. Volta
Department of Electronics for Automation, University of Brescia
Via Branze, 38, 25123 Brescia, Italy
*email: enrico.pisoni@ing.unibs.it

ABSTRACT

In order to implement sound air quality policies, Regulatory Agencies require mathematical tools to evaluate both the effectiveness and the cost associated to different emission reduction strategies. These tools are even more useful when atmospheric PM10 concentrations are considered, due to the complex non-linear processes affecting the production and accumulation of this secondary pollutant. In this work the formulation of a multi-objective problem to control particulate matter is proposed, formalizing: (a) air quality indicators and cost functions; (b) constraints for the decision variables; (c) local source-receptor models, describing the cause-effect relation between air quality indicators and decision variables. The methodology has been implemented for Lombardia Region (Northern Italy), often affected by PM10 pollution episodes. The local source-receptor models used in the multi-objective analysis have been identified processing long term simulations of GAMES multiphase modelling system. Results in terms of non-dominated solutions for the multi-objective problem are analysed..

1. INTRODUCTION

The EU Directive (1999/30/CE) has fixed limit values for several atmospheric pollutants including atmospheric particulate matter. As for *PM10* concentrations, the Directive fixes annual and daily limit values. The daily limit of 50 µg/m3 should not be exceeded more than 35 times per year by 2005, and not more than 7 times per year by 2010. The annual limit values are 40 and 20 µg/m3, respectively referred to the same dates. At the moment the area of Northern Italy (surrounding the city of Milan) is not respecting both the daily and the annual limit value regulation. For this reason Environmental Authorities are interested in developing air quality plans, acting in terms of precursor emission reductions. Due to non linearities in the formation and accumulation phenomena of secondary pollutants, it is very challenging to develop sound policies considering both air quality improvements and implementation costs. Different methodologies are available to evaluate alternative emission reductions: (a) scenario analysis (Thunis et al., 2007), (b) cost-benefit analysis (Moussiopoulos et al., 2005), (c) cost-effectiveness analysis (Mediavilla-Sahagun and ApSimon, 2003) and (d) multi-objective analysis (Guariso et al., 2006, Carnevale et al., in press).
In this paper, a new integrated assessment methodology is proposed. It is focused on the mesoscale to better interpret the specific features of the area, the local meteorological conditions, the contribution of regional and local precursor emissions. It solves a two-objective (air quality and costs) optimization to select effective abatement strategies. The nonlinear relations between the decision variables (precursor emissions reduction) and PM10 exposure index, defining the air quality objective, are described by neuro-fuzzy models, identified processing long-term 3D deterministic multi-phase modelling simulations.

2. METHODOLOGY

2.1. Multi-objective problem formulation

The target of this study is to control particulate matter exposure at ground level. This issue can be attained by optimizing both air quality indicators and emission abatement costs. The emissions reduction rates (decision/control variables) are so computed by a two-objective mathematical programming algorithm as the ones corresponding to the most efficient strategies, with respect to both the objectives.
The problem can be formalized as follows:

$$\min_{\vartheta} J(\vartheta)$$
$$J(\vartheta) = \left[AQI(E(\vartheta)); CPI(E(\vartheta))\right]$$
$$\vartheta \in \Theta$$

where E represents the precursor emissions for the reference case, ϑ are the decision variables (namely the emission reductions) constrained to assume values in Θ, AQI(E(ϑ)) and CPI(E(ϑ)) are the Air Quality Index and Cost of Policy Index respectively, both depending on precursor emissions and emission reductions.

2.2. Control Variables

A comprehensive problem formulation should consider each emission source as a decision variable, but this assumption leads to an unfeasible computational problem due to the high number of control variables

deriving from this assumption. Consequently common percentages of reduction for groups of activities are considered as decision variables.
This work assumes the CORINAIR categories, subdividing emission sources in the 11 macrosectors (EMEP/CORINAIR, 1999). In this way the control variables of the decision problem are the percentage emission reductions $\vartheta = \{\vartheta^{p,k}\}_{k\in K}^{p\in P}$ for each $p = \{NO_X, VOC, SO_2, NH_3, PM\}$ secondary pollutant precursor and CORINAIR macrosector $k = \{1,\ldots 11\}$; being NO_x, VOC, SO_2, NH_3 and PM the precursors for secondary particulate matter, there are in principle 55 decision variables for the particulate matter control problem. The decision variables are subjected to the constraints:

$$0 \le \vartheta^{p,k} \le R^{p,k}$$

where $R^{p,k}$ are the maximum feasible reductions for precursor *p* and macrosector *k*.

2.3. Air Quality Objective

In a multi-objective optimization procedure, the precursor-secondary pollutant relationship should be given by the simulation of a 3D modelling system. The integrated deterministic models can not actually be used in the optimization problem, due to the high computational time that these systems require to perform a simulation; moreover to feed an optimization algorithm it is necessary to evaluate quite a large number of emission scenarios. That's why simplified source-receptor models by means of neuro-fuzzy networks have been identified processing simulations performed by the deterministic modelling system. In this study GAMES (Volta et al., 2006) modelling system has been applied. Source-receptor models are then identified and validated to be able to reconstruct pollutant exposure.
The Air Quality (AQI) objective can be formulated as follows:

$$AQI(E(\vartheta)) = \Psi(E_{x,y}^{p,k}(\vartheta^{p,k}))$$

where:
- $p = \{NO_X, VOC, SO_2, NH_3, PM\}$ identifies the secondary pollution precursors;
- *k* is the Corinair emission macrosector
- $E_{x,y}^{p,k}$ is the emission of the *p* precursor species for macrosector *k* in the reference case, for the cell x, y;
- $\vartheta = \{\vartheta^{p,k}\}_{k\in K}^{p\in P}$ is the decision variable set, namely the percentage of precursor *p* emission reduction in macrosector *k*.

2.4. Cost Objective

The cost objective function associated to emission reduction policies has been formalized identifying cost functions linking technology efficiency to reduction unit cost. A cost function has been implemented for each precursor-macrosector pair, using data derived from IIASA (Amann et al., 2004) and CORINAIR 97 (EMEP/CORINAIR, 1999) dataset. The methodology to derive cost functions is detailed in Carnevale et al. (in press).
So the cost index has been associated to control policies (CPI) as follows:

$$CPI(\vartheta) = \sum_p \sum_k TC^{p,k}(E^{p,k}(\vartheta^{p,k}), UC^{p,k}(\vartheta^{p,k}))$$

where:
- $TC^{p,k}$ represents the total cost associated to reduction of precursor p in macrosector *k*;
- $E^{p,k}$ is the total annual emission of the *p* precursor species for macrosector *k* in the reference case;
- $UC^{p,k}$ represent the cost functions linking emission reductions and unit cost, for each *p* precursor species and macrosector *k*.

2.5. Problem solution

Several approaches are used to solve a multi-objective optimization problem. The technique adopted in this work is the Weighted Sum Strategy (Ehrgott, 2000), using coefficients to quantify the respective importance assigned to the considered objectives. Mathematically, the method corresponds to minimize the weighted sum of all the objective functions over a set of admissible decisions.
The Weighted Sum problem in this way can be formalized as follows:

$$\min_{\vartheta} J(\vartheta) = \min_{\vartheta}(\alpha \cdot AQI(E(\vartheta)) + (1-\alpha) \cdot CPI(E(\vartheta)))$$

If $\alpha = 0$ it means that only the policies costs (CPI) are minimized (base case). If $\alpha = 1$ only the Air Quality Index is considered and the best performance in air quality improvement is the goal. All the other values of α relate to minimization of different combinations (with different weights) of the two considered targets.

3. RESULTS AND DISCUSSION

The domain selected for this study is centred on Lombardia region (approximately 10 million inhabitants). Lombardia is one of the most industrialized area in Northern Italy, and is characterized by high traffic emissions. Furthermore, adverse atmospheric circulation with stagnant conditions, low wind speed, temperature inversion are frequent in the region, mainly in winter. Consequently the European long-term *PM10* threshold of 40 µg/m3 is not respected in urban areas.

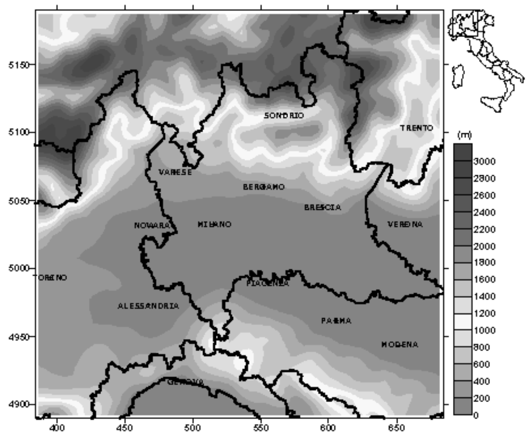

Figure 1: The selected domain with main cities, Lombardia Region boundaries and orography.

Source-receptor models have been identified on the domain, using simulations performed during Citydelta II project (Cuvelier et al., 2007) by means of GAMES modelling system (Carnevale et al., 2005, Gabusi et al., 2005). Starting from the deterministic simulations, neuro-fuzzy models have been selected to reconstruct mean PM10 concentrations using as input emission reduction scenarios. Features and performances of these source-receptor models can be found in Carnevale et al., in press. After the identification and validation of neuro-fuzzy models, the optimization problem has been solved, taking into account only the 50% most polluted cells over the domain. The Pareto boundary features resulting from the optimization (shown in Figure 2) illustrate results in terms of absolute (left) and relative (right) values, evidencing the not-dominated solutions of the problem. Some interesting points can be pointed out from Figure 2, as point A, corresponding to a zero cost PM10 mean value over the domain of 42 µg/m3. This condition is implemented if the Decision Maker is not acting to reduce emissions. The analysis of point C indicates that an investment of 2 billion Euros aimed to implement the best available pollution abatement technologies may reduce PM10 mean concentrations to a value of 24 µg/m3. It is also interesting to investigate the value of intermediate points, as B, showing that it is possible to reduce mean PM10 exposure of more than 60% (to a value of roughly 31 µg/m3), with a budget less than 15% of the maximum cost.

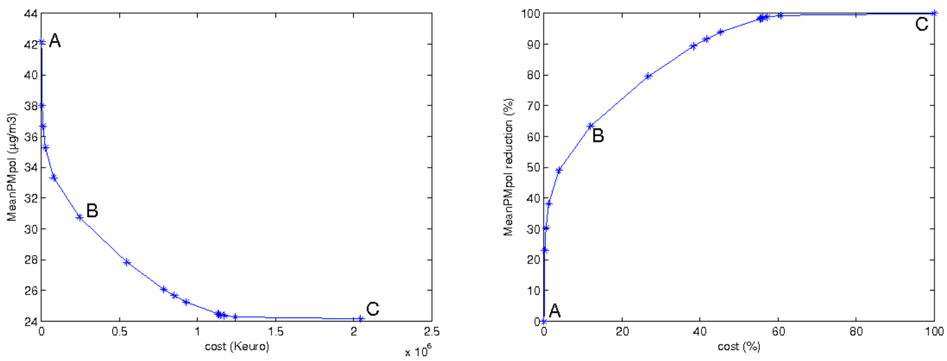

Figura 2: The set of non-dominated solutions, in absolute (left) and percentage (right) values.

4. CONCLUSIONS

Particulate matter long-term exposure is an increasing problem, due to the dangerous effect that this contaminant has on human health. An important task of Environmental Agencies is to develop plans to reduce such pollutant exposure, acting on *VOC*, NO_x, NH_3, SO_2 and primary *PM* emissions.
This research has been focused on multi-objective optimization, a technique not yet used for PM control due to numerical problems rising in the optimisation procedure, when the non linear dynamics bringing to particulate matter formation and accumulation are simulated. In the present case study, the Pareto boundary suggests that it is not possible to respect European Union legislation standard at 2010 even if all the best available technologies are implemented (point C of Pareto Boundary is associated to a value of 24 µg/m3, while legislation threshold is set to 20 µg/m3). This result shows that, to reduce PM exposure in Northern Italy, it is necessary to act both at a national and a transnational level.

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REFERENCES

Amann, M., Bertok, I., Cofala, J., Gyarfas, F., Heyes, C., Klimont, Z., Schopp, W., Winiwarter, W., 2004. Clean Air For Europe (CAFE) Programme final. Tech. rep., IIASA, Laxenburg, (AU).

Carnevale, C., Volta, M., Finzi, G., 2005. Design and validation of a multiphase 3D model to simulate tropospheric pollution. In: Proc. 44th IEEE Conference on Decision and Control and European Control Conference 2005.

Carnevale, C., Pisoni, E., Volta, M., in press. Selecting effective ozone exposure control policies solving a two-objective problem. Ecological Modelling.

Cuvelier, C., Thunis, P., Vautard, R., Amann, M., Bessagnet, B., Bedogni, M., Berkowicz, R., Brandt, J., Brocheton, F., Builtjes, P., Carnavale, C., Denby, B., Douros, J., Graf, A., Hellmuth, O., Hodzic, A., Honor, C., Jonson, J., Kerschbaumer, A., de Leeuw, F., Minguzzi, E., Moussiopoulos, N., Pertot, C., Peuch, V., Pirovano, G., Rouil, L., Sauter, F., Schaap, M., Stern, R., Tarrason, L., Vignati, E., Volta, M., White, L., Wind, P., Zuber, A., 2007. CityDelta: A model intercomparison study to explore the impact of emission reductions in European cities in 2010. Atmospheric Environment 41 (1), 189–207.

Ehrgott, M., 2000. Multicriteria Optimization. Springer.

EMEP/CORINAIR, 1999. Atmospheric Emission Inventory Guidebook, second edition. Tech. rep., European Environment Agency.

Gabusi V., M. Volta (2005) Seasonal modelling assessment of ozone sensitivity to precursors in Northern Italy, Atmospheric Environment, 39, 2795-2804

Guariso, G., Pirovano, G., Volta, M., 2004. Multi-objective analysis of groundlevel ozone concentration control. Journal of Environmental Management 71, 25–33.

Mediavilla-Sahagun, A., ApSimon, H., 2003. Urban scale integrated assessment of options to reduce PM10 in London towards attainment of air quality objectives. Atmospheric Environment 37, 4651–4665.

Moussiopoulos, N., Douros, I., Reis, S., Friedrich, R., 2005. Merlin: the study of urban air quality in 20 european cities. In: Proc. 9th Int. Conf. on Environmental Science and Technology. pp. 1044–1049.

Thunis, P., Rouil, L., Cuvelier, C., Stern, R., Kerschbaumer, A., Bessagnet, B., Schaap, M., Builtjes, P., Tarrason, L., Douros, J., Moussiopoulos, N., Pirovano, G., Bedogni, M., 2007. Analysis of model responses to emission reduction scenarios within the CityDelta project. Atmospheric Environment, 41 (1), 208–220.

Volta, M., Finzi, G., 2006. GAMES, a comprehensive Gas Aerosol Modelling Evaluation System. Environmental Modelling and Software 21, 587–594.

THE ENVIRONMENTAL COSTING MODEL: A TOOL TO ADVISE POLICY MAKERS IN FLANDERS ON ISSUES OF COST EFFICIENCY

P. Lodewijks[1], E. Meynaerts[2]
Flemish Institute for Technological Research (VITO), Boeretang 200, 2400 Mol, Belgium
Tel. +32 14 33 59 55, Fax +32 14 32 11 85
[1]pieter.lodewijks@vito.be
[2]erika.meynaerts@vito.be

ABSTRACT

The Flemish Region of Belgium aspires to achieve ambitious environmental targets that involve high costs. Consequently, it is essential to obtain an overview of available abatement measures, their costs and reduction potential, as well as to find cost effective solutions. Therefore, VITO developed the Environmental Costing Model, a bottom-up, techno-economic model that contributes to a more efficient environmental policy by indicating how environmental targets can be realised in a cost effective way.

Currently, the model is operational for the industrial emission sources of SO_2, NO_x and VOC in Flanders. The model has been used successfully to determine the least-cost combination of abatement measures to comply with the NEC Directive in 2010. If the optimal solution is determined in a 'multi pollutant' analysis, the total annual cost for Flanders mounts up to 92 M€. Additional scenarios have been simulated to support the policy makers in Flanders in making well-founded choices.

1. INTRODUCTION

As many industrialized countries, the Flemish Region of Belgium with its high population density, large degree of industrialization and intensive livestock farming, is confronted with serious environmental problems. The Flemish Government aspires to achieve ambitious environmental targets that involve high costs for both the Government and the private sectors. Consequently, it is essential to obtain an overview of available abatement measures, their costs and emission reduction potential, as well as to find cost efficient solutions to reach these environmental objectives.

The BAT-Centre of the Flemish Institute for Technological Research (VITO) started in June 2001, under the authority of the Flemish Government, with the development of the Environmental Costing Model (MilieuKostenModel or MKM in Dutch). The Flemish Government aspires with this project the development of a tool to (i) determine the costs of environmental policy and (ii) contribute to more efficient environmental policy by indicating how environmental targets can be reached in a cost effective way. Currently, the model is operational for the industrial emission sources of SO_2, NO_x and VOC in Flanders. The model has been used successfully to determine e.g. the least-cost combination of abatement measures to comply with the emission targets imposed on Belgium (and Flanders) by Directive 2001/81/EC of the European Parliament and of the Council on National Emission Ceilings (NEC) for certain pollutants.

