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ACHIEVING THE EU AIR QUALITY LIMIT VALUES - A CITY VIEWPOINT

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ABSTRACT
The city authority in London is doing as much as it can to achieve the EU Limit Values, and national air quality objectives. Some of the measures are outlined here. Measures the Greater London Authority are undertaking to reduce PM_{10} and NO_2 concentrations are set out in the London Mayor's Air Quality Strategy, and London local authorities are generally further advanced than their colleagues in the rest of the UK.

While control efforts in Berlin have resulted in a significant improvement of the air quality within the last decade the Senate Department of Urban Development is currently developing an air pollution abatement plan which will spell out a suite of measures aimed at achieving compliance with the EU Limit Values for fine particulates (PM_{10}) and nitrogen dioxide (NO_2).

However, cities such as London, Berlin and Paris are finding that they cannot achieve them without some further assistance. In many cases, the national authorities and the EU are best placed to give the local authorities tools to increase the effectiveness of local measures. Greater dialogue between different levels of governance will assist in achieving the Limit Values, by informing policy makers at each level of the activities and problems with which each are faced. Cities also need to talk together to share best practice and raise these matters with their national authorities and the international organisations. This paper sets out some of the issues and suggests further measures needed.

INTRODUCTION

The EU has set health-based air quality Limit Values to protect the health of its citizens. There are three reasons why authorities on all levels, i.e. the European institutions, national governments, regional and city governments are to work together and to co-ordinate action to meet these objectives:

- It is a common problem that poor air quality damages health and quality of life, particularly affecting the most vulnerable in society – the very young and the old. High levels of air pollution are known to exacerbate cardiovascular and respiratory diseases, both of which are common causes of death in Europe. This will become increasingly important if, as is predicted, longevity increases in the European countries.

- Setting common environmental standards is more (cost-) effective. The EU has put in place several Directives to assist in meeting these environmental objectives, most notably those on vehicle emissions standards, fuel quality and national emissions ceilings, which have had a significant impact on air quality. Being largely compatible with the EU standards, a similar framework has been put in place in the UN-ECE, notably stimulated by several protocols under the Convention on Long-range Transboundary Air Pollution (CLRTAP). The EU can negotiate much more effectively with large manufacturers than individual member states. National governments have introduced incentives to accelerate the take-up of cleaner vehicle technology and fuels, while in turn manufacturers enjoy the benefits of a larger framework with consistent harmonised environmental standards. Local authorities are taking action including traffic management and cleaning their own vehicle fleets, showing the way for others to follow towards meeting the common objectives.

- Air pollution does not respect administrative boundaries, and a significant proportion of the air pollution problem in many urban areas is caused by pollution blown into that area, often across national frontiers, particularly in the case of ozone and PM_{10}. This highlights the need for international action.

European and national measures have resulted in a significant improvement of the air quality in large parts of Europe. However, there are many areas where meeting the air quality Limit Values requires significantly more action, especially for nitrogen dioxide (NO_2), fine particles (PM_{10}) and ozone. For NO_2 and PM_{10} this is mainly urban areas – where the majority of the EU population live – that have difficulty achieving the Limit Values. High ozone levels are mainly in more rural areas, but caused by emissions from urban or industrial areas[1], but levels are also increasing in urban areas. Ozone concentrations cannot be reduced by local action, but will result from reductions in the emission of other primary pollutants, and so are not discussed further.

There are significant local measures that can be taken, and some examples of the measures being taken by cities are set out in this paper. However, even with these, in cities such as London, Berlin, Paris and smaller cities such as Stockholm, Rotterdam and Munich, local measures are really struggling to meet the EU Limit Values. Although in London and Berlin, local measures are achieving significant reductions in pollution concentrations, there are at present no local measures that could meet the Limit Values. Therefore additional measures at national and international levels are needed. Indeed, in many cases it is these additional tools that are needed in order for measures at the local level to achieve their full impact.

These aspects and a number of emerging issues have been put into a resolution (see Annex) at the end of a city-conference[2] in Berlin in November 2003, which was signed by senior politicians from major cities in Europe. In sending the resolution *inter alia to* the European Commission and the European Parliament, the conference aimed to make the EU aware of the difficulties cities have encountered in meeting the EU air quality standards, and of the requirements at the European level when reviewing the European Directives on air quality and related emission sources. The resolution calls, among other things, for a better consistency between environmental objectives and available measures to control emissions on local, national and European level.

While stressing the major problems in meeting the air quality standards at city level, this paper points to a number of potential areas for action at different levels, in particular on the European level which should help achieving an improved protection of public health from air pollution, and the European air quality standards.

[1] Ozone is a secondary pollutant, caused mainly by reactions of pollutants such as nitrogen oxides and hydrocarbons.
[2] "Metropolitan challenges in noise and air policies: facing new EU regulations at local level", city conference hosted by the Senate of Berlin and funded by the Commission, with representatives from London, Paris, Prague, Rome, Stockholm, Stuttgart and Warsaw. For the resolution and the conference documentation see http://www.stadtentwicklung.berlin.de/umwelt/luftqualitaet/staedtekonferenz/index_en.shtml

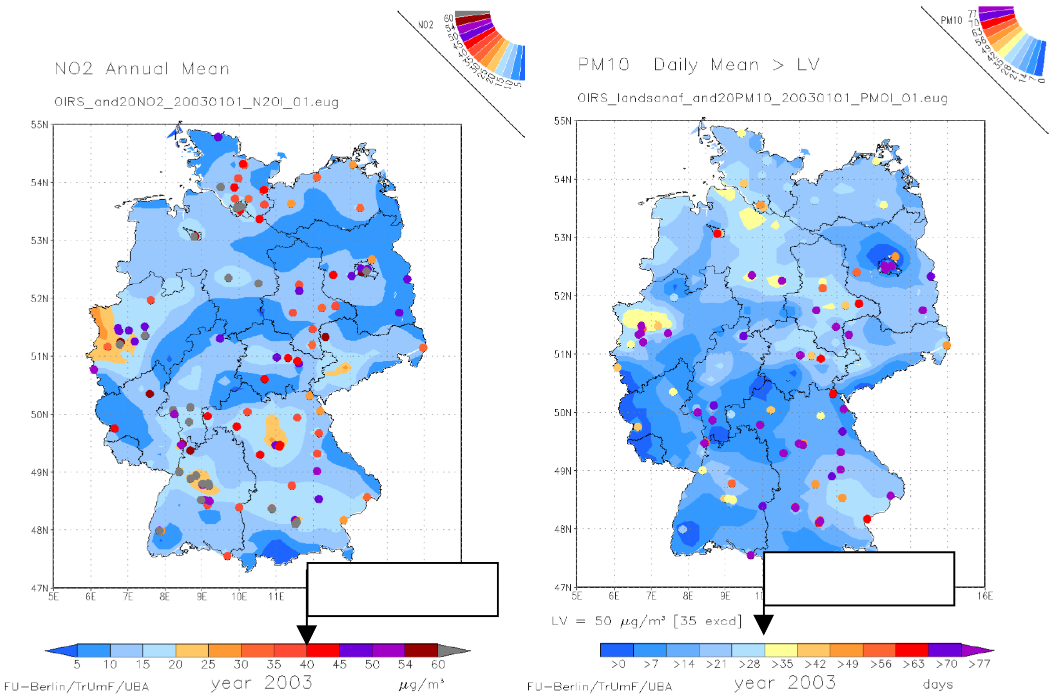
MEETING THE EU LIMIT VALUES

According to the data reported to the EU, PM_{10} concentrations are rather high in relation to the PM_{10} Limit Values for 2005[3] (stage I). In 2001 the PM_{10} Limit Values were exceeded at 34% of the more than 700 monitoring stations in the EU, the majority being in hot spot sites in urban areas. Of the 750 cities where data were reported, 180 cities were in non-compliance with the 24 hour PM_{10} Limit Value. A number of cities, with a total of about 20 million people, have exceedances on more than 45 days at least at one monitoring station[4].

A recent survey in Germany revealed that between 70 and 120 urban areas do not expect to achieve the PM_{10} Limit Values by 2005, unless tangible additional measures are taken. Similar bad news is anticipated for NO_2, where around 70 towns are not expecting to comply with the annual NO_2 Limit Value in 2010. Figure 1 depicts the 2003 distribution of annual NO_2 concentration and of the number of days with exceedances of the 24h PM_{10} Limit Value in Germany, with a larger number of urban hotspots in non-attainment..

Moreover, for PM_{10}, there was a significant increase of regional background PM_{10} concentrations in Germany in 2002 and the first half of 2003, which makes compliance by 2005 harder to achieve than suggested above.
The same gloomy picture emerged from a survey among European cities recently performed by the city of Stockholm. 16 out 25 responding cities said that they encounter serious difficulties in meeting the PM_{10} Limit Values by 2005.

Figure 1. Measured distribution of annual NO_2 concentrations (left) and number of days above 50 μgm^3 daily mean PM_{10} (right) in Germany in 2003. The coloured areas are generated by an "optimal" interpolation of model results and rural and urban background measurements, while the spots depict values recorded at traffic sites.[5]



[3] The EU Limit Values for PM10 is set for 1/1/2005, although in UK legislation it is referred to as 31/12/2004, hence in this paper, the dates will often be referred to as 2004/5.

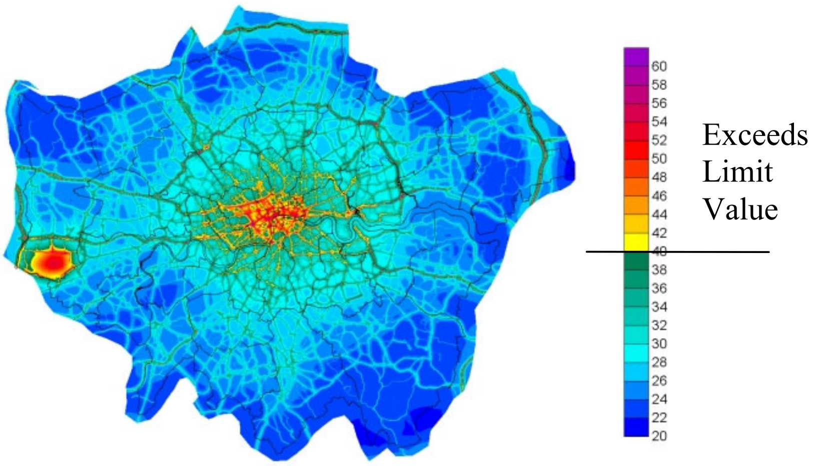
Different parts of the EU find different pollutants harder than others, for example south-eastern England has a much larger secondary PM_{10} contribution than the rest of the UK. In Spain, on the other hand, the contribution from soil erosion, re-suspension and even Sahara dust is quite significant. Northern Italy, with its high population density and resulting economic activity the coincidence of high emissions, surrounding mountains and frequent stagnant weather conditions in winter often leads to records levels of PM10. In the Scandinavian countries, wood burning, winter sanding and road abrasion from the use of studded tyres contribute significantly to the PM_{10} problem.