2. METHODOLOGY

Cost efficiency plays a key role in the Environmental Costing Model. If only one environmental objective, for one pollutant and few emission sources has to be taken into account, the cost efficiency analysis is a straightforward exercise. In this case, it would be sufficient to rank possible abatement measures based on their (marginal) costs and reduction potential and to select the cheapest measure or combination of measures to realize the environmental objective. Usually, the analysis involves multiple emission sources, pollutants, abatement measures, interactions and trade-offs. In consequence, the least cost solution cannot be determined by a simple overview of the (marginal) costs and emission reduction potential of abatement measures. These interactions and trade-offs are taken into account in the Environmental Costing Model and makes it possible to optimize for one or multiple pollutants at the same time (e.g. what is the least cost solution to reduce emissions? What is the marginal cost curve for a particular pollutant) and to simulate (e.g. what is the impact of more stringent environmental objectives on the least cost solution? What is the impact of the reduction of polluting activities?).

The core of this bottom-up, techno-economic model is a detailed database of emission sources and abatement measures with their associated emission reduction potential and annual costs.

If emissions for one or more pollutants exceed a certain threshold, companies in Flanders are legally bounded to report to the Flemish Environmental Agency (VMM). This reporting obligation relates to all emission sources and includes typical characteristics such as mass flow, emission concentration, number of operational hours and energy consumption. The database of the VMM is used to identify and describe industrial emission sources in the Environmental Costing Model. Other sources of information are literature, surveys and contacts with experts and federations. Depending on the data available, emission sources are identified on sector or individual company level. The format of the database makes it possible to describe emission sources as individual installations or as so-called ‘reference installations’. A ‘reference installation’ is a representative category of installations for which the same emission abatement measures are available and for which a particular abatement measure has similar abatement results and costs. For each pollutant, emissions are linked to an activity that can be considered as the source of the pollution e.g. amount of fuel or solvent consumed, amount of products produced. Consequently, the Environmental Costing Model can be used to make emission projections based on the evolution of the activities or emission factor. Also, it is possible to compare data with the input of other models e.g. the RAINS-model of IIASA (Amann et al., 1999).
Abatement measures are described by means of their investment costs, operating costs, lifetime, capacity and reduction efficiency. The main sources of information are literature, surveys and contacts with experts and federations. The format of the database makes it possible to describe end-of-pipe techniques (e.g. flue gas cleaning) and process-integrated measures (e.g. switch from liquid fuels to natural gas).

The database of the Environmental Costing Model contains a Visual Basic based program that generates import files for the MARKAL software. Although the MARKAL model is designed within the Energy Technology Systems Analysis Programme (ETSAP) of the International Energy Agency (Loulou et al., 2004) for modelling energy systems, VITO uses the software also for modelling non-energy related systems and their emissions. The link with the MARKAL software has also the advantage that all MARKAL facilities can be integrated in the Environmental Costing Model e.g. dynamic modelling, elastic demand and endogenous learning.
The results that are presented and discussed in the next section, illustrate the ‘static’ use of the Environmental Costing Model, i.e. only one future time period (e.g. 2010) is considered in which abatement measures can be implemented and environmental targets can be imposed. Typically, a series of model runs is generated, examining a range of ‘alternative scenarios’. First, a baseline scenario is defined in which, for example, at a given activity level no abatement measures are required. Then, a series of alternative scenarios is run with successive reductions of emissions (for one or more pollutants at the same time). In each run, the model will find the least expensive combination of abatement measures to meet the required emission reduction - up to the limits of feasibility. The total system cost will increase with an increase of the required emission reduction. Finally, the total annual costs of emission reduction can be plotted as continuous abatement cost curves. In addition, the marginal costs of emission reduction can be determined and plotted (for one pollutant).

3. RESULTS AND DISCUSSION

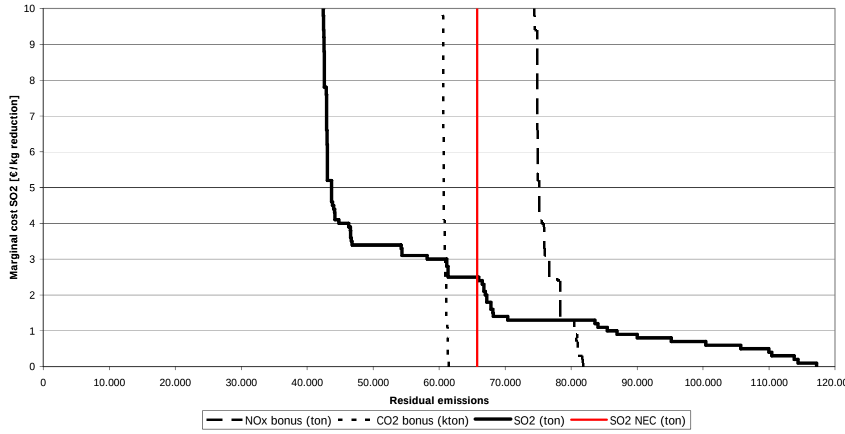
Directive 2001/81/EC of the European Parliament and of the Council on National Emission Ceilings (NEC) for certain pollutants, sets upper limits for each Member State for the total emissions in 2010 of the four pollutants responsible for acidification, eutrophication and ground-level ozone pollution. In 2010 the Flemish Region of Belgium has to comply with following emission ceilings: 65,8 kton SO_2, 58,3 kton NO_x, 70,9 kton VOC and 45,0 kton NH_3.

In order to meet these ambitious emission ceilings, the emission reduction potential of the different polluters has to be carefully balanced against each other. Under the authority of the Flemish Environmental Administration AMINAL, Ecolas and VITO (2005) developed a methodology, taking into account the economic feasibility and cost efficiency of potential abatement measures. The methodology was applied to the industrial emission sources of SO_2, NO_x and VOC in Flanders. The Environmental Costing Model was used to determine the least cost combination of abatement measures to satisfy the multi-pollutant target for SO_2, NO_x and VOC in 2010.

First, the (reference) emissions for the year 2010 were calculated based on projections concerning activity level, energy consumption and energy efficiency, and degree of implementation of abatement measures between 2000 and 2010. Environmental regulation that would come into force in Flanders between 2000

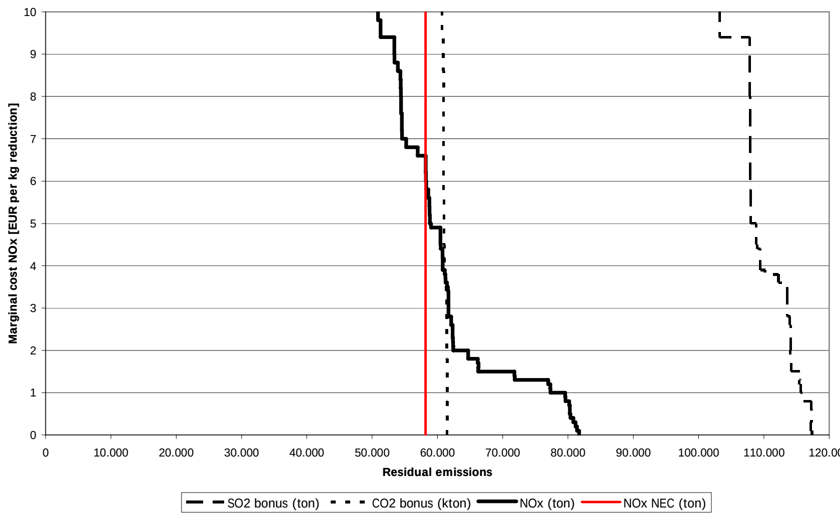
and 2010 (e.g. Solvent Directive 1999/13/EC), was not taken into account. The reference emissions of stationary sources in Flanders in 2010 were estimated: 117 kton SO_2, 82 kton NO_x, 91 kton VOC.
Next, the Environmental Costing Model was used to generate marginal cost curves that describe for one pollutant the most cost effective combination of abatement measures for various emission reductions. The database of the Environmental Costing Model identified and described more than 1.000 (reference) installations and more than 2.100 abatement measures for the year 2010. The level of detail (e.g. source specific compared to generic) varied between sectors.
The cost curve for SO_2 starts at an emission level of 117 kton. Emissions can be reduced until 37 kton or there is a maximum reduction potential of 68%. In order to realize the emission ceiling of 65,8 kton, abatement measures with a marginal cost < 2,5 EUR per kg have to be implemented. The additional effect on NO_x and CO_2 is limited or an emission reduction of 3 kton and 376 kton respectively. The reduction of SO_2 is mainly realized by the sectors 'power plants' (39%), 'refineries' (32%), 'ceramics' (18%), 'iron and steel' (4%) and 'non ferrous metals' (4%).

Figure 1. SO_2 marginal cost curve for Flanders
+ bonus effect on NO_x and CO_2



The cost curve for NO_x starts at an emission level of 82 kton. Emissions can be reduced until 40 kton or there is a maximum reduction potential of 51%. In order to realize the emission ceiling of 58,3 kton, abatement measures with a marginal cost < 6,6 EUR per kg have to be implemented. The additional effect on SO_2 and CO_2 is significant or an emission reduction of 9 kton and 513 kton respectively. The reduction of NO_x is mainly achieved by the sectors 'power plants' (68%), 'iron and steel' (14%) and 'refineries' (6%).

Figure 2. NO_x marginal cost curve for Flanders
+ bonus effect on SO_2 and CO_2



The cost curve for VOC starts at 91 kton and emissions can be reduced until 65 kton or there is a maximal reduction potential of 29%. In order to realize the emission ceiling of 70,9 kton abatement measures, with a marginal cost < 3,1 EUR per kg have to be implemented. The abatement measures that are implemented for the reduction of VOC have no effect on SO_2 or NO_x. The reduction of VOC is mainly achieved by the sectors ‘coatings’ (i.e. metal and plastic) (21%), ‘refineries’ (18%) and ‘printing industry’ (14%).
Finally, the Environmental Costing Model was used to determine the optimal (i.e. least cost or cost effective) allocation of emission reduction efforts to achieve the emission ceilings for SO_2, NO_x and VOC (for stationary sources) in 2010. In the calculations a discount rate of 5% was used.
The total annual costs for Flanders to comply with the emission ceilings in 2010 are 92 million EUR or 0,05% of the annual turnover of the sectors ‘industry’, ‘energy’ and ‘agriculture’ in Flanders in 2003. The sectors with the highest total annual costs are ‘power plants’ (30 million EUR), ‘refineries’ (21 million EUR) and ‘glasshouse horticulture’ (9 million EUR).
If the optimal solution is determined for each pollutant separately, the total annual cost for Flanders to comply with the emission ceilings in 2010 is overestimated with 21% (20 million EUR).

In order to support the policy makers in Flanders in making well-founded policy choices, a sensitivity analysis of the optimal solution was done. For example, the effect of 5-10% less and more stringent emission ceilings was analyzed. Also, additional scenarios were run to take into account the financial strength and/or the environmental impact of a sector.

4. CONCLUSIONS

The results illustrate the added value of the Environmental Costing Model as a tool to determine the least-cost combination of abatement measures to comply with multi-pollutant targets for SO_2, NO_x and VOC. If the optimal solution is determined for each pollutant separately, the total annual cost for Flanders is overestimated. In addition to the optimal solution, other scenarios can be simulated with the model to support the policy makers in Flanders in making well-founded policy choices.
Moreover, the Environmental Costing Model has been proven to be very useful for the policy maker in Flanders. The Flemish Government uses the results of the model as a starting point in bilateral negotiations with the industrial sectors and their federations.
As environmental regulation changes continuously, the model is currently adapted in order to optimize and simulate beyond 2010. In addition, the extension of the model with CO_2 and ‘particulate matter’ is investigated.

5. REFERENCES

Amann, M., Bertok, I., Cofala, J., Gyarfas, F., Hettelingh, J.P., Heyes, C., Klimont, Z., Makowski, M., Posch, M., Schöpp, W., Simpson, D. and Syri, S. 1999. Economic Evaluation of a Directive on National Emission Ceilings for Certain Atmospheric Pollutants. Commission of the European Communities, Brussels.

Eyckmans, J., Meynaerts, E. and Ochelen, S. 2004. The Environmental Costing Model: a tool for more efficient environmental policymaking in Flanders. The ICFAI Journal of Environmental Economics, Volume III, n° 2.

Loulou, R., Goldstein, G. and Noble, K. 2004. Documentation for the MARKAL family of models. Energy Technology Systems Analysis Programme.

Meynaerts, E., Ochelen, S. en Vercaemst, P. 2003. Milieukostenmodel voor Vlaanderen – Achtergronddocument. VITO.

Meynaerts, E. en Vercaemst, P. 2003. Het Milieukostenmodel Vlaanderen. EcoTips, jaargang 8, n° 1.

Meynaerts, E. en Lodewijks, P. 2005. Intersectorale afweging van de haalbaarheid en kostenefficiëntie van mogelijke maatregelen voor de realisatie van de NEC-plafonds. Nieuwsbrief Milieu & Economie, jaargang 19, n° 4.

Meynaerts, E. en Lodewijks, P. 2006. Nationale emissieplafonds: het kostenplaatje voor Vlaanderen. EcoTips, jaargang 11, n° 1.

VITO en Ecolas 2005. Opstellen en uitwerken van een methodologie voor een intersectorale afweging van de haalbaarheid en kostenefficiëntie van mogelijke maatregelen voor de reductie van diverse polluentemissies naar de lucht. AMINAL.

NEW METHODOLOGIES FOR THE ZONING OF THE TERRITORY IN OBSERVANCE OF THE LAST EUROPEAN AIR QUALITY DIRECTIVES

M. Cardone, P. Iodice, A. Maresca, M. Migliaccio, A. Senatore
Dipartimento di Ingegneria Meccanica per l'Energetica – D.I.M.E.
University of Naples Federico II
ITALY

ABSTRACT

This paper presents a resolution procedure of the territory environmental zoning, that has been followed for the realization of the "*Campania Regional Project for Reclamation and Protection of the Air Quality*". This activity was executed by the Dipartimento di Ingegneria Meccanica per l'Energetica for the Campania Regional Government.
The appraisal of the air quality to local scale and the successive zoning has been carried out processing air quality data, and integrating these with elaborations of diffusional models and with a statistical methodology that estimates the polluting concentrations all over the regional territory. This methodology consists in determining a mathematical correlation between the hourly polluting concentrations measured from air monitoring stations and the hourly emissions that derive from the Inventory of the total emissions, through a function applicable all over the territory.

1. INTRODUCTION

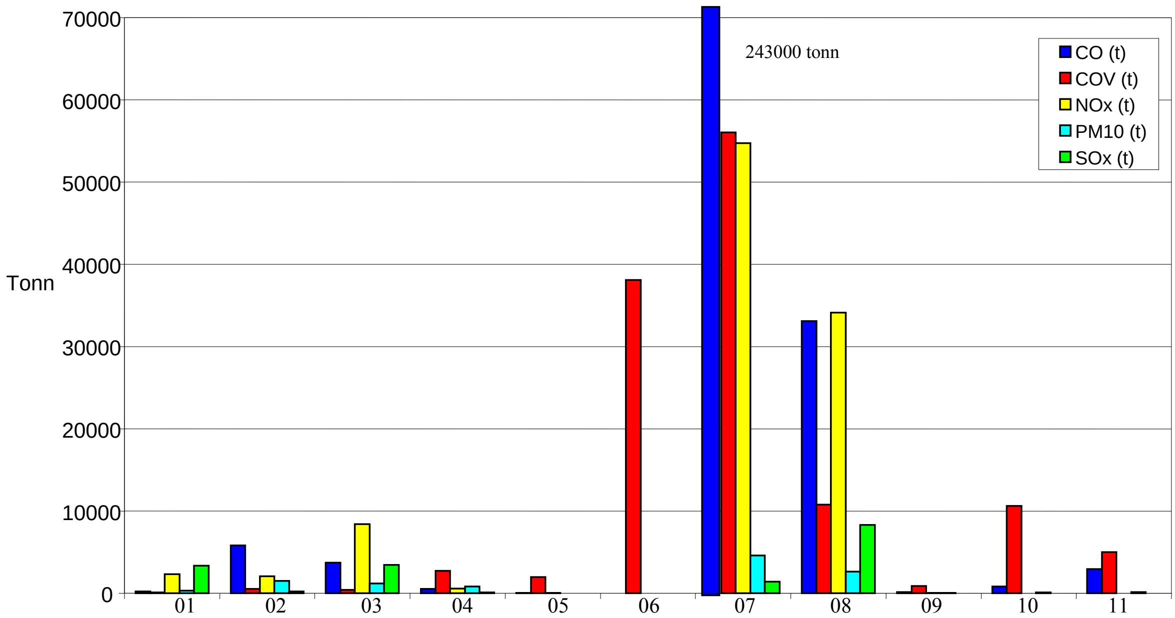
The sustainable development and the improvement of the environment are, by now, main objective of the National and Europeans politics.
The paper shows a work methodology that proposes oneself as a complete and useful instrument for the realization of the territory environmental zoning and, then, for the execution of the "*Projects for Reclamation and Protection of the Air Quality*", through the employment of dispersion and chemical transformation mathematical models, and of statistical models for the analysis of the air quality data. The environmental zoning can be considered as the core of these "*Projects*", that are characterized essentially from two phases:

- Cognitive phase: qualification and quantification of the air polluting sources (Emissions Inventory); analysis of meteorological and air quality data.
- Valuation phase: definition of the air quality state all over the regional territory by integration of the available data (Emissions Inventory) with results of mathematical models; comparison of the air quality data with air standards; subdivision of the regional territory in zones (environmental zoning);

The "projects" and the environmental zoning, as already established from the most recent European directives and Italian legislative decrees that have regulated the environmental matter, are oriented to the planning and determination of the more opportune strategies for the health safeguard and for the ecosystem protection. It appears obvious, therefore, that the regional planning and programming must use appropriate cognitive instruments to estimate the air quality state and the origins of the air pollution in order to support prevention and reorganization decisions.