Different parts of the EU also have different ways of estimating the sources and concentrations, using different emissions factors, or different models and methodologies. However, these do not change the overall conclusions – that the NO_2 and PM_{10} Limit Values will be hard to meet in many urban areas in Europe.

Take **London** as an example. The Greater London area covers 1,600 km^2, and although much of the area will achieve the objectives, significant areas are estimated to exceed the EU Limit Values. These are mainly in central and inner London, near the main roads and around Heathrow airport.

Figure 2 and Figure 3 show modelled maps of the situation in London without further national measures, or the planned local measures for NO_2 and PM_{10} with respect of the EU Limit Values[7] - ie business as usual scenarios. In order to allow for the precautionary principle, weather from a fairly poor year have been used. It should be remembered that weather conditions do affect the PM_{10} situation considerably, and Figure 4 is showing a good weather year for comparison. In terms of scale, it should be noted that the area covered in these maps is 1,600km^2.

Figure 2. Modelled 2010 annual mean NO_2 concentrations in $\mu g/m^3$ (poor weather year[6])



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[4] Taken from the 2nd Position Paper on Particulate Matter by the CAFE ("Clean Air for Europe") Working Group on PM (see http://europa.eu.int/comm/environment/air/cafe/pdf/working_groups/2nd_position_paper_pm.pdf)
[5] Source: Umweltbundesamt (German Environment Agency)
[6] 1997 is used, but weather year does not make as much of a difference for NO_2 as it does for PM_{10}.
[7] A semi-empirical modelling method is used, for more information see the background papers to the Mayor of London's Air Quality Strategy at: http://www.london.gov.uk/mayor/environment/air_quality/research/index.jsp

Figure 3. Modelled 2010 daily mean PM_{10} concentrations, in number of days above the EU Limit Value of 50 µg/m^3 (poor weather year[8])

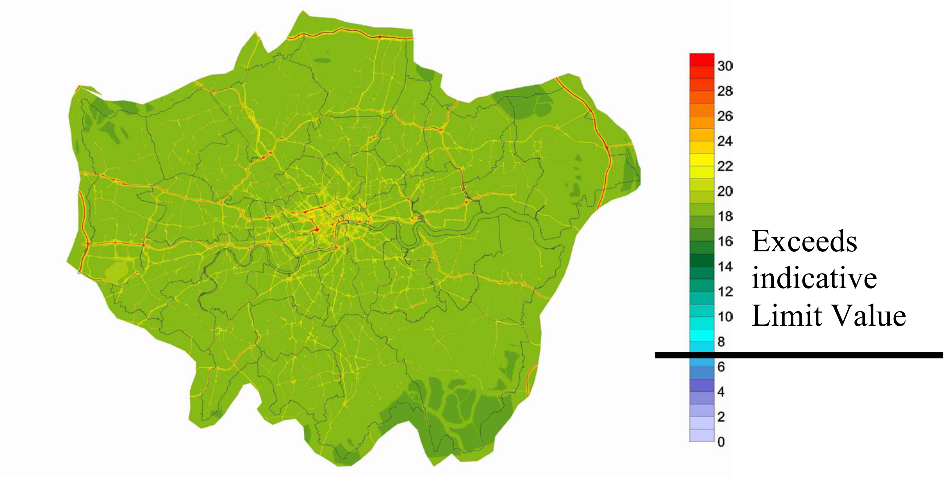


Figure 4. Modelled 2010 daily mean PM_{10} concentrations, in number of days above the EU indicative Limit Value of 50 µg/m^3 (good weather year)

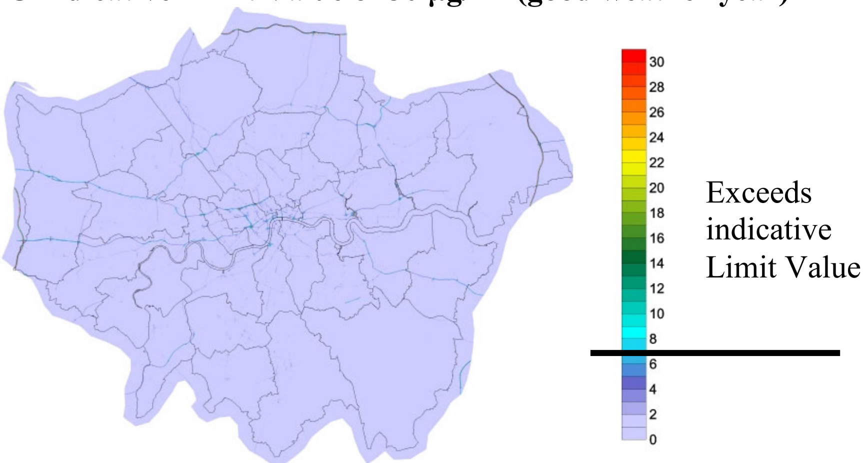
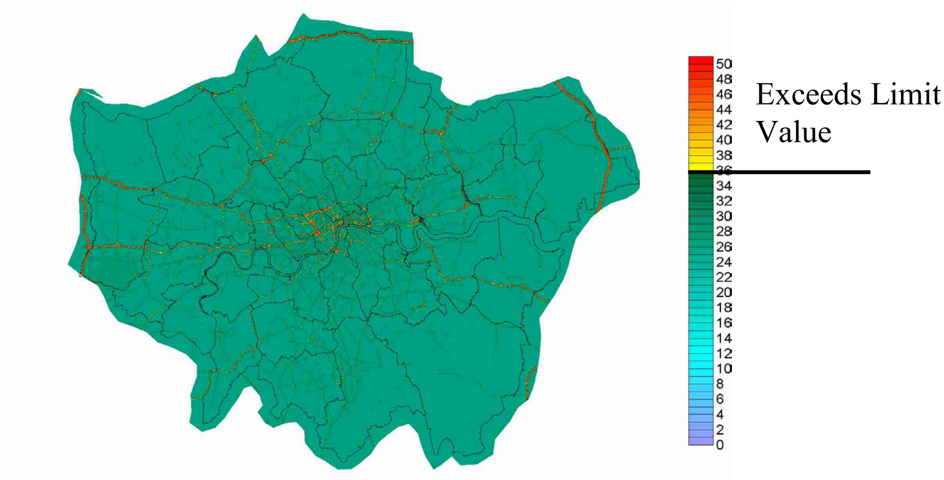


Figure 5. Modelled 2005 daily mean PM_{10} concentrations, in number of days above the EU Limit Value of 50 µg/m^3 (poor weather year[8])



[8] 1996 is used, which was a particularly bad weather year for PM_{10} in the UK.

Figure 5 shows the predicted concentrations for the 2004/5 PM_{10} Limit Value, including the measures within the London Mayor's Air Quality Strategy that are quantifiable[9].

In **Berlin** there is also a problem in achieving the EU Limit Values for NO_2 and, even more seriously, for PM_{10}. The annual NO_2 limit value is exceeded at all traffic sites. Street canyon modelling suggests non-compliance along several hundred kilometres of the main road network in Berlin. As Figure 7 indicates, only a weak downward trend could be observed during the last decade, which has diminished by now. Achieving the 2005 EU Limit Value for PM_{10} is harder for Berlin than London, and the impact of the large-scale background of PM_{10} is greater. Figure 6 illustrates the number of days with daily mean concentrations of more than 50 µg/m³ PM_{10} in 2003. By 2005 this must not be exceeded more than 35 times per calendar year. While in 2001, violation of the 35 days criterion was limited to the three traffic sites, the significant increase in regional PM_{10} background has resulted in non-compliance even in residential areas at the periphery of Berlin in 2003. This problem will be broader discussed later in this paper.

Figure 6. Monitored PM_{10} levels in Berlin in 2003

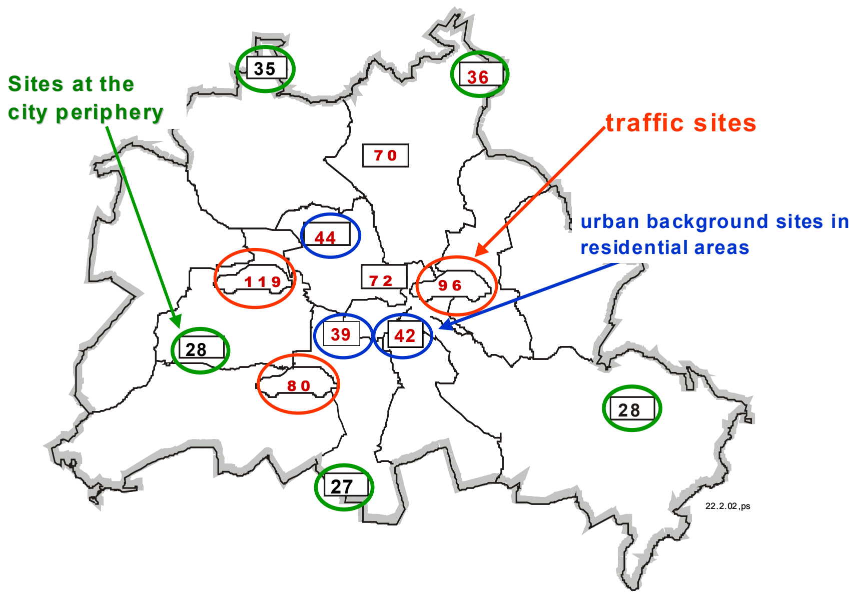
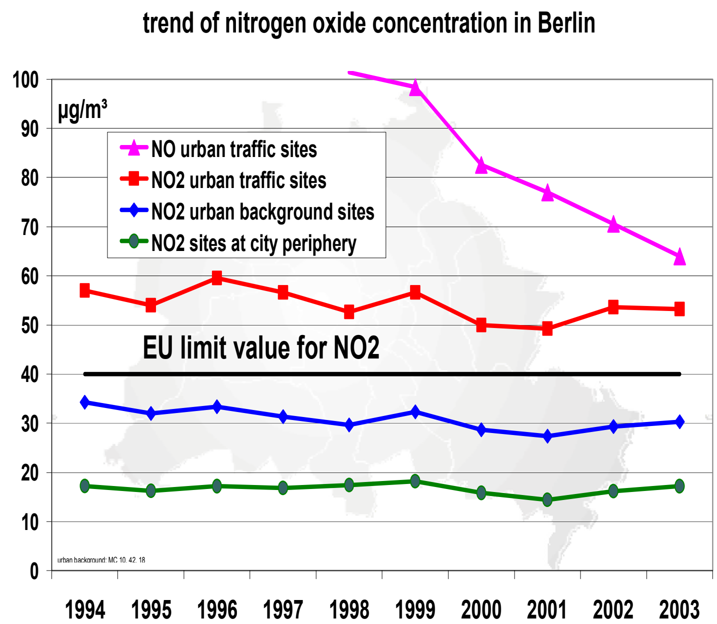