2. METHODOLOGIES AND RESULTS

The regional inventory of emission sources is a preliminary and fundamental cognitive element for the planning activity and for the air quality management. The inventory has been drawn up with CORINAIR Methodology. Such inventory constitutes a technological, economic and territorial data collection, that concurs to individualize the pollution sources (industrial, civil, transports, etc.), their localization with spatial disaggregation (regions, provinces and towns), the amount and the typology of the polluting substance (CO, SOx, VOC, NOx, etc.). The amounts of pollutants emitted from the various sources in the zones under investigation can be obtained through direct and continuous measures where possible, otherwise through estimates. The direct measure of the emissions, generally, can be carried out only for the principal industrial systems, usually schematized as punctual sources. For all other sources, called diffused sources (small industries, hating systems, natural sources, etc.) and for the linear sources, it must resort to estimate: the emissions are estimated on the basis of opportune activity indicators and fixed emission factors concerning specific emissive activity.
In diagram 1, with regard to the inventory drawn up for the year 2002, the final results are shown; the total value of the main polluting emissions are disaggregated for activity groups.
After the realization of the inventory in the described way, it's possible to value the air quality condition through a methodology that supplies the concentration estimate of the pollutants all over the regional territory, on the basis of statistical and numerical elaborations; such method, therefore, turn out to be a resolution procedure of the "valuation phase" and then of the territory environmental zoning.
The starting point of such methodology consists, first, in the realization of a detailed emission inventory on communal scale in which the diffused, linear and punctual sources are specified, and then, in the presence on the territory of a air quality monitoring net that satisfies completeness and reliability criteria.



ACTIVITY GROUPS: 01 Combustion in Energy and Transformation Industries; 02 Non-Industrial Combustion Plants; 03 Combustion in the Manufacturing Industry; 04 Production Processes; 05 Extraction & Distribution of Fossil Fuel and Geothermal Energy; 06 Solvent and Other Product Use, 07 Road Transport; 08 Other Mobile Sources and Machinery; 09 Waste Treatment and Disposal; 10 Agriculture; 11 Other Sources and Sinks

Fig. 1. Total polluting emissions disaggregated for activity groups in 2002 [tonn]

In particular, this technique is based on the application of two complementary procedures: the first one consists in a statistical method to determine the concentration deriving from linear and diffused emissions, the second one integrates these elaborations with diffusional models for the punctual emissions.
The statistical method is articulated in the following steps. Initially it's necessary to select a set of air monitoring stations that are significant in order to generalize the measures detected from the stations all over the regional territory. Subsequently these stations are attributed to specific meshes 1 km x 1 km of the reticulum used for the spatial disaggregation of the emission census. At least, in the meshes of the reticulum in which the stations fall back, the linear and diffused polluting emissions are extracted from the inventory.
In this way it's defined a model based on the multiple linear regression that lies in constructing a fourth level polynomial relation between the concentration value measured from the monitoring station, the emission of the more significant activity groups inside the mesh in which the same station falls backs, and the total emissions deriving from the adjacent meshes. Therefore, the generic concentration $C_{i,k,m}$ measured from the station k in territorial mesh m due to the pollutant i is considered a function f both of the emission $E_{i,j,m}$ originated from the group j calculated in the mesh $m,$ and of the emission $E_{i.l}$ deriving from all the activity groups in the adjacent territory:

$$C_{i,k,m} = f\,(E_{i,j,m}\,,\,E_{i.l}) + \varepsilon; \qquad \begin{matrix} i=1,..,I; \\ k=1,..,K; \\ j=1,..,J; \\ m=1,..,M \end{matrix} \qquad (1)$$

where ε is the error of the statistical model. At least, the polynomial relations (and the relevant regression coefficients) individualized for these meshes extend to all others in which there aren't stations, so as to estimate the polluting concentrations all over the regional territory on the basis of the emission values concerning the various sources. It's reported the NOx polynomial function to find the polluting concentrations in the meshes of Campania territory in which the activity group emissions are known, (by way of example, but similar relations have been found for all polluting substances):

$$\begin{aligned} C_{NOx} &= 32{,}95\,E_{07} - 6{,}51\,E_{07}{}^2 + 0{,}49\,E_{07}{}^3 - 0{,}01\,E_{07}{}^4 + 1{,}10\cdot 10^2\,E_{02} + \\ &- 1{,}38\cdot 10^2\,E_{02}{}^2 + 58{,}5\,E_{02}{}^3 - 7{,}62\,E_{02}{}^4 + 7\cdot 10^{-8}\,E_l{}^4 + 0{,}32\,E_l - 4\cdot 10^{-3}\,E_l{}^2 \end{aligned} \qquad (2)$$

where C is the concentration in $\mu g/m^3$ and E the emissions of the activity groups in ton/year. Of course, to find the statistically more significant activity groups for every pollutants it has been necessary a correlation analysis.
In the map of figure 3, the application of equation (2) has located the meshes 1 km x 1 km (due to diffused and linear sources and estimated with statistical method) in which the NOx concentration exceeds the limit fixed from the environmental legislation in force.

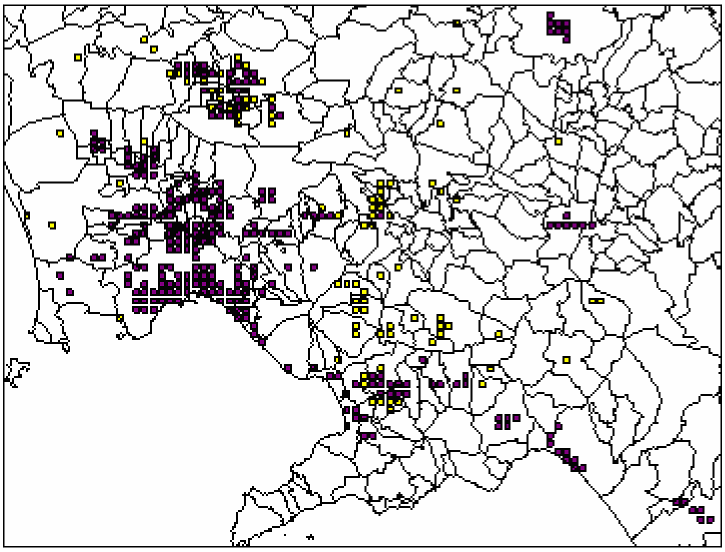


Fig. 3. Territorial distribution of the meshes that exceed the NOx law standards in Campania Region

The second procedure is based on the application of the diffusional models and, as already evidenced, determines the concentrations deriving from punctual emissions to integrate the results of regressive statistical technique. The diffusional models analyse the physical phenomena regarding the gas atmospheric diffusion with a deterministic approach, also considering meteorological factors. The inputs of the model are the meteorological data (opportunely processed) acquired from the weather stations, and the polluting emission (from inventory); the output will be the concentration of the same pollutant in a specified point of the territory object of the simulation. The choice of the models depends on various factors, the main ones are: the detail and the accuracy of the available database (emission inventory, meteorological factors, air quality data), the morphological complexity of the area under investigation, the characteristics of the emissive sources, field of application (urban, rural or industrial area), the detail of the results that are desired to obtain.
The model proposed for the specific requirements of the "*projec*t" is the well known gaussian model ISC. Although the fundamental assumption of the gaussian approach, that is the normal distribution of the concentrations, comes true in absolutely ideal conditions of atmosphere homogenous turbulence, the models that are based on this hypothesis are instruments of widest employment because they are characterized from a simple and practical use. The mathematical structure has an easy formulation and the results of the elaborations are in accordance with experimental data, above all for estimates in long term. On the other hand, the gaussian method sure turns out not much suitable to deal situations characterized from not homogenous atmospheres, complex orography and unstable pollutants.
The result of the diffusional model is shown in the map of figure 4, in which it's possible to gain the estimated concentration of the pollutants in every mesh of the reticulum. In this specific example the NOx concentrations are displayed for the Naples-Caserta zone.

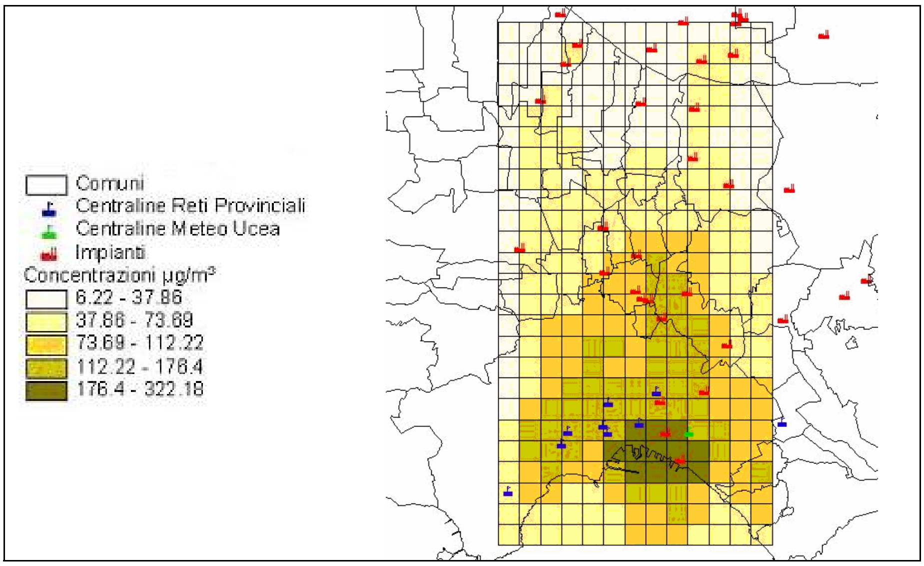


Fig. 4. NOx concentrations estimated through ISC diffusional model

The integration procedure of the two simulation models (regressive statistical technique and diffusional model), if is extended all over the regional territory and for all pollutants, allows to get the territory zoning through the comparison between the air quality present background (that it's emerged by means of the estimate mathematical models) and the existing law standards.
In this way, the zoning individualizes the more critical zones of the territory, definite reclamation zones, in which the value of the pollutants exceeds the limit fixed from the environmental legislation in force.
In the figure 5, it's remarked as the Campania territorial zoning has assembled all communes in macro areas, revealing in 2002 four reclamation zones and one observation zones, for which reorganization strategies will be necessary to the aim to catch up the established limits.

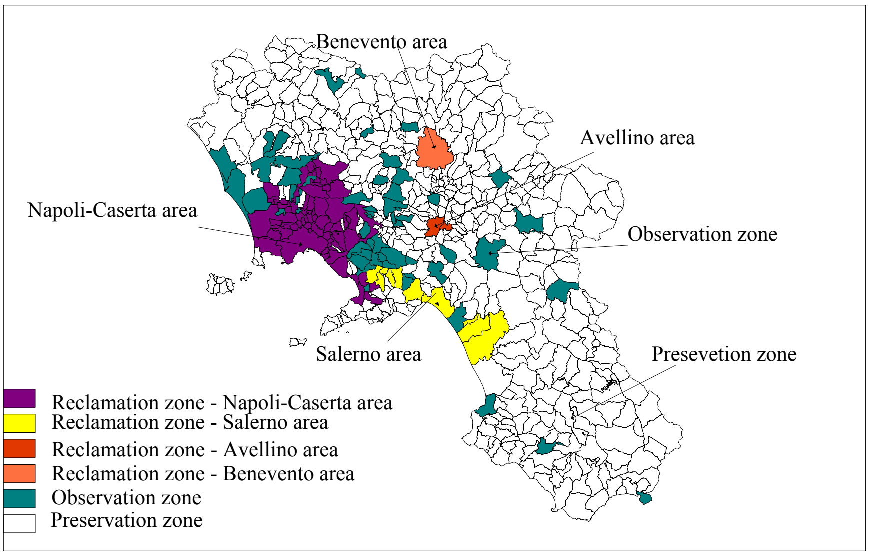


Fig. 5. Campania territory environmental zoning

4. CONCLUSIONS

In this paper resolution models and methods have been investigated in order to define a general procedure for air quality appraisal and for the realization of the territory environmental zoning.
The main aim of all these methodologies (applied to the specific case of the Campania regional Government) is to define a valid and enjoyable environmental programming instrument and to supply an efficient methodological base for the realization of the "air quality project". Through all described procedures and models, in fact, it's possible to determine mainly responsible sources of air pollution with relevant affected areas, and to forecast future emissions in those zones. The same simulation models, besides, can be used to examine strategies oriented to the air quality improvement; so new emissive background will be defined according to the adoption of new environmental laws and to the virtual implementation of low environmental impact technologies in the several analysed fields (transports, productive activities, energetic efficiency, etc.)
The environmental zoning, moreover, must be considered as a dynamic instrument since both the updating of many information and the data reliability and detail are in continuous evolution and improvement.

5. REFERENCES

[1] M. Migliaccio, A. Senatore, "Piano regionale di risanamento e tutela della qualità dell'aria", Lavoro svolto nell'ambito della convenzione tra la Regione Campania e D.I.M.E., Novembre 2005
[2] A. Gimelli, P. Grassia, M. Migliaccio, A. Unich, "Sulla efficacia della regolamentazione del traffico dei veicoli con motori a c.i. nei centri urbani per il contenimento della produzione di inquinanti", Convegno Internazionale Energia e Ambiente 2002 – Capri, 6-8 giugno 2002.
[3] A. Corti, E. Carnevale, A. Senatore, M. Migliaccio L. Vetere, "La pianificazione territoriale per la qualità dell'aria nella Regione Campania", 56° Congresso Nazionale ATI, Napoli 10-14 settembre 2001.
[4] R. Cozzolino, P. Jannotti, M. Migliaccio, F.P. Violano,"In tema di normative sulle emissioni di ciclomotori e di motocicli per l'ottenimento di un basso impatto ambientale", XI Convegno Commissione Tecnica ACI - L'Uomo e l'Automobile – Salerno, 3-4 giugno 1999.
[5] M. Migliaccio, A. Senatore, progetto preliminare di una rete di monitoraggio ambientale. Qualità dell'aria per la provincia di Salerno, Lavoro svolto nell'ambito della convenzione tra la Provincia di Salerno e D.I.M.E., Settembre 1998
[6] D. Lgs. n. 351 del 4 agosto 1999: "Attuazione della direttiva 96/62/CE in materia di valutazione e di gestione della qualità dell'aria ambiente".
[7] emep/corinair "Atmospheric Emission Inventory Guidebook" - 3rd edition EEA, October 2002.
[8] Rapporto ANPA, "Linee guida agli inventari locali di emissioni in atmosfera", RTI CTN_ACE 3/200.
[9] A. Corti, A. Senatore, "Project of an air quality monitoring netwotk for industrial site in Italy", in Environmental Monitoring and Assessment Journal, Vol. 65, Nos. 1-2, ISSN 0167-6369

SPATIAL FREQUENCY DISTRIBUTION OF THE MAIN AIR POLLUTANTS AND NETWORK DESIGN OF A REPRESENTATIVE MONITORING SYSTEM IN LANZHOU, CHINA

F.Costabile, G.Bertoni, F.De Santis, F.Wang, and I.Allegrini
Institute for Atmospheric Pollution, National Research Council, Via Salaria km 29,300 C.P. 10, 00016 Monterotondo Stazione, Rome, Italy (costabile@iia.cnr.it).

ABSTRACT
An assessment of SO_2, NO_2, NO_x, Benzene, Toluene and Xylene in ambient air was performed in Lanzhou in 2005-2006. Diffusive samplers geo-statistically analysed were used along four measurement campaigns at 40 locations representative of regional and urban background pollution, population-exposure, and traffic or industrial emissions. The major objective was to analyse the space-series so generated aiming at statistically inferring pollutant frequency distributions and seasonal variability, as well as designing a representative air quality monitoring network.
It was found that the frequency distributions (FDs) of most of the pollutants are successfully estimated from the Normal distribution within 95% confidence. This result is used to show how the study of the spatial FDs enhances the process of network design providing the input data for selecting the representativeness of the locations.

1. INTRODUCTION

The need for a cost effective way to simultaneously evaluate multiple air pollutants, perform survey (preliminary assessment) of air quality, and design representative monitoring network has driven the development of diffusive sampling technique (e.g.:Costabile et al., 2006a). The issue of representativeness of air quality measurements, however, has been overlooked in the past. The lack of a quantitative method to describe this concept results often in inconsistent comparison for air quality data among different sites (Costabile et al., 2006b).
This paper describes an assessment of SO_2, NO_2, NO_x, Benzene, Toluene and Xylene in ambient air performed in Lanzhou (China) in 2005-2006 by means of diffusive samplers geo-statistically analysed. The major objective was to analyse the space-series so generated aiming at statistically inferring pollutant FDs and seasonal variability, as well as designing a representative air quality monitoring network.
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2. METHODOLOGY

Measurements were taken at 40 locations representative of regional and urban background pollution, population-exposure and traffic or industrial emissions. Four campaigns were carried out on a yearly basis: (I) Autumn (October 15th - November 15th), (II) Winter (January 15th - February 15th), (III) Spring (April 15th -May 15th), (IV) Summer (July 15th -August 15th). Sampling locations were selected fitting a geometric grid as more as possible; the protocol to select the micro-scale locations of each site was previously described (Costabile et al., 2006c). As the main part of quality assurance/control duplicated samplers were collected covering the 20% of the total sites; the sampling error calculated for each pollutants between the co-located samples were found to be suitable for the purpose of the work (Costabile et al., 2006c). Thanks to the big number of measurements it was possible to collect significant statistical samples that were subsequently numerically analysed along the space coordinates (Costabile et al., 2006a).

3. RESULTS AND DISCUSSION

The results of the pollutants' measurements relative to all the 40 sampling locations and the four seasonal campaigns are presented in figure 1. All the pollutants showed a common seasonal variability with lower values in Summer and significant differences between the colder and the warmer seasons. Benzene values were lower than 5 $\mu g/m^3$ (limit value set by European Union, reference year 2010) only in Summer peaking in Autumn over 10 $\mu g/m^3$. Similarly, Xylenes values were on average 4-5 $\mu g/m^3$, with the exception of Autumn when the concentrations were almost doubled probably because of increased emission levels. Toluene averaged around 15 $\mu g/m^3$, peaking in Winter as the inorganic pollutants, SO_2 and NO_2, whose yearly average concentrations almost exceeded the EU limit values (20 $\mu g/m^3$ and 50$\mu g/m^3$, respectively). Besides the different emission levels, insights to these seasonal variations may be provided considering the Lanzhou semi-arid continental monsoon climate characterised by a little precipitation 60% concentrated in Summer, and a significant temperature difference between Winter and Summer (Lanzhou EPB, 2004).

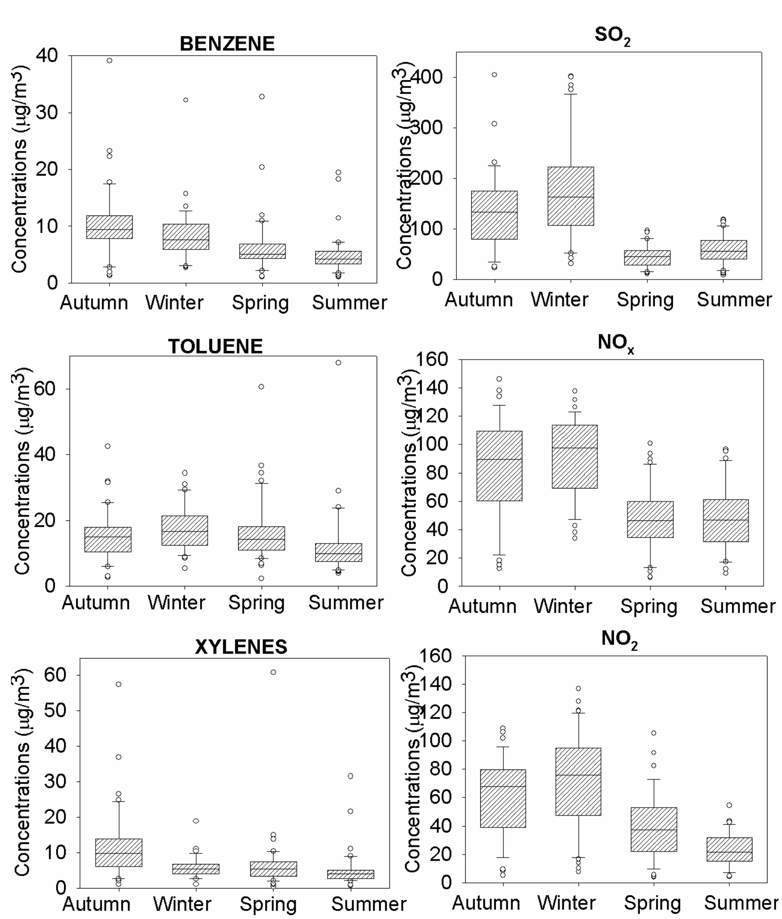

Figure 1: *Box-plot of pollutant concentrations calculated among the 40 sites. Upper and lower dots indicates the outliers. Filled boxes indicates interquartile and horizontal lines show the Max and min values.*

The data set comprised between the maximum and minimum values (thus not including the outliers, fig.1) were tested for statistical Normality of the FD in order to evaluate the statistical model describing it (tab. 1). The outliers values were calculated by the equation 1 [Buccianti et al., 2003]:

$$\text{Outlier} = \begin{cases} IF > 75_{th} + 1{,}5 \bullet IQ \\ IF < 25_{th} - 1{,}5 \bullet IQ \end{cases} \qquad \text{[Eq.1]}$$

where IQ indicates the interquartile range, that is:

$$\text{IQ} = 75^{\text{th}} \text{ percentile- } 25^{\text{th}} \text{ percentile.}$$

With only one exception, all the space-series passed the Normality test indicating that the dataset matches the pattern expected if the data was drawn from a population with a Normal distribution. Therefore, mean and median values (quite same) can correctly be used to represent the concentration values of these pollutants all over the city for air quality management purposes. Moreover, this result is very important in understanding the characteristic of the spatial trend of the main air pollutants in an urban area; every process where the pollutant particles show a Normal distribution of the spatial trend density, satisfies the diffusion equation and thus should represent such a mechanism (Costabile et al., 2006a).
The knowing of the pollutants' spatial distribution model can significantly enhance the process of network design (fig.2). The EU Directives (European Union, 1998) explain in detail the way to develop an air quality monitoring network and to select the monitoring stations, providing indications for the minimum number of stations for air quality assessments, location of stations, and measurement techniques. The stations should be classified according to: (i) type of station (traffic, industrial, background), (ii) type of zone (urban, suburban, rural), (iii) characterization of zone (residential, commercial, industrial, agricultural,

Table 1: Normality Test for the total data without outlier

Pollutant	*campaign ID*	*K-S Distribution*	*Probability*	*Test result*
Benzene	I	0,122	> 0,200	Passed
	II	0,099	> 0,200	Passed
	III	0,152	= 0,046	Failed
	IV	0,086	> 0,200	Passed
Toluene	I	0,071	> 0,200	Passed
	II	0,132	= 0,120	Passed
	III	0,089	> 0,200	Passed
	IV	0,118	> 0,200	Passed
Xylenes	I	0,084	> 0,200	Passed
	II	0,124	> 0,200	Passed
	III	0,085	> 0,200	Passed
	IV	0,088	> 0,200	Passed
SO_2	I	0,115	> 0,200	Passed
	II	0,078	> 0,200	Passed
	III	0,079	> 0,200	Passed
	IV	0,114	> 0,200	Passed
NO_x	I	0,100	> 0,200	Passed
	II	0,136	= 0,068	Passed
	III	0,075	> 0,200	Passed
	IV	0,095	> 0,200	Passed
NO_2	I	0,117	= 0,195	Passed
	II	0,071	> 0,200	Passed
	III	0,088	> 0,200	Passed
	IV	0,083	> 0,200	Passed

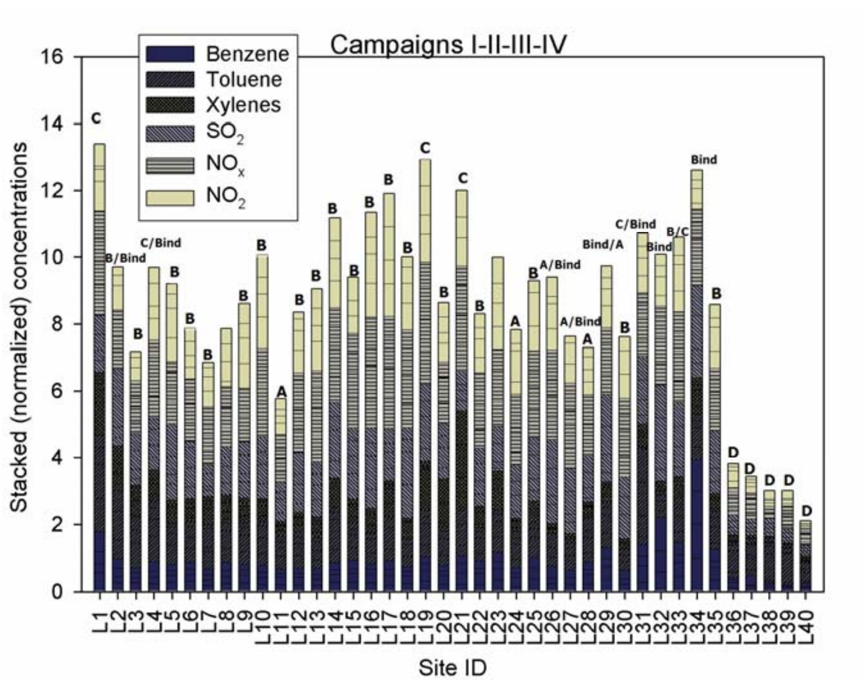

Figure 2: *Stacked concentrations (normalized between 0 and 1 and averaged among the four campaigns) of the main air pollutants at 40 sites (L1,.., L40). Each site is classified according to: Type A) urban background station in urban area, Type B) residential zone, Type C) traffic station in urban area, Type Bind) industrial station, Type D) regional background station in suburban/rural area.*

natural and combinations). The network is to have stations that monitor: (1) the highest pollutant concentrations; (2) the representative concentrations in areas of high population density; (3) the impact of major pollution emissions sources; (4) the general background concentration levels. The ideal case is that the station is sited exactly where the modelled maximum is calculated (European Union, 1998). That is, the possibility that the AQMS measures all the exceedences is connected to the possibility to have stations at the locations of the highest concentration in each representative area. Therefore, the stations should be located at the sites reporting the maximum modelled concentrations for each area of representativeness, that is to say (fig. 2):

a) a station type C sited at the site 1 to represent the maximum concentrations of traffic-generated pollutants;
b) a station type Bind sited at the site 34 to represent the maximum concentrations of industrial-related pollutants;
c) a station type B sited at the site 17 to represent the maximum concentrations of the measured pollutants in residential areas;
d) a station type D sited at the site 36 to represent the maximum concentrations of the measured pollutants in regional-background areas;
e) a station type A sited at the site 24 to represent the maximum concentrations of the measured pollutants in urban-background areas.

Finally, known the Normality of the pollutants' FDs, the concentrations measured at the fixed stations can, therefore, be used to reconstruct the spatial distributions of each pollutants along the study area.

4. CONCLUSIONS

This paper shows a new methodology to measure air pollutant spatial variability and design a representative monitoring network. This technique allows to map at extremely low cost big areas difficult to be reached with heavy or large instrumentation. The results of the campaigns performed all over one year (2006) of the main air pollutants in Lanzhou gave a comprehensive multi-pollutant, multi-seasonal assessment of air pollution in the city. The considerable number of samples taken with the technique proposed in this work allowed for the statistical treatment of data along the space coordinates. It was found that most of the pollutant data-sets are fitted by the Normal FD. That is very useful in air quality management and control, due to the possibility to compare its parameters with reference values, such as mean, limit or standard values, etc. Moreover, this result is used to show how the study of the spatial FDs enhances the process of network design providing the input data for selecting the representativeness of the locations.

5. ACKNOWLEDGEMENTS

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6. REFERENCES

Buccianti, A., Rosso, F., Vlacci, F., 2003. Metodi matematici e statistici nelle scienze della terra, ed. Liguori, Naples, Vol.3 (Italian).

Costabile, F., Bertoni, G., Desantis, F., Wang, F., Hong, W., Liu, F., Allegrini, I., 2006a. A preliminary assessment of major air pollutants in the city of Suzhou, China. Atmospheric Environment 40 (33), 6380-6395.

Costabile, F. , Desantis, F. , Wang, F., Hong, W., Liu, F. and Allegrini, I., 2006b. Representativeness of Urban Highest Polluted Zones for Sitting Traffic-Oriented Air Monitoring Stations in a Chinese City. JSME International journal-B 49 (1), 35-41.

Costabile,F., Wang,Q., Bertoni, Ciuchini, Wang,F., & Allegrini,I. 2006c. A preliminary assessment of BTX pollution in urban air in the city of Lanzhou. In: Air Pollution XIV, pp.241-250. J.Longhurst & C.A. Brebbia (ed.), WIT press, UK.

European Union, 1998. Guidance Report on Preliminary Assessment under EC Air Quality Directives, Project Manager Gabriel Kielland, European Environment Agency

Lanzhou EPB, 2004. Personal communication.

A MODEL APPLICATION FOR THE ESTIMATION OF THE TRAFFIC POLICY RESTRICTION EFFECTIVENESS

F. Liguori, S. Pillon, F. Dalan, A. Benassi
ARPA Veneto – Italy.

ABSTRACT

The objective of the Project "Atmospheric pollution in Padua" is to provide the municipality with a modelling tool for the policy decision-making process in the matter on traffic. The modelling tool employed is CALPUFF provided with a traffic net database, a set of meteorological data and an traffic emission inventory. The analysis includes a 5-weeks period and focuses on two pollutants: benzene and PM10.
Three scenarios have been evaluated. The concentration reduction for the benzene (PM10) is around 70%-75% (27-35%) for peak emissions. In the five-weeks simulation the working-day emissions are constant while the domain-averaged daily concentration of benzene (PM10) vary between 0.3 (0.4) μg/m^3 and 8.2 (9.8) μg/m^3. Therefore the meteorology can determine the area-averaged concentration for more than 90% of its value. This illustrates the difficulty in measuring the effectiveness of traffic policy restrictions as their impact is less than impact of the day-by-day meteorological condition.

1. INTRODUCTION

This paper illustrates a model application developed in order to give to Padua's policy makers an estimation of the effectiveness of traffic policy restrictions introduced during the autumn and winter 2002-2003 to avoid high levels of pollution, above all pollution from benzene and PM10. Three realistic emission scenarios have been evaluated essentially forbidding the traffic to pre-Euro and Euro 1 diesel vehicles between 7am and 9pm (scenario 1) with increasing restriction on the total volume of traffic (6% for scenario 2 and 18% for scenario 3). The emission reduction for the benzene (PM10) is around 50% (20-25%) on average and 70%-75% (27-35%) for peak emissions. The same reduction applies to the model concentration due to the linearity between emissions and concentrations for primary species in absence of chemistry. As the total working-day emission is constant in time in the simulations, the daily average concentration variability indicates the ability of the meteorology in dispersing the pollutants and its contribution in determining the pollution concentration at ground level. The effect of both the traffic restrictions and the meteorology is here assessed and compared.

2. METHODOLOGY

Traffic policy restriction effectiveness was assessed applying three different scenarios of traffic flows decrease to a model chain that includes: PBL parameters processor - road transport emission processor - dispersion model. CALPUFF (Scire J.S. *et al*., 2001) was selected for this application thanks to its capability of dealing with wind calms. The city of Padova, in fact, is situated in the middle of the po-valley where, especially in winter time, calm events are frequent. CALPUFF was used to calculate benzene and PM10 concentrations, coming from urban traffic. Because no chemical transformation options was used, only primary PM10 was modelled.

2.1. Description of the modelling system

According to CALMET's fomulas (Scire J.S. *et al*., 2000) for PBL characterisation, the Meteorological Centre of ARPAV developed a code which calculates PBL parameters using local measurements of temperature, wind's velocity and direction, solar radiation, precipitation rate and humidity. The cloud cover was given by a spatial interpolation from the nearest synoptical stations and, in the same way, the vertical structure of the troposphere is the result of a spatial interpolation applied to three radiosoundings at a distance that varies between 120 and 250 kilometres. The PBL and meteorological data are inputted in CALPUFF that works in a single station mode.
The 170.5 kilometres of the Padua's road network, (223 roads) were divided in 4370 adjacent volumes, with a length of about eight times the road's wideness. The initial lateral and vertical spread of the puff in volumetric sources is given by the volume's length and height divided by 2.15 (Scire J.S. *et al*., 2001), the height of a volumetric sources assigned to be five metres. Such a parameterization of road sources proved to work well in a model inter-comparison exercise of Venezia-Mestre ring road (Biancotto et al., 2004).
The traffic database (ARPAV, 2003) contains 24 hours traffic flows of a winter weekday for seven categories of vehicles: mopeds and motorcycles; passenger cars; light duty vehicles; heavy duty vehicles less than 32 tons; heavy duty vehicles over 32 tons; urban buses; coaches. A processor calculates the road transport emissions following COPERT III methodology (Ntziachristos and Samaras, 2000), with the supplement of IIASA's factors emissions for fine Particulate Matter (Lükewille *et. al*, 2001).

2.2. Estimation of model performance

The model results for benzene were compared with five weekly passive samplings collected simultaneously in 30 different sites all around the city (ARPAV, 2003) and 35 daily concentration measurements in two air quality station sited in the urban area, while for PM10 only 35 daily concentration measurements where available in the same two stations. The monitoring period spans from the 11th of November to the 16th of December 2002 and it is representative of a critical period for winter air pollution.