Figure 7. Trend of the annual average nitrogen concentrations at the various locations in Berlin



Projections of a scenario that assumes implementation of measures due to current legislation suggests by

[9] It should be noted that for many of the measures it is not possible to reliably quantify their impact, and only measures that can be reliably quantified have been included in the modelling, which is likely to underestimate the impact of the measures within the Strategy. The business as usual map can be found in the Mayor's air quality strategy on www.london.gov.uk,

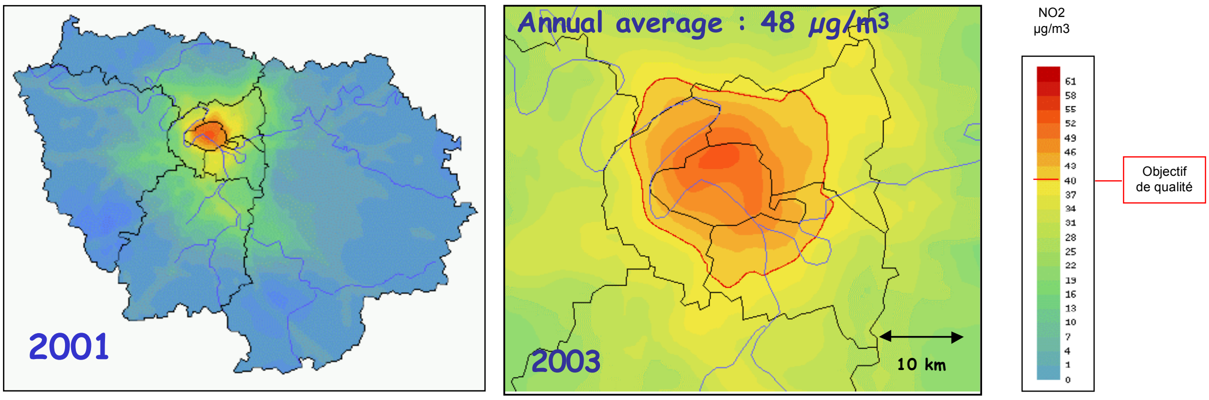
2010 only a moderate decline of the Berlin emissions of PM10 (by 7%) and of NOx (by 21%) in relation to 2002. In combination with a predicted decrease of the regional background PM_{10} an improvement of between 10 and 15% of the 2002 urban background PM_{10} can be expected. The corresponding decrease of NO_2 pollution ranges between 20 and 25%. Similar figures are estimated for the potential decrease of local traffic pollution. Taking into account the estimated reduction of urban and regional background concentration, total PM_{10} and NO_2 levels in the main road network will still be higher than the Limit Values. So, additional measures beyond current legislation are clearly necessary.

In **Paris** the situation is slightly different, and the main pollutants of concern are NO_2, ozone (O_3), and to a lesser extent PM_{10}. The French state regard the EU Limit Values in terms of the margin of tolerance for the year the data is for[10], so the data presented is slightly different to that for Berlin and London. Data given here is for 2003, which was a particularly bad year for air quality in Paris.
The 2005 PM_{10} EU Limit Value, plus the margin of tolerance (daily average 60µg/m^3 with 35 exceedences), was only exceeded at two roadside measurement sites in 2003, and the annual average (43 µg/m^3) was only exceeded at one site.

For NO_2 in 2003 the EU Limit Value, including the margin of tolerance (annual average 54µg/m^3), was exceeded at all the roadside measurement sites, and one of the background sites. The EU Limit Value level alone (annual average of 40µg/m^3) was exceeded at 70% of background sites. The maximum value in 2003 was 103 µg/m^3 on the Periferique ring road. Figure 8 shows modelled concentrations over central and Greater Paris for 2001 and 2003, and as illustrated in Figure 9 there is only a limited downward trend between 1997 and 2002, but a 5 % yearly decrease for NO_2 since 1994, suggesting – as is seen in London and Berlin – that the NO_2 concentration is ozone limited[11].