The model performance was evaluated using the following statistical indices (Mosca *et al.* 1998): Pearson's correlation coefficient, Bias, Normalised Medium Squared Error (NMSE). Table 2 summarizes the statistics for benzene. The modelling system shows a general over estimation: only in the fourth week of simulation there is a negative bias. This week was associated with a sensible increment of wind's intensity.

Tab. 2 Statistical indices of model performance for benzene concentrations.

	11-18 November	18-25 November	25 November - 2 December	2 -9 December	9-16 December	All periods
Number of cases	30+2 *	30+2 *	30+2 *	30+2 *	30+2 *	32x5 **
Observed mean (ug/m^3)	5.7	4.5	4.5	4.8	7.5	5.4
Calculated mean (ug/m^3)	8.9	7.7	7.9	3.7	10.6	7.7
Pearson's Coefficient	0.54	0.58	0.58	0.62	0.58	0.59
Bias (ug/m^3)	3.2	3.1	3.3	-1.2	3.1	2.32
NMSE	0.43	0.51	0.52	0.26	0.28	0.41

(*) 30 passive samplings + 2 air quality station measurements; (**) 32 cases for 5 weeks

For PM10 the model performance indices were calculated separately for the two air quality stations (tab. 3).

Tab. 3 Statistical indices of model performance for PM10 concentrations

Air quality station	Arcella	Mandria
Number of cases	35	35
Observed mean (ug/m^3)	56	47
Calculated mean (ug/m^3)	10	6
20% of Observed mean (ug/m^3)	11	9
Pearson's Coefficient	0.82	0.40
Bias (ug/m^3)	-42.7	-37.3
NMSE	3.7	6.0

The modelling system shows a drastic under estimation for PM10. Correlation coefficient is acceptable for the Arcella station but scarce for Mandria station.
Because the model estimates only the primary component of PM10 derived from local road transport, the calculated means should be most fairly compared with the 20% of observed means. Cirillo (2002) in fact estimates a 20% contribution of local traffic to the observed PM10 concentration in a typical Italian city. Our model estimate is in line with Cirillo's one as the calculated concentrations are roughly one fifth of the observed concentrations for Arcella station (tab. 3). Mandria station is underestimated by the model and also the Pearson's coefficient is low for this station. This different capability of the model in estimating PM10 in the urban sites is explained by the different position of the stations with respect to the road network: Arcella is placed in the centre of the urban area while Mandria station is placed at its border, near extra-urban roads not included in the simulations.

2.3. Traffic flows scenarios

The three scenarios had been evaluated according to traffic restrictions applied in Padua during autumn and winter 2003-2004. The first one sees a total turn over of gasoline and diesel pre-Euro vehicles and of diesel Euro I in the whole road network. The second (third) scenario applies to the first scenario an additional decrease in traffic flows of 6% (18%) from 9am to 6pm. The percentage of traffic flows decrements had been chosen from a previously evaluation (ARPAV, 2004) and corresponds to an actual decreases of urban traffic during days of no pre-Euro and no diesel Euro I circulation (6%) and during days of alternate number plate in addition to no pre-Euro and no diesel Euro I circulation (18%). In every scenarios urban buses were not restricted as it happened in the reality; applying the traffic restriction to the whole road network was not a realistic assumption as in the reality the traffic restriction did not apply to the road ring.

3. RESULTS AND DISCUSSION

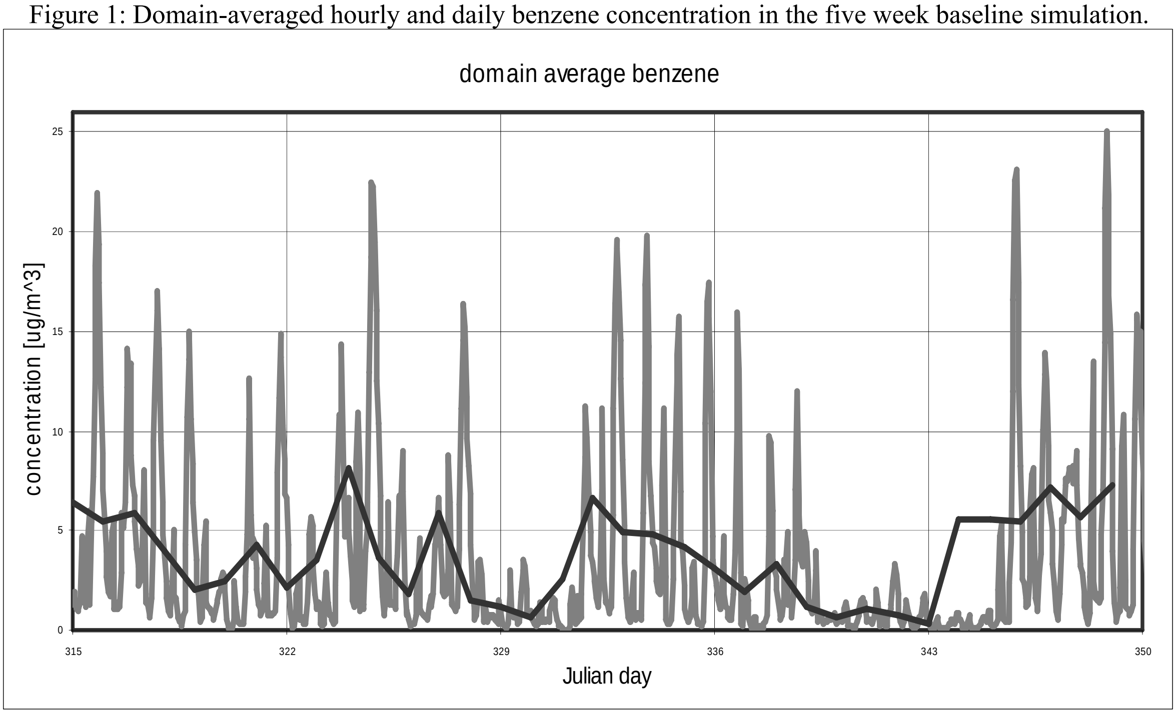
In table 4 the maximum percentage emission decreases are shown for both benzene and (primary) PM10 for every scenario.

Tab. 4 Benzene and primary PM10 emission maximum decreases for traffic restriction scenarios

Scenario	Benzene (%)	PM10 (%)
1 No pre-Euro and no diesel Euro I vehicles	71	27
2 No pre-Euro and no diesel Euro I vehicles and -6% traffic flows h 9-18	72	30
3 No pre-Euro and no diesel Euro I vehicles and -18% traffic flows h 9-18	74	35

With the exception of a short transient phase after emission rates changes, the domain average concentration decrement calculated by CALPUFF was the same as the emissions decrement, hence about 70-75% for benzene and 27-35% for PM10. In the case of PM10 it is to be kept in mind that this model application considered only the primary component of PM10. As the traffic control actions take effect only on about one fifth of the PM10 concentrations (Cirillo, 2002), the actual decrease of PM10 concentrations due to traffic restrictions is about 5-7%.

Figure 1: Domain-averaged hourly and daily benzene concentration in the five week baseline simulation.



In the assessment of traffic control effectiveness it is important to compare the concentration variability induced by meteorological conditions with the one induced by the different emission scenarios. In the five-weeks simulation the total working-day emissions are constant while the domain-averaged daily concentration of benzene (PM10) on a working day can vary between 0.3 (0.4) µg/m^3 and 8.2 (9.8) µg/m^3. If an atmosphere with average or low dispersing ability can lead to domain-averaged ground concentrations of few micrograms per cubic metres of benzene or PM10, a highly dispersive atmosphere will most likely take the concentration down of more than an order of magnitude. Therefore the meteorology can determine the value of the ground concentration (averaged over an area of few kilometres squared) for more than 90% of the value the concentration would assume in an average or low dispersive atmosphere.

4. CONCLUSIONS

The model application here presented allowed to understand how assessment of traffic control policies can be extremely difficult when it is performed only using observed concentrations. The effect of the meteorological variability on observed concentrations is larger than emission scenarios variations for benzene and much larger for PM10 and, contrary to model simulations, it can not be controlled.

The meteorological conditions introduce a variability in the domain-averaged daily concentration that most certainly overcomes the change due to even the most stringent traffic restriction policies. In this exercise the meteorology caused a change in the domain-averaged daily concentration of more than 90% of its highest value while the traffic restrictions lead to a maximum concentration reduction between 70 and 75% of benzene and between 5% and 7% of primary PM10. It is therefore not possible to estimate the effect of traffic policies using only measurements. To this end models can be very helpful tools that allow to separate the meteorology effect from the emission effect.

5. REFERENCES

ARPAV, 2003 La Qualità dell'aria nel Comune di Padova. Rapporto 2002. A cura di M. Bressan.

ARPAV, 2004. *Valutazione dell'efficacia dei provvedimenti di limitazione del traffico nei comuni capoluogo di provincia del Veneto - Novembre 2003 - Marzo 2004*. In http://www.arpa.veneto.it/

Biancotto R.; L. Coraluppi L., F. Liguori, K. Lorenzet, G. Maffeis, S. Pillon, S. Pistollato, M. Rosa, E. Tarabotti, 2004. *Model simulation of Venezia-Mestre ring road air pollution: experimental ceck and model intercomparison*. In 9th Int. Conf. On Harmonisation within Atmospheric Dispersion Modelling for Regulatory Purposes. Garmisch – Germany 1-4 June 2004.

CAFE Working Group on Particulate Matter, 2004. *Second Position Paper on Particulate Matter.* December 20th, 2004

Cirillo, 2002. ***Stima del Contributo per fonte di emissione alla concentrazione in aria di PM10 in Italia.*** Relazione presentata al Workshop "Valutazione della qualità dell'aria e dei livelli di esposizione alla luce del recepimento della direttiva 99/30/CE sui valori limite della qualità dell'aria. Roma, Istituto Superiore di Sanità, 18-19 novembre 2002.

Lükewille A., I. Bertok, Amann M., J. Cofala, F. Gyarfas, C. Heyes, N. Karvosenoj, Z. Klimont and W. Schöpp, 2001 *A framework to estimate the potential and costs for the control of fine particulate emissions in Europe*. International Institute for Applied Systems Analysis (IIASA), IR-01-023, Laxenburg, Austria.

Mosca S., G. Graziani, W. Klug, R. Bellasio, R. Bianconi, 1998, *A statistical methodology for the evaluation of long range dispersion models: an application to the ETEX exercise, Atmospheric Environment*, vol 32, pp 4307-4324.

Ntziachristos L. and Z. Samaras, 2000. *COPERT III, Computer programme to calculate emission from road transport. Methodology and emission factors (Version 2.1)*, EEA, Copenhagen, Denmark.

Scire, J.S., F.R. Robe, M.E. Fernau, and R.J. Yamartino, 2000. *A User's Guide for the CALMET Meteorological Model (Version 5).* Earth Tech, Inc., Concord, MA.

Scire J.S., D.G. Strimaitis, R.J. Yamartino, 2001. *A user's Guide for the CALPUFF Dispersion Model (Version 5.7),* Earth Tech, Concord, MA.

Methods of Economic Damage Caused by Air Pollution

A.H. Melkonyan- Armstatehydromet, department of Mathematic Modeling of Hydrometeorology, E:mail: ani_melkonyan@yahoo.com*, Adrress: Leo54, Yerevan, Armenia, Tel: (37491)70-50-42, S. G. Tonapetyan- Armstatehydrome , department of Environment Pollution Research, E:mail:shake1983@mail.ru, Adrress: Leo54, Yerevan, Armenia, H.A. Melkonyan – executive of Armstatehydromet, Adrress:Leo54, Yerevan, Armenia, E:mail: hamlet_melkonyan@yahoo.com*

Abstract

In the given paper sulphur dioxide dispersion and distribution from Alaverdi city cropper-molybdenum factory in the terms of different wind directions are observed. Economic damage has been calculated in this Active Pollution Zone on the basis of the methodology used in Former Soviet Union, but the latter was developed by as having used especially climate elements. This methodology with adding is offered to be accepted for the evaluation of economic damage caused by pollution in Armenia.

Environment management and control issues are always of great importance in developing countries. While economic growth in developing countries increases, the government doesn't manage to implement new technologies to support environment purity.

1. Introduction

After the Soviet Union collapse many Armenian large industrial enterprises stopped operating due to which emissions decreased to minimum.

Since 1998 in Armenia with GDP increase by 10% in average and putting out of action of the clearing equipment, the growth of pollutant emissions into the atmosphere and water has increased and it often exceeds the external permissible values for different ingredients.

The important task of this problem is to have a method for assessment of Value Economical Damage (VED) of atmospheric pollution impact on environment.

For evaluation of economic efficiency, economic growth and environment purity should be balanced, for which economic damage caused by different enterprises should be estimated.

2. Methodology

Damage calculation caused by pollution is divided into two parts here: pollution distribution in the area and economic damage assessment in the same area.

The description of pollution diffusion in atmosphere is the following. Equation of mixture distribution on the basis of mathematic model [5] is.

$$\frac{\partial\varphi}{\partial t}+u\frac{\partial\varphi}{\partial x}+V\frac{\partial\varphi}{\partial z}+w\frac{\partial\varphi}{\partial z}+p\varphi-\frac{\partial}{\partial x}k_x\frac{\partial\varphi}{\partial x}-\frac{\partial}{\partial y}k_y\frac{\partial\varphi}{\partial y}-\frac{\partial}{\partial z}k_z\frac{\partial\varphi}{\partial\varphi}=F(x,y,z,t) \quad (1.),$$

where $\varphi(x,y,z,t)$ - is mixture concentration in air (mg/m^3), t- is time, x, y, z –decardian coordinates, ox and oy –are axis directed in horizontal plane, oz-is vertical axis, u, v, w - are wind speed components corresponding to axis: k_x, k_y, k_z –are horizontal and vertical components of mixture coefficient, p-is parameter describing the mixture life period. F(x, y, z, t) –is function describing the mixture life period.

F(x, y, z, t) is given:

$$F(x, y, z, t) = Q\gamma(t)f_{xoyo}(x,y)\delta(z-h), \quad (2)$$

where Q is source power,

$$\gamma(t)=\begin{cases}1, & 0<=t<=t_0\\ 0, & t>t_0,\end{cases}$$

$$f_{xoyo}(x,y)=\begin{cases}1, & x_0-\Delta x<=x_0<=x_0+\Delta x, Y_0-\Delta y<=y_0<=y_0+\Delta y\\ 0, & \text{outside of that interval}\end{cases}$$

t_0 – source acting period, $\Delta x, \Delta y$ describe source horizontal sizes, δ -function

Integrating interval is given:

$$\Omega=\lfloor(x,y,z),0<=x<=l_x,o<=y<=l_y,z_0(x,y)<=z<=z_0(x,y)+h\rfloor, \quad (3)$$

where $z=z_0(x, y)$ is relief, l_x, l-is horizontal scale.

Edge parameters on verticals are:

$$\alpha \frac{\partial \varphi}{\partial z} - \beta \varphi = 0 \qquad \text{when } z=z_0(x,y) \qquad (4)$$

$$\varphi = 0 \qquad \text{when } z = z_0(x,y)+H$$

where β -is constant describing connection between mixture and land surface: Ω interval sizes are chosen so that on its edges

$$\varphi/_{\Gamma} = 0 \qquad (5)$$

Initial condition is given.

$$\varphi/_{t=0} = \varphi_0 (x, y., z) \qquad (6)$$

To take into account relief impact on pollution mixture dispersion variable exchange is done in the following way:

$$\xi = x, \eta = y, \zeta = b\{1 - \exp[-a(z - z_{0)})]\} \qquad (7)$$

a and b parameters are chosen correspondingly. Doing corresponding formation formula (1) is changed so that integration uniform steps are provided. Five levels are taken on vertical district.

On the basis of this scheme SO_2 emissions from cropper-molybdenum factory in Alaverdi city are calculated.

The area for which the calculations have been carried out has the following horizontal sizes: on x axis - 18360 m, on y-15840 m: Horizontal steps are taken Δx=Δy=90 m, which have M • N calculation units: M=204, N=177:

Pollution source power has been taken from statistical report and is 600 g/sec. Wind on land layer is taken from meteorological observations and on the next level it is defined within logarithmic rule.

For the upper 3 layers wind speeds are taken from the ten year's observations of Yerevan radiosonde.

Logarithmic rule for concentration calculation on land layer we take wind speed $\overline{u}(z)$ change and turbulent exchange of K(z) [3,6]: k_z on land layer is defined

$$k_z = k_{1p} \frac{z}{z_1} \sqrt{1 - \overline{R_i}} \ , \qquad R_i = \frac{g(\partial t / \partial z)}{t_a (\partial u / \partial z)}, \qquad k_{1p} = \lambda^2 u_1 / \ln \frac{z_1}{z_0} \ ,$$

where k_{1p} is the value of k_z on z_1 height, R_i -average value of Richardson on edge layer, t – temperature (^{0}C), t_a-absolute temperature, g –acceleration of gravity, χ = 0.4 –Karman parameter, u_1 –wind speed on z_1 height, z_0 –roughness parameter, h –land layer height, k_1 and h are taken from [2]:

Coefficient of horizontal turbulence is taken from Richardson-Obukhov formula [2].

$$K_{x,y} = 0.2\ L^{4/3} \ ,$$

where L is horizontal scale off observational area. In these calculations $K_{x,y}$ is 90 m^2/sec :

Integrating time step is 60sec due to scheme sustainability.