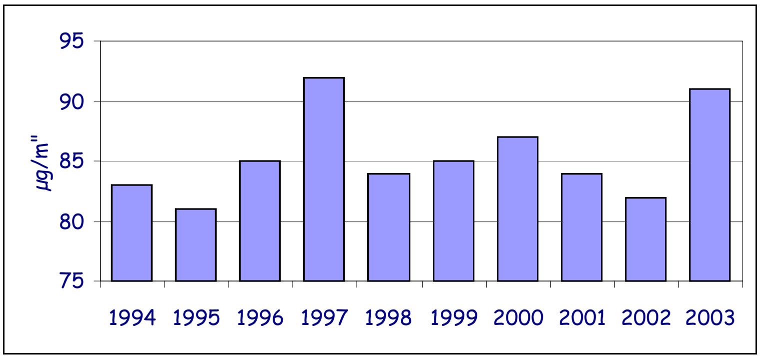
Achieving the EU Limit Value for NO_2 is of concern in Paris. A 50% reduction in NO_x emissions is needed to achieve the EU Limit Values, whereas a 32% reduction is expected from measures already in place. Figure 10 shows the NO_2 modelled for Paris in both 2000 and

Figure 8. Modelled NO_2 concentrations in 2001 for the whole of Paris and 2003 for central Paris



[10] Margin of tolerance are a set of temporary targets set within the EU Directive, for the period between the coming into force of the Directive and the attainment date for the Limit Value. These gradually approach the EU Directive levels. If air pollution exceeds the Limit Values plus the margin of tolerance an abatement plan must be set up within two years, published and sent to the European Commission.
[11] For more information on this, see the Mayor of London's Air Quality Strategy: Appendix A3 – Technical Information at: http://www.london.gov.uk/mayor/strategies/air_quality/index.jsp.

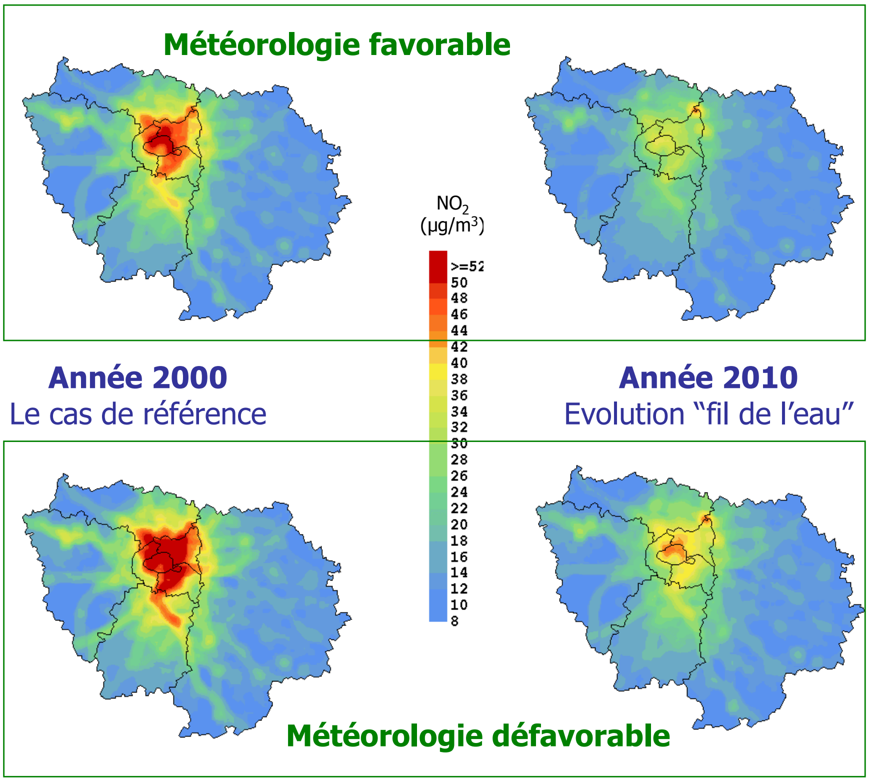
Figure 9. Recent measured NO_2 roadside average in Paris[12]
(Note: the scale on the left starts at 75µg/m^3)



2010, with 'favourable' and 'unfavourable' weather conditions. This shows that with favourable weather conditions, the NO_2 Limit Value is likely to be met in all but a very small part of the Periferique ring road. However a much more significant part of central Paris and the Periferique is likely not to meet the Limit Values under unfavourable weather conditions. Looking at this in terms of the risk of exceeding the EU Limit Values, with a business as usual case in 2010, between 95 to 634 km^2, depending on the weather, has over a 25% risk of exceeding the Limit Values in 2010, with 502km^2 for a weather year like 2003. This compares with the area ranging from 746 to 1007km^2 for the reference case in 2000. While this is a significant reduction, it still leaves a large area at significant risk of not meeting the Limit Values.

The Paris abatement plan, or "Plan de Protection de l'Atmosphère" (PPA), is expected to reduce NO_x emissions by 10.1%, so that in a more favourable year, the area at over a 25% risk of exceeding the Limit Value is limited to 52km^2.

Figure 10. Modelling of NO_2 in Paris for 2000 and business as usual in 2010, with both favorable and unfavorable weather[13]



[12] Based on a fixed number of 5 roadside monitoring stations

Figure 12. Backward-trajectories for an ozone episode in Paris on the 7th August 2003

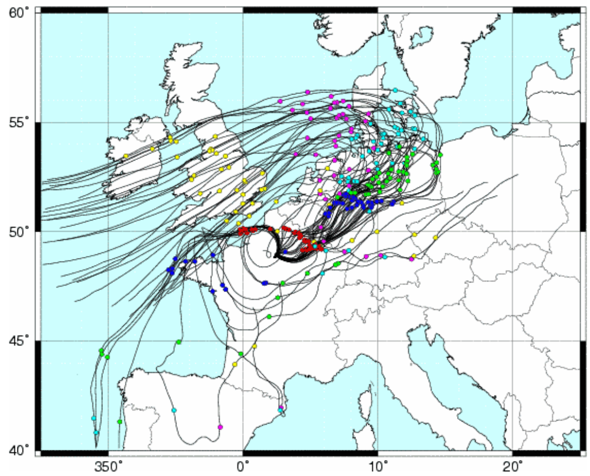
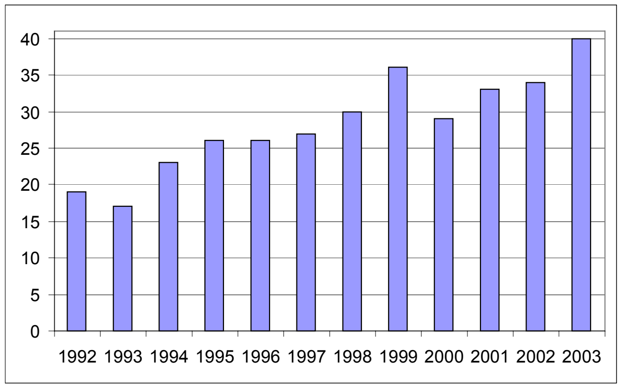
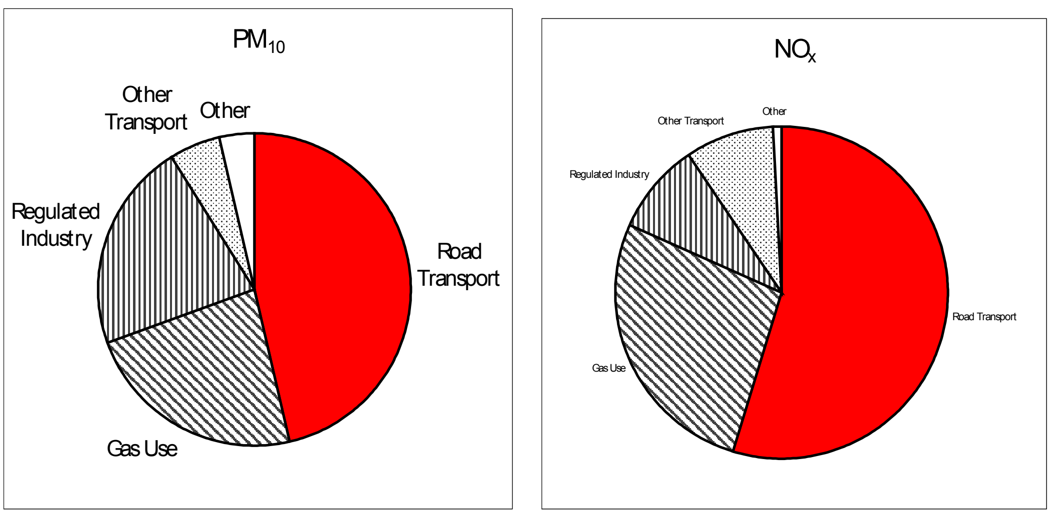


Figure 11. Recent annual average ozone measurements in Paris



The above discussion is all assuming that ozone levels stay constant. With higher ozone cities such as those discussed here, where NO_2 levels are ozone-limited, NO_2 levels are likely to be higher than those discussed here. This is significant, as increasing ozone levels, particularly in the summer is a growing problem for many cities, as Figure 11 shows for Paris. The French national target value of (8 hour average of 110µg/m3) is exceeded between 37 and 91 times a year at different monitoring sites. The French national ozone target is slightly more stringent than the EU Limit Value but required to be met now[14]. However, as with other cities, there is little Paris itself can do about ozone levels due to its secondary nature. For example during an acute ozone episode, 60% to 70% of the ozone concentrations in Paris were of long-range European nature, as shown in Figure 12.

Figure 13. Proportion of emissions of NO_X and PM_{10} from different sources within Greater London in 2001



[13] Translations: Le cas de référence = reference case, Evolution 'fil de l'eau' = business as usual predictions, météorologie = meteorology/weather, favorable = unfavourable, défavorable = unfavourable.

SOURCES OF POLLUTION

In most urban areas the major local source is road traffic. Figure 13 shows the estimated emissions sources in London in 2001 from PM_{10} and NO_x as an example. Figure 14 shows the results of a source apportionment of PM_{10} for Berlin estimated from pollution monitoring data[15] for 2002, and Figure 15 shows a source apportionment estimated through modelling of NO_2.

The proportion of primary emissions of both pollutants being predominantly from road transport is a common theme. However, in other respects the sources of NO_x and PM_{10} differ. For example, more distant sources producing secondary aerosol are very significant for PM_{10}, whereas for NO_2 this is much less so. The main source of emissions in Paris is also road transport, as shown in Figure 16. However, it should be noted that in the case of Paris that the emissions occurring within the city itself, given in Figure 16 below, account for only 10 % of the regional emissions for both PM_{10} and NO_x.