Pollution distribution for two cases (a-calm, b-for eastern winds) is given in Pict.1. On the basis of this calculation results economic damages are evaluated.

In this paper methods of economic damage calculations are analyzed, which were used in the Soviet Union: we have also tried to implement some adding, which allow specifying calculation results. Given methodology comes to the damage (D) estimation, which is caused by emissions into the atmosphere for any source and can be presented as the following formula.

$$D = \gamma * \sigma * f * M \ , \qquad (9)$$

D-damage estimation (dram/year),

χ-constant, the numerical value of which is 480drams ($1.2 US),

σ-coefficient of air relative air pollution damage in the different types of territories (in bales),

f -correction in response to air pollutants distribution,

M-annual emission mass (conventional ton/year).

Air pollutants concentration distribution and dispersion aren't taken into account in this methodology: meteorological conditions impact on damage forming is estimated with temperature and wind annual values.

As χ and M are constant values, for σ and f estimation we made completions. These completions are related to damage calculations for different seasons of year. Mathematic model of emission distribution and dispersion based on numerical solution of turbulent diffusion equation, where region relief is taken into account is used.

For σ calculation Pollution Active Zone (POZ) is implemented which isn't homogeneous and consists of the areas to which different values of σ_j are peculiar. σ calculation formula is.

$$\sigma = \sigma_{PAZ} = 1/S_{PAZ}\sum_{j=1}^{K}\sigma_j S_j = \sum_{j=1}^{K} S_j / S_{PAZ}\sigma_j, \qquad (10)$$

S_{PAZ}-is the total square of PAZ,

j -number of the PAZ part which shows the change of relative damage coefficient (0,05-pasture, 10-reserves, resorts),

K-total number of area types, which exist in PAZ,

S_j- is j-th part square of PAZ.

For organized sources PAZ is a ring, which is limited in $r_{PAZ}^{inside}=2\varphi h$ and $r_{PAZ}^{outside}=20\varphi h$, where

h - is source height,

φ- is coefficient of warmth coming out from emission torch and is defined:

$$\varphi = 1 + \frac{\Delta T}{75^0 C} \text{ , where}$$

ΔT – annual values of differences between atmosphere, source and temperature,

f –multiplication value is calculated on the basis of gas mixture settling

$$f = \frac{100(m)}{100(m)+\varphi h} * \frac{4m/\sec}{1(m/\sec)+u} \text{ , where}$$

u- is gas mixture settling:

This methodology has undergone to some changes due to meteorology. Calculations should be carried out for different seasons, wind speed, directions. Taking into account wind repeatability σ is calculated:

$$\sigma_{ij}^K = \sigma_{i,calm}^K + \sigma_{i,district}^K \text{ , where}$$

j- is wind direction,

k- is accepted for seasonal mean months-January, April, October.

3. Results.

Having used meteorological conditions and pollution modeling results of Alaverdi city damages caused in the radius of 6 km have been assessed. These calculation results are given in the table.

σ values of Pollution Active Zone in months and wind directions.

PAZ	January	April	July	October
σ_{calm}	1.55	0.93	0.65	1.28
σ_w	1.39	1.15	1.00	1.09
σ_s	1.98	2.20	1.91	1.73
σ_e	0.30	0.26	0.31	0.35
σ_n	0.03	0.04	0.06	0.04

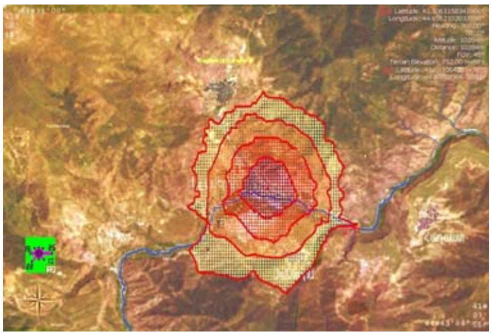
4. Conclusions.

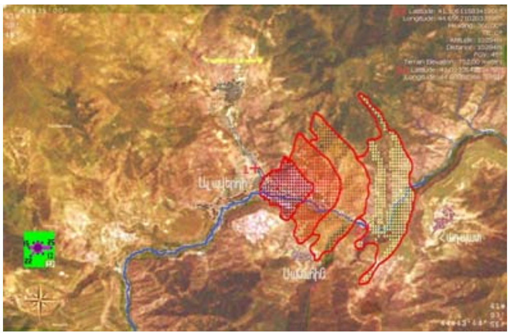
Evaluating σ_s for each month and wind direction and f values for months, damages caused by pollution have been estimated for seasonal cut and annual damage has been evaluated. Annual damage calculated on the basis of Soviet methodology surpasses approximately for 2 times the damage calculated by this given methodology. The latter shows that damage caused by pollution in winter is much more than damage caused in warm period. This phenomenon is due to atmosphere stratification and inversion repeatability. After having tested the methodology, it can be applied in practice.

SO_2 distribution in Alaverdi city in case of calm – a) and eastern winds – b)

a)

b)





5. References

1. A. Melkonyan, H. Melkonyan"Mathematical . Model of Atmosphere Pollution in Yerevan Caused by Industrial Emissions, Sissi, Crete, Greece, 17- October, 2005

2. Batchvarova E., Spassova T., Valkov N., Iordanova L. Atmospheric Chemistry Research in New EU Countries. *Department of Composition of the Atmosphere and Hydrosphere at the National Institute of Meteorology and Hydrology (Bulgaria)* Bulgaria, 2005.

3. Berlyand M.E., Actual Isuues of Atmosphere Diffusion and Pollution, Hydromet Publ, Ë.,1975,.

4. Berlyand M.E Atmisphere Pollution Control Supervising (edit.M. E. Berlyand). Hydromet Publ Ë.,1979, 448p.

5. H. Melkonyan, D. Melkonyan. Study and Prediction of Atmosphere Pollution in cities of Armenia., Garmish-Partenkirchen, Germany, 1-4 June, 2004

6. H. Melkonyan., Mathematic Modeling of Pollutant Distribution in Atmosphere in Armenia, Hydrometcenter , Edit. 204, 1978, ñ. 71 – 92.

APPLICATION OF THE ISHTAR SUITE FOR THE ASSESSMENT OF THE ENVIRONMENTAL POLICIES IN 7 EUROPEAN METROPOLITAN AREAS

E. Negrenti[1], A. Agostini[1], P. Mudu[2], A. Parenti[3]
1) ENEA, Italy; 2) WHO-ECEH, Rome, Italy; 3) ASTRAN s.r.l.Viterbo, Italy

ABSTRACT
The ISHTAR Suite is an innovative software for the simulation of the effects of transport policies on the urban environment, population health and artistic heritage. Starting from the effects of the measure on citizens behaviour, the calculation path goes through the modelling of transport, vehicles safety and emissions of pollutants and noise, pollutants dispersion and noise propagation, exposure of population, health effects assessment, monuments degradation, up to the comparison of the alternative scenarios in terms of cost-benefit or multi criteria analysis. The ISHTAR Suite was tested in the seven cities involved in the Project: Athens, Bologna, Brussels, Graz, Grenoble, Paris and Rome.

1. INTRODUCTION
Worldwide cities face common challenges concerning their quality of life: degradation of the urban environment, significant risks for citizens health, traffic congestion causing stress and economic inefficiency, progressive damage of the artistic and monumental heritage. Additional difficulties derive from the lack of integrated tools that allow cities to make balanced decisions on a wide range of issues. In this context the European Commission co-funded from 2001 to 2005 the ISHTAR (Integrated Software for Health, Transport efficiency and Artistic heritage Recovery) Project [Negrenti et al. 2002]. The Project aimed at building an Integrated Suite of software models for assessing the impacts of various types of urban policies and actions on the quality of life of citizens, and in particular on traffic congestion, air quality, citizens health and conservation of cultural heritage (see fig. 1)

2. METHODOLOGY
The ISHTAR Project had four main scientific and technological objectives:

- The integration of a large number of software tools and the creation of specific modules for the simulation of key processes such as transport and its direct impacts on the urban environment.
- The achievement of a high spatial and temporal flexibility, for maximizing the possibilities of application from local short-term actions to widespread long-term policies.
- The development of specific modelling areas such as policies effects on citizens behaviour, the integrated 24 hours simulation of traffic emissions, noise and safety, the microscopic analysis of air pollution effects on health and monuments.
- The application of the tool to the analysis of measures tested or planned in the seven involved cities: Athens, Bologna, Brussels, Graz, Grenoble, Paris and Rome.

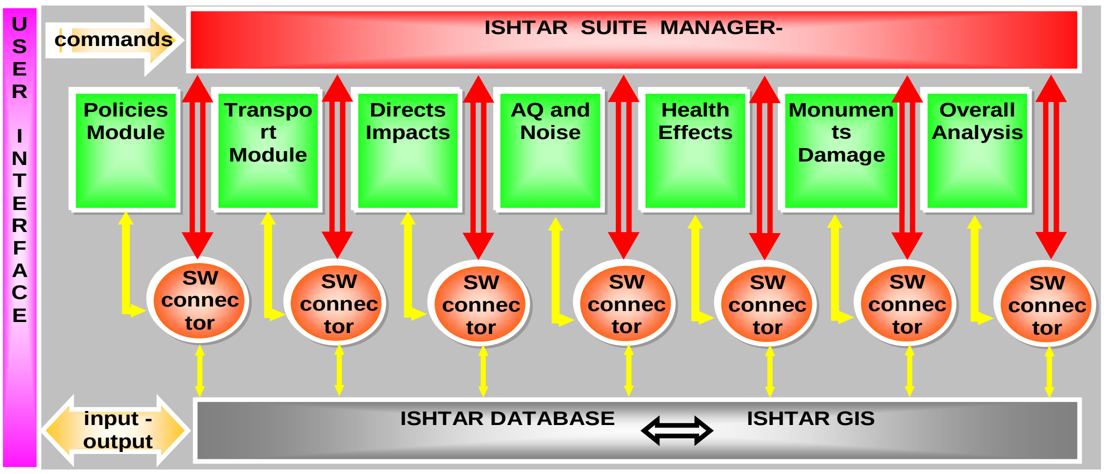


Fig. 1 ISHTAR Suite integration architecture

3. RESULTS AND DISCUSSION
While it was at the outset of the ISHTAR project the intention to ideally apply the whole ISHTAR suite to all of the case studies, it turned out during the course of the project that the majority of the case studies covered the application of single modules of the suite. The performed case studies [see 2] can be described as follows in the next sections.

Athens and Attiki region new motorway

The application of the ISHTAR suite in the Attica region case study dealt with the new roadway construction, the so-called "Attiki Odos". This new toll highway was assessed in terms of traffic, toll strategy and pricing, environmental conditions in the highway and all of its accesses. ISHTAR suite modules for traffic, emissions, air pollution and noise have been applied. With the operation of the highway (after case study analysis) 250.000 vehicles travel in Attica Road at an average of 15 km per trip, meaning 3.750.000 vehicle-km daily. This highway is becoming very popular for the Athenians, and the traffic is increasing every month, reaching, on certain days and hours, serious congestion levels.

In the cases where the noise caused by the traffic was proven to be above the limits for the surrounding settlements, noise barriers have been installed along the motorway achieving the prevention of the dispersion of sound towards residential and other sensitive areas (schools, hospitals, etc.). The analysis of air pollution and noise impacts indicated that this motorway has not caused significant negative side effects to the environment. Now, people once opposed to such an enormous project within Athens city's bounds were re-assured and relieved since no great health impacts were about to be imposed on their lives. Special notice was also shown to the accident factor; the report on this analysis indicated that accidents have been reduced within the region of Attica. ISHTAR project provided various benefits to a) the Ministry of Planning, Environment & Public Works, b) "Attica Road" realisation, and c) the citizens of Athens (especially those living in areas adjacent to the highway) by explaining in clear manner the highway's operation and its globally positive impacts.

Bologna province : the Imola case

The Bologna Province case study concerns an Environmental Impact Assessment of a new infrastructure for the City of Imola. The goal of the simulation was to estimate the impact on air quality of a new urban road. Different infrastructural scenarios have been considered aiming at supporting the decision-making process to choose among the alternatives which are likely to have less significant effects on the environment. The ISHTAR modules used to carry out this case study were the Direct Impacts Module (TEE2004), the pollutants dispersion module ARIA IMPACT and the noise propagation module SOUNDPLAN.

The scenarios were built up with reference both to direct interventions of traffic management (new paths, roadway adjustment, intersection regulation) and to indirect interventions (public transport services, etc.). The air concentration of NOx, CO and PM10 from road emissions were modelled. These pollutants were chosen because they are the most critical ones for the Province of Bologna. The simulation of some of the different scenarios offered the opportunity to test the suite as an integrated tool for supporting decision-makers in adopting environment-conscious actions.

The Province of Bologna case study tested the three core tools of the suite integrated in the first prototype of the ISHTAR Suite. The case study was also run by the Province but with the tools not integrated, and the results were obviously the same, showing a clear advantage for the so called 'Definitive Project' vs. the postulated alternatives. This case study was not a 'before-after' study but a pure planning exercise. This test has been very useful for the identification of bugs and necessary development and improvements of the integration software.

Brussels Capital Region banning policies

After having observed for years the strong relationship between road traffic intensity and air pollutant concentrations, the Brussels Capital Region (BCR) decided to prepare a set of traffic banning measures and related accompanying measures to be implemented when air pollution forecasts exceed specific thresholds. The aims of this ISHTAR case study were to design crisis scenarios with different severity degrees, then forecast the behaviour of travellers facing the scenarios through preliminary surveys, and design accompanying measures such as parking provision, intensified public transport etc. Moreover belgian colleagues estimated traffic impacts by means of traffic models and 'noise and pollutants emissions' through key ISHTAR models. The ultimate objective was to test the feasibility and the efficiency of a Car Free Day as part of a 'global ozone plan' for the Brussels Capital region. In order to model the impact of banning measures, a survey has been performed to persons travelling by car as drivers at some strategic places in Brussels. This survey allowed forecasting required car parks and modal shift. New trips matrices for transport models could be built. The main results in terms of transport were: 33 % of trips cancellation, 51 % of modal shift (public transport & pedestrian mode), 11% of measure infringement. As a result, on average, noise was reduced by ten dB, while the highest level of NOx emissions recorded at the city's busiest traffic intersection was eight times lower than for a normal weekday. Car free days appear to be efficient to reduce pollutant concentrations like NOx, CO and PM but are useless for decreasing ozone levels in short-term.

The general main conclusions were the following: the most efficient scenario was the scenario banning all EURO 3 not conformable vehicles; the Diesel banning scenario got a very significant impact in terms of PM10 emissions reduction; the fleet evolution has at least as much impact as the traffic reduction in itself.

As a consequence, weekdays car free days can be organised punctually according to environmental conditions, by providing travellers valid transportation alternatives.

City of Graz new tunnel

In the city of Graz the historically grown road network lacked in a certain region in a good connection between two major roads. This unsatisfactory situation led to an increased traffic load in residential areas between these two roads. In order to improve the situation a new connection was built in the form of a 'cut and cover' tunnel. As one of the portals of this tunnel is situated very close to residential buildings the concern about local environmental impacts was very high. The main reason for this measure was the improvement of the situation within the residential area concerning : a) reducing the potential risk related to accidents, b) reducing noise pollution, c) improving the traffic situation concerning the connection of the main roads. The ISHTAR modules used were the emission module TEE-2004 and the dispersion model ARIA IMPACT. In addition the emission module was assessed against the Austrian standard emission calculation tool (Handbook of Emission Factors) and the dispersion tool against the GRAL model. The inter-comparison between the emission tools proved that with TEE software reliable emission estimates are to be expected. The module ARIA IMPACT was able to show the general trend. The trend on the small scale (portal regions) was confirmed by application of more detailed models. The overall effect of the measure on air quality is not very high. The main effects of the measure on the noise pollution were that in the central part of the residential area a strong noise reduction was achieved while at the boundaries of the study area no remarkable changes were achieved. The traffic increase at that location due to the implementation of the measure did not counteract the benefits gained due to the noise barriers. The positive effect of this measure was proven also by noise and air quality measurements.

City of Grenoble measures for enhanced Public Transport

Grenoble is the major city of the Grenoble urban area (470 000 inhabitants). The city has a high density of population on a small surface and many urban streets have heavy traffic. The case study was intended to monitor the effects of the installation of reserved lanes for public transportation and new traffics lights on 'boulevards' with heavy traffic in city centre (60 000 vehicles/day or more). The objectives of these measures were: to test the possibility of reducing the number of lanes dedicated to car traffic (from 6 to 4), to increase the average speed of public transport and to reduce car speed, and monitor the impact on traffic flow.

The aim of this ISHTAR case study was to compare the results of the simulations done with the modules of the ISHTAR suite to the measurements done before the measures implementation in 1999 and after in 2000 in terms of traffic, air pollution and noise. The implementation of the measures led to a small reduction in emissions (~ 3% for CO, NOx and VOC). However it can not be expected that the small changes in emissions in a restricted area can have a measurable impact on air quality.