Figure 14. Estimated contribution to PM_{10} at a busy traffic spot from all sources for Berlin in 2002 (also accounting for secondary sources of PM)

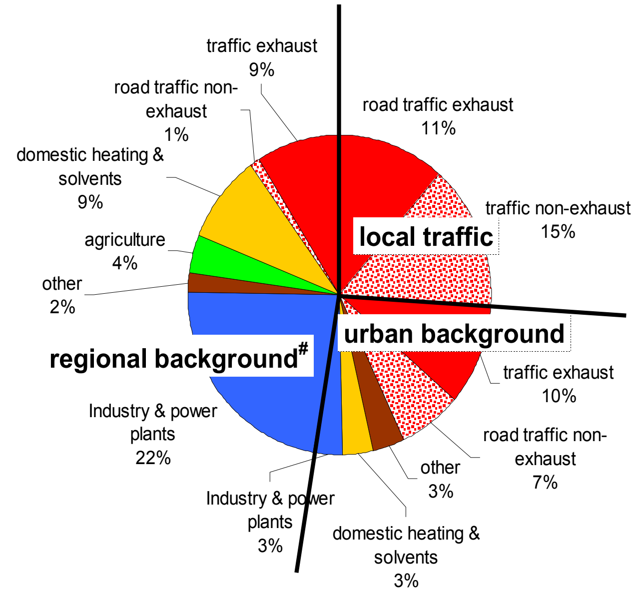
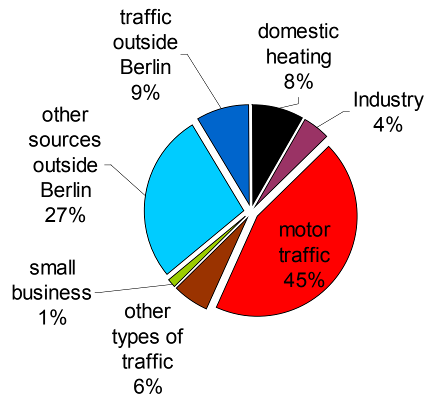


Figure 15. Modelled contribution to NO_2 urban background concentrations from all sources for Berlin in 2002



based on values recorded at the top of a radio tower 324m above ground

NO_2 POLLUTION

For NO_x the main sources other than road traffic are gas combustion and, in particular for London, airport-related emissions. It should be noted that this is purely in emissions terms, and height and temperature of emissions means that sources such as aircraft, gas use and industry usually have less impact on air quality per tonne emitted than ground level emissions such as road transport. Achieving reductions in concentrations of NO_2 through reducing emissions in large urban areas are also limited by the reactions of nitrogen monoxide (NO)

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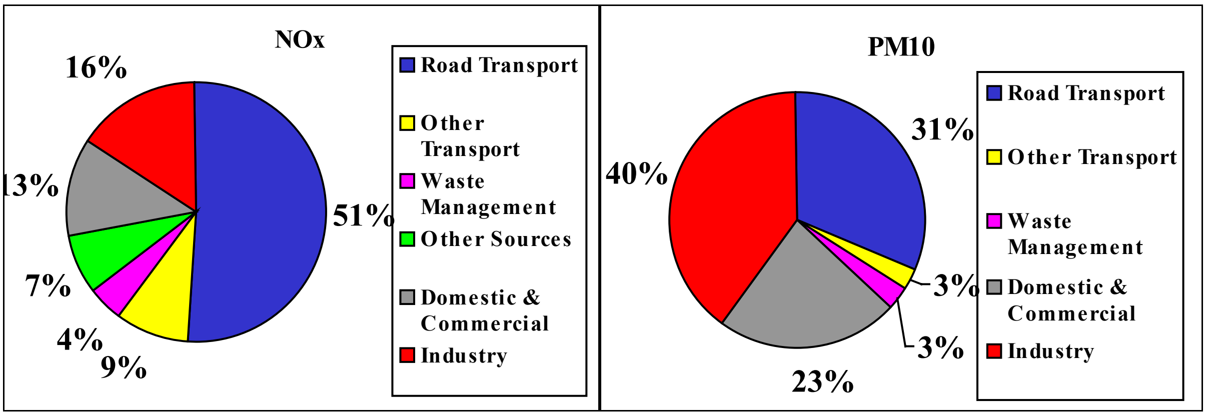
[14] The EU target value, to be met by 2010, is an 8 hour average of 120µg/m^3 not to be exceeded more than 25 days per calendar year, averaged over 3 years

[15] Again noting that different countries and cities use different estimation methods: the Berlin data is a result of a source apportionment exercise based on the evaluation of measured pollution data. So, unlike the emission data from London, it accounts, among other things, for the effect of differing distances between emitter and receptor of industrial stack emissions in comparison to traffic exhaust emissions. It is for the same reason, why aviation does not explicitly appear in Berlin's result, apart from the fact, that air traffic in Berlin is only a fraction of the air traffic around London. Also note that London does not include re-suspended road dust or construction specifically in the emissions inventory, but as a coarse fraction in the air quality modelling.

Figure 16. Proportion of emissions of NO_x and PM_{10} in the City of Paris



and ozone[16]. Figure 7 shows an example for such a differing trend between NO und NO_2 levels. Over the recent years NO_2 at Berlin's traffic stations remained virtually constant while NO levels have gone