The monitoring programme included noise measurements at one location and air quality at two locations. Referring to noise pollution a reduction of 2 dB is reported for one part of the domain while in a second part no changes could be found. Referring to air quality a reduction of some 8% in NOx and up to 40% (!) in PM for short term and 2% in long term were found. The short term (14 days) reduction was definitely biased by the different general meteorological conditions between the monitored period in 1999 and year 2000. The long term values (6 months) were much more reliable. Within this study the following ISHTAR modules were used: 1) the full ISHTAR interface as a module manager, 2) the ISHTAR GIS module, 3) the emission module TEE, 4) the dispersion tool ARIA IMPACT. The general trend of the changes due to the action could be followed in the emission calculation as well as in the monitored values.

City of Paris 'Car Free Day'

Every September 22nd, the City of Paris takes part in a car free day called "En Ville Sans Ma Voiture". In years 2002 and 2003, the experiment was implemented in the historical centre of Paris (area concerned: 3 x 2 kms). Between 7 a.m. and 7 p.m., this central area was only accessible to public transport, taxis, "green" vehicles (LPG and electric cars) and professional users. The temporal and spatial scale of the experiment focussed the assessment on the short-term road-side air quality impact. The background pollutant concentration, which is a regional parameter with strong weather dependence, sets the context.

The aim of the ISHTAR case study was to test the enhancements to the modelling tools contained in the ISHTAR suite. The traffic and pollution dispersion modules were applied. The ISHTAR project has given us the opportunity to make a first assessment of traffic simulation in congestion (see figure 2) with a new version of VISUM software integrating the Metropolis algorithm. This software uses hourly origin-destination matrices which keep the total traffic volume, but allows better modelling of congestion by allowing to distribute demand over time slices of a few minutes at peak hours.

We also tested the dispersion model Aria IMPACT. Globally, an evaluation of Car Free Day 2003 impact on air quality in the central area could be estimated as ~ 60 % decrease for the roadside pollution.

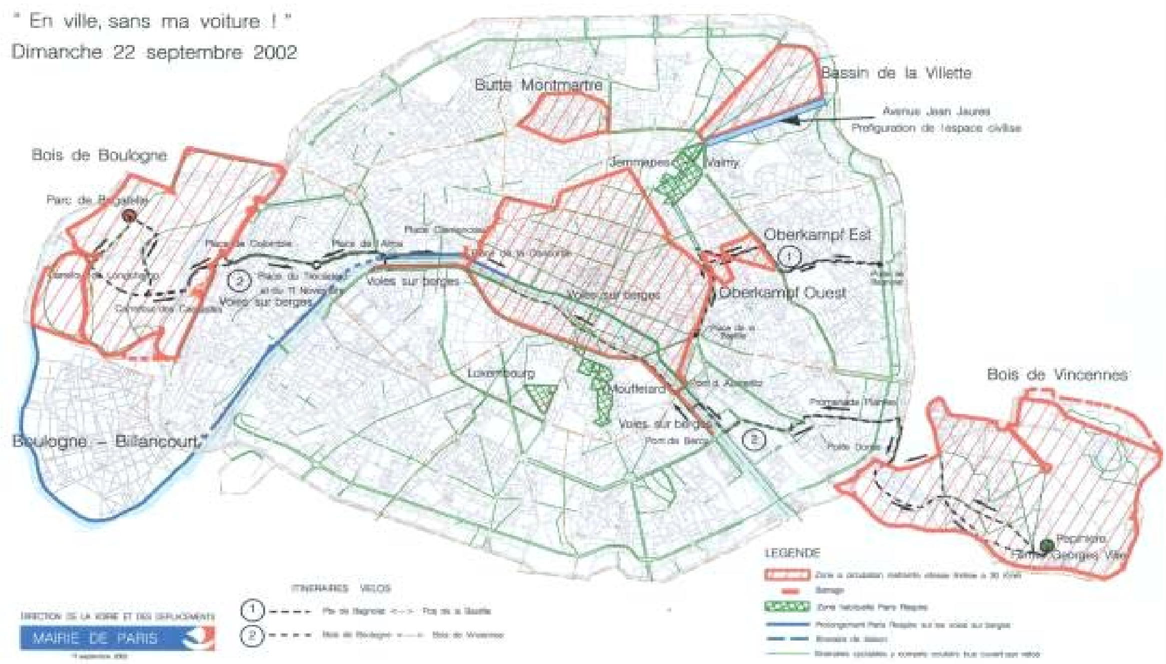


Fig. 2: Paris case study area for "en ville sans ma voiture" day

City of Rome traffic banning policy

In the city of Rome an access restriction for non-catalyst vehicles was implemented within the "Rail Ring". A simulation of the ISHTAR suite was prepared to test the input-output connections among different software modules, data exchange with external software, modelling factors, and clarity of output. The analysis carried on was based on a comparison between two simulated scenarios: the 'do nothing' scenario and the 'actual' scenario (based on the traffic limitation measures described). The cited measures had as their main effect a change in the fleet composition and no significant effects were expected and measured on traffic flows. Traffic data from O/D matrices were available and – in this case - the Suite Entry Point was the 'direct impacts model' TEE-2004. Pollutants modelled both by the Emission and Dispersion modules within the semi-central area named 'HEAVEN area' in a given day were CO and PM10. CO was also considered by the exposure module and PM10 by the Health effects module. The PM10 dispersion modelling output were used to generate an exposure and health effects assessment. The simulation gave a small difference between the two scenarios in terms of health impacts of the tested policy. The low difference between the scenarios, and between the scenarios and the background, can be explained with the small dimensions of the area under analysis, that is strongly affected by the surroundings that include sources that have not been modelled. The case study of Rome can be considered as the most comprehensive ISHTAR suite application so far and was managed directly at ENEA

4. CONCLUSIONS

This work summarises the main outcomes of the application of the ISHTAR suite to the seven case studies included in the ISHTAR Project, concluded in 2005. These applications gave several positive indications on the performance of single tools and of the whole integrated software, but also put into evidence areas of needed improvement as it regards models refinement and user friendliness. In the near future the ISHTAR suite will be used in Europe and elsewhere for advanced planning and evaluation of urban and metropolitan environmental policies.

5. ACKNOWLEDGMENTS

The authors wish to thank all the colleagues having cooperated directly or indirectly in the ISHTAR Project.

6. REFERENCES

Negrenti E. & Zaini D. 2002 ISHTAR Project Web Site : www.ishtar-fp5-eu.com
Negrenti E. & Agostini A. 2005 : ISHTAR Project Final Publishable Report – Deliv. 11.6

The AERAS project: data base implementation and Neural Network classification tests

Tymvios F.[1], *Constantinides P.*[1], *Retalis A.*[2], *Michaelides S.*[1], *Paronis D.*[3], *Evripidou P.*[4] *and Kleanthous S.*[5]

[1] *Meteorological Service of Cyprus*
[2] *National Observatory of Athens, Institute for Environmental Research & Sustainable Development*
[3] *National Observatory of Athens, Institute for Space Application & Remote Sensing*
[4] *University of Cyprus, Department of Computer Science*
[5] *Ministry of Labour and Social Insurance, Department of Labour Inspection, Cyprus*

ABSTRACT

The aim of the AERAS project is the development and establishment of a system that can be used for spatial mapping and temporal evolution forecasting of particulate air pollution loading. The primary source of this loading is considered to be the dust transport from the Sahara Desert, but also of anthropogenic nature. The first stages of the project have been completed: the development of the project's database and of the appropriate algorithms for Neural Network classification.

1. INTRODUCTION

Air quality has attained considerable scientific interest during the last decades. Several studies and projects have attempted to deal with aerosol monitoring and assessment both for naturally and anthropogenically induced aerosol particles. To this end, satellite remote sensing has been widely used for air quality monitoring on a global scale. This paper is an attempt to study air quality in terms of monitoring dust events in the SE Mediterranean region, and especially over Cyprus through the AERAS project.

The project aims at the development and establishment of an appropriate system that can be used for spatial mapping and temporal evolution forecasting of particulate air pollution load, resulting mainly from the Saharan dust transport in SE Mediterranean region and secondary, from anthropogenic sources. It is based on the development of an efficient Neural Network classification system. The system integrates meteorological maps of synoptic situations, remotely sensed data and *in-situ* measurements for the development of statistical models.

The main results that would be derived at the end of the project include:

- Climatology analysis of particulate air pollution based on remotely sensed data and *in-situ* air pollution measurements.
- Development of Spatial Synoptic Classification algorithms using Neural Networks.
- Development of statistical models for forecasting air pollution levels.
- Monitoring / Mapping of significant pollution events using remotely sensed imagery.
- Development / improvement of algorithms for the localisation of urban pollution and airborne dust using remotely sensed imagery.

At its current phase, the project has completed its first tasks which comprise the implementation of a specifically designed data base and the development of the algorithms for Neural Network application to synoptic pattern classification (see Liassidou et al., 1999; Michaelides et al., 2007). These two tasks of the project are described below, together with some preliminary results.

2. DATA BASE DESIGN AND IMPLEMENTATION

Designing a suitable data base system for the project is the cornerstone for fulfilling the project's tasks. After defining the data requirements, the data base system has been designed. The components and interfaces of the system have been designed in order to achieve maximum flexibility. The majority of the components are already mature and the system has recently become operational.

The functional requirements of the system are the collection of the data from the project's partners, the preparation and the storage of the data to a database, the retrieval of the data with the desirable format and finally the processing of the data from the components that are responsible to make the classification or forecasting the dust transportation. The system's architecture is shown in Fig. 1.

The system collects data that make up the respective meteorological maps of the synoptic situation, remotely sensed data and *in-situ* measurements; all of these are supplied to a web server which can be accessed by the partners who can remotely login and upload their data. Having the data available, the "importer", parses the files and inserts them into the database tables. The "exporter" provides the interface to select a portion or all of the data in a desirable format. The other components of the system, including the Neural Network, can use the "exporter" to retrieve their input data and then to produce the final product.

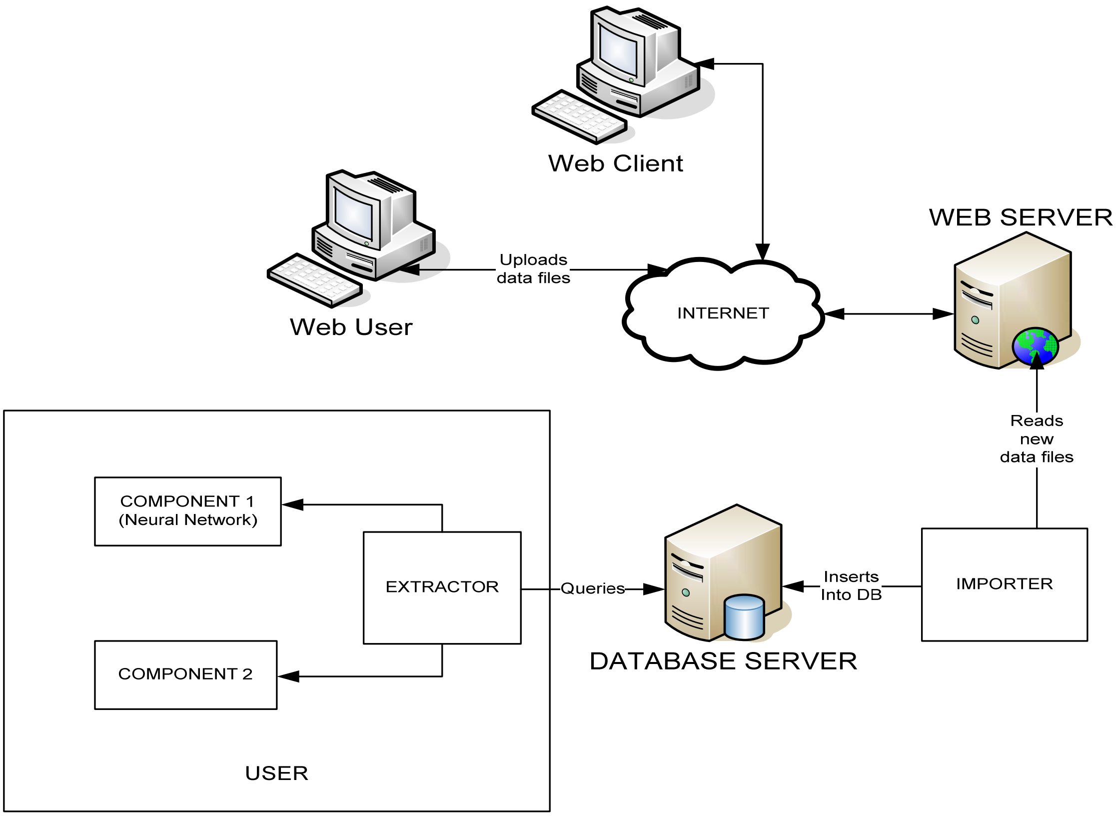


Figure 1: System Architecture

3. NEURAL NETWORK IMPLEMENTATION

The project includes a series of tasks which require the implementation of Neural Networks capable of :
a. Categorizing the meteorological conditions that prevail and possibly encourage episodes of pollution,
b. Approximating at a satisfactory level the dust load of the atmosphere via the synoptic meteorological situation and to forecast dust episodes,
c. Determining the spatial distribution of pollutants at the points of the ground measurements.

To classify the synoptic weather patterns, a Kohonen network was implemented (Kohonen, 1995). The self-organizing map (SOM) is a subtype of Artificial Neural Networks. It is trained using unsupervised learning to produce low dimensional representation of the training samples, while preserving the topological properties of the input space. This makes SOM reasonable for visualizing low-dimensional views of high-dimensional data (multidimensional scaling).The input of the network is the 5551 points of each day and the output is the cluster the day belongs to. The network was trained for 16 and 24 clusters.

4. DATASET

For the synoptic classification of weather patterns, data from the ECMWF reanalysis project (ERA40) were used. More specifically, the 500hPa isobaric surfaces were utilized. The dataset consists of the 1200UTC isobaric heights, in geopotential meters, over an area defined by the geographical points 80^{o}N, 35^{o}W (upper left) and 20^{o}N, 55oE (lower right) and for the years of 1958 to 2001 at a resolution of 1^o x 1^o. Each day includes 61x91 points which are converted to a column vector of 5551 points. For practical reasons, the resolution was further reduced to 2^o x 2^o due to computing power and memory limitations.

5. CLASSIFICATION TESTS

At present, the Neural Network classification system that was developed is tested for its performance and its capability to recognize and classify synoptic patterns. Three examples of such tests, showing the weather pattern analyses resulting from a 16-cluster implementation with Neural Networks are presented in Figs. 2, 3 and 4. These figures illustrate three successive patterns (cluster 9, cluster 8, cluster 7, respectively) of a hypothetical dust episode, as a result of a Neural Network classification with 16 clusters.

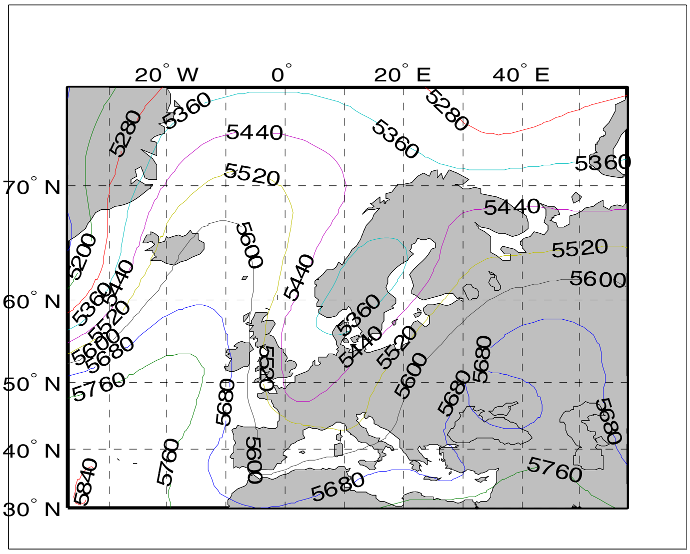


Figure 2. Cluster 9 (16 cluster case).

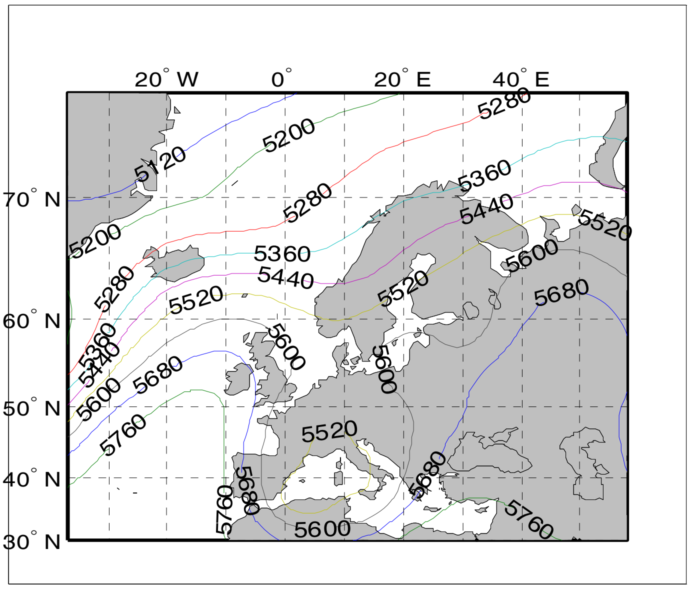


Figure 3. Cluster 8 (16 cluster case).

Figure 2 presents a deep trough over Europe, progressing southwards and deepening. In the next stage of this case, the trough becomes stationary and starts filling. These two instances advect into the eastern Mediterranean significant amounts of dust, originating from the Sahara Desert and subsequently suspended in the air. Fig. 4 illustrates the final stage of this episode, with a blocking pattern over the Mediterranean sea and high pressure building over Cyprus, thus intercepting the replenishment of the area with more Saharan dust.

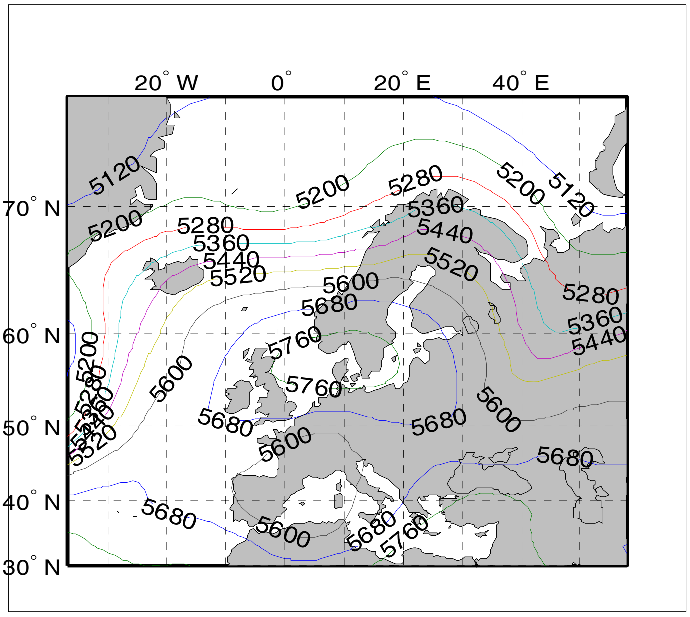


Figure 4. Cluster 7 (16 cluster case).

The classification tests have produced quite satisfactory results, in the sense that the Neural Networks that were trained were capable of classify distinctively varying synoptic patterns. The next step in the Neural Network classification task is to classify all the synoptic cases in the period under study and then statistically investigate which clusters are related to recorded dust episodes.

6. ACKNOWLEDGEMENTS

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7. REFERENCES

Kohonen, T., (1995): Self-organising maps. Springer Verlag.

Liassidou, F., Michaelides, S.C., Neocleous, C.C. and Schizas, C. (1999): Identification of synoptic patterns on weather charts by artificial neural networks. Proceedings of the 5th International Conference EANN’99. Warsaw, Poland 13-15 September 1999, 247-252.

Michaelides, S.C., Liassidou, F. and Schizas, C.N. (2007): Synoptic classification and establishment of analogues with artificial neural networks. Journal of Pure and Applied Geophysics, (in press).

THE USE OF GENERALISED ADDITIVE MODELLING TO INVESTIGATE THE AIR QUALITY IMPACTS OF A BUSY ROAD CLOSURE IN YORK, UK.

E. Westmoreland[1], N. Carslaw[1], D. Carslaw[2], E. Bates[3].*
[1]*Environment Department, University of York. Heslington, York. YO10 5DD*
[2]*Institute for Transport Studies, University of Leeds*
[3]*City of York Council*

Abstract
The link between traffic-related pollutants and health is well established and the control of traffic emissions is now the principle strategy open to local authorities in terms of air quality management. The well known traffic-related pollutant nitrogen dioxide is the sole cause of the air quality management area declared in York in 2002. A significant traffic reduction at Gillygate, York in 2005 provided a unique opportunity to investigate the role of local traffic emissions on ambient NO_2 concentrations. Generalised additive modelling was used to predict the hourly concentrations of NO_x and NO_2, using only a handful of meteorological, air quality and traffic variables. The final models explained a large amount of the variation in hourly pollutant data and predicted on average NO_2 concentrations within 7% of those measured. The model results indicate that traffic reductions of this nature can result in NO_2 concentrations falling by as much as 20%.

1. Introduction
The link between traffic-related pollutants and health is well established, with symptoms including respiratory and cardiovascular problems, impaired lung function, chronic bronchitis, development of asthma and mortality (Kunzli et al., 2000; Paramesh, 2002; Pope et al., 2002). NO_2, a well known traffic-related pollutant, is currently the single biggest cause of air quality problems in urban areas of the UK; a total of 92% of Air Quality Management Areas (AQMAs) are declared as a result of ambient NO_2 concentrations exceeding the hourly (200 μg/ m^3 or 105 ppb) or annual (40 μg/m^3 or 21 ppb) guideline concentrations (Carslaw, 2005). Recent studies have shown that primary NO_2 concentrations are on the increase (AQEG, 2004) and so it is likely that ambient NO_2 concentrations across the country are likely to continue to pose an air quality challenge in the years to come. The control of traffic emissions is now the principle strategy open to local authorities in terms of air quality management.

Some studies have used the variation in traffic volumes between weekday and weekends in an attempt to determine the role of traffic emissions on ambient concentrations (Lonati et al., 2006; Fujita et al., 2003). These studies illustrate how a natural experiment, such as the 'weekend effect', can be exploited to provide test cases for analysing emission reduction strategies. In addition, the use of the regression based modelling technique, generalised additive modelling, has been successfully applied to predict and explain air quality (Aldrin and Haff, 2005; Reiss, 2006). Generalised additive modelling provides a relatively simple and easy technique to predict pollutant concentrations using relatively few input covariates.

In the autumn of 2005 a pollution 'hotspot' street in the centre of York was closed for a two week period and resulting traffic volumes were reduced on average by 91% during daytime hours. Since all other influential factors were constant, this natural experiment provided a unique opportunity to investigate the influence a traffic reduction had on the ambient concentrations of NO_x and NO_2 at this location.

2. Methodology
Gillygate is a heavily trafficked street in the city centre of York. The street is located to the north of the city, close to where the A19 arterial route meets the inner ring road (see figure 1). As part of a road resurfacing project around the City of York, Gillygate was closed for part of a two week period from the 31st of October to the 10th November 2005. This closure restricted public access for the majority of the weekdays (the road was actually open from 18:00 till 08:00 daily). The road was also open during the middle weekend (5th and 6th of November). Daily traffic volumes were reduced by 53% over the whole period, whereas during the hours of 08:00 - 18:00, a 91% traffic reduction was achieved (see figure 2). The SCOOT (Split Cycle and Offset Optimisation Technique) traffic system deployed in the Gillygate area provided data regarding the vehicle count for both directions of traffic flow in the street. Simultaneous air pollutant concentrations were also obtained from the permanent monitoring stations at Gillygate (NO_x and NO_2), the urban background location of Bootham (NO_x and NO_2) and the background site of Dunnington (O_3) using standard analysis techniques. Further, meteorological data recorded from a 10 metre mast on campus at the University of York provided wind speed (m/s), wind direction (degrees), temperature (degrees), humidity (percent), rainfall (mm) and pressure (mbars) during this period.

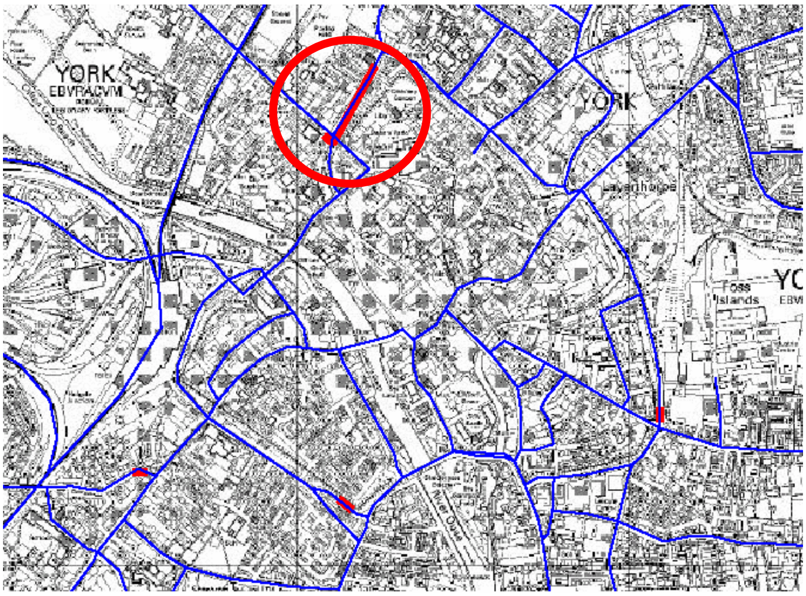

Figure 1: Map of York, UK. Blue lines indicate the major roads in York and the red shaded areas indicate the areas of the city most unlikely to meet the air quality targets. Gillygate is circled. Taken from the City of York Council's website.

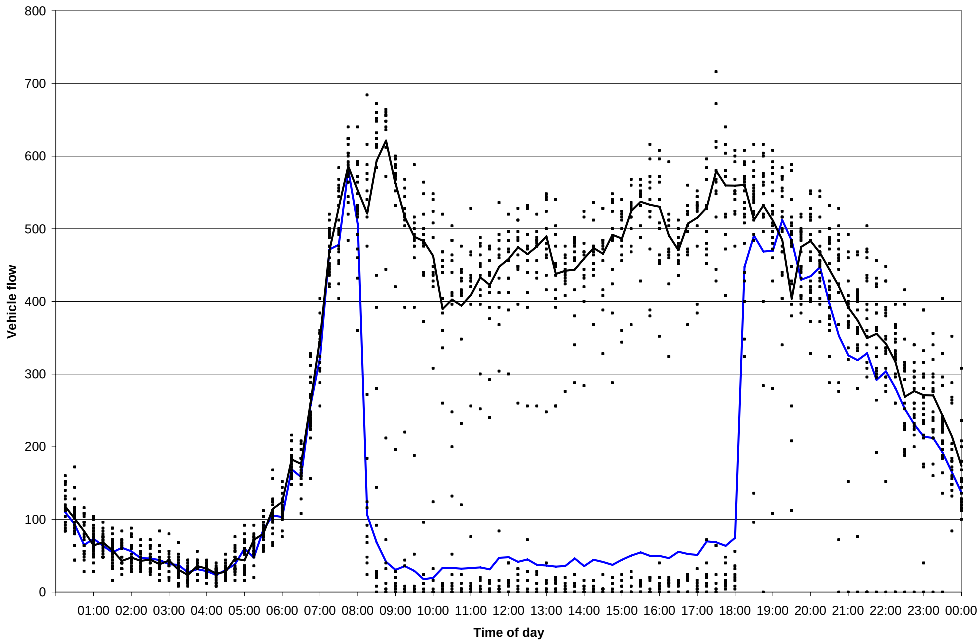

Figure 2: Hourly traffic volume at Gillygate for the first week of the road closure compared to the week prior to the closure. The black solid line indicates the average traffic flow for the week prior to road closure and the blue solid line indicates traffic flow for the road closure week.

3. Results

Generalised additive models (GAMs) were constructed for NO_x and NO_2 with hourly data for the year 2005 using the R programming language. Only hours where data were available for all variables were included in the model construction process. In addition, the period when Gillygate was closed was omitted, thus leaving a total of 7307 data points (83%) for the GAM construction process. The choice of variables was selected using the iterative process outlined in Wood and Augustin (2002) in which variable selection is based around the computationally efficient generalized cross validation (GCV) score. In an effort to capture the complex interaction between wind speed and wind direction these covariates were modelled as an interactive term, (u,v), where u is [wind speed].sin(wind direction) and v is [wind speed].cos(wind direction). The final models took the following form:

$$Log(NO_x) = s_1(bgd\ NO_x) + s_2(u,v) + s_3(flow) + s_4(hour) + s_5(temp) \quad (1)$$
$$Log(NO_2) = s_1(bgd\ NO_x) + s_2(u,v) + s_3(flow) + s_4(hour) + s_5(O_3) + s_6(temp) \quad (2)$$

Where bdg NO_x is the urban background NO_x concentrations measured at Bootham, (u,v) is the interactive wind speed and direction term, flow is the hourly traffic count at Gillygate, temp is the hourly temperature and finally O_3 is the background O_3 concentration for the city of York. Both the final NO_x and NO_2 models explain a respective 80.8% and 78.5% of variance in the observed data. In both cases the background NO_x concentrations were the most significant (in terms of explaining the observed variance), followed closely by the bivariate wind term component (u,v) and traffic flow.

The models (1) and (2) were used to predict the hourly logged concentrations of NO_x and NO_2 as a function of the explanatory variables for the two week road closure. Predicted concentrations were validated against the measured NO_x and NO_2 taken from the chemiluminescence analyser located midway along Gillygate. On average the GAM under-predicted NO_2 concentrations within 7% of the measured. The NO_x GAM however did not perform as well, predicting average concentrations 20% lower than those observed. Further analysis indicated that model performance becomes worse at high concentrations (i.e. those over 40 ppb), for both NO_x and NO_2 predictions, most probably caused by reduced data capture for high concentrations in the model construction dataset.

Further models for NO_x and NO_2 were constructed to simulate ‘normal’ traffic conditions at Gillygate thus providing an indication of the likely pollutant concentrations had the road closure not occurred. Data from previous years were used to construct an average diurnal traffic flow representing road open conditions. The results indicate a dramatic effect on the predicted NO_x and NO_2 concentrations in response to the reduced traffic volume, with both pollutants substantially reduced. The daily average predicted NO_2 concentrations were 20% lower during the road closure compared to ‘normal’ traffic conditions. The few instances where the daytime road open and closed scenarios are extremely similar are most likely a result of the road re-surfacing equipment used by the workmen. Furthermore, during the hour preceding 08:00 (the start of the road closure) the road closed scenario often predicted high concentrations. This phenomenon is most probably caused by a rush of traffic using the street before it is shut and also the arrival of the equipment for the day ahead.

4. Conclusion

We have shown that the statistical technique, generalised additive modelling, can be used to investigate air quality in a busy urban street with relative success. The models developed here predict with confidence the hourly NO_x and NO_2 concentrations at Gillygate, explaining a respective 81% and 79% of the data variability. The model predictions indicate that a road closure of this nature results in a significant reduction in ambient NO_x and NO_2 concentrations at this location and that if traffic volumes of this nature were sustained, the annual NO_2 objective would undoubtedly be achieved. This analysis has therefore promoted the use of traffic management as a worthwhile and effective strategy in terms of NO_2 reduction. However, a reduction in traffic volume seen at Gillygate (91%) is not a feasible solution to the air quality problem in this area. Further analysis into the sensitivity of ambient NO_2 concentrations is needed so as to pinpoint the exact level of traffic reduction needed to achieve the objective.

5. Acknowledgements

The authors gratefully acknowledge the City of York Council for providing SCOOT and air quality data, Pete Turner for providing the meteorological data and finally NERC and the City of York Council for provision of a CASE studentship.

6. References

Aldrin, M., Haff, I.H. 2005. Generalised additive modelling of air pollution, traffic volume and meteorology. Atmospheric Environment. 39, 2145-2155

Air Quality Expert Group (AQEG). 2004. Nitrogen Dioxide in the United Kingdom. Department for Environment, Food and Rural Affairs.

Carslaw, D.C. 2005. Evidence of an increasing NO_2/NO_X emissions ratio from road traffic emissions. Atmospheric Environment, Volume 39, Issue 26: 4793-4802.

Fujita, E.M., Stockwell, W.R., Campbell, D.E., Keislar, R.E. 2003. Evolution of the magnitude and spatial extent of the weekend ozone effect in California's South Coast air basin, 1981-2000. Journal of Air and Waste Management Association, Volume 53, July 2003, Pages 802-815.

Kunzli, N., Kaiser, R., Medina, S., Studnicka, M., Chanel, O., Filliger, P., Herry, M., Horak Jr., F., Puybonnieux-Texier, V., Quenel, P., Schneider, J., Seethaler, R., Vergnaud, J.-C., Sommer, H. 2000. Public-health impact of outdoor and traffic-related air pollution: a European assessment. The Lancet 356, 795–801.

Lonati**,** G., Giugliano, M., Cernuschi, S. 2006. The role of traffic emissions from weekends' and weekdays' fine PM data in Milan. Atmospheric Environment, Volume 40, Issue 31, October 2006, Pages 5998-6011

Paramesh, H. 2002. Epidemiology of asthma in India. Indian Journal of Paediatrics. 69: 309–312.

Pope III, C.A., Thun, M.J., Namboodiri, M.M., Dockery, D.W., Evans, J.S., Speizer, F.E., Heath Jr., C.W. 1995. Particulate air pollution as a predictor of mortality in a prospective study of U.S. adults. American Journal of Respiratory and Critical Care Medicine 151, 669–674.

Reiss, R. 2006. Temporal trends and weekend-weekday differences for benzene and 1,3 butadiene in Houston, Texas. Atmospheric Environment. 40, 4711-4724.

Wood, S.N. and Augustin. N.H., 2002. GAMs with integrated model selection using penalized regression splines and applications to environmental modelling. Ecological Modelling 157(2-3): 157-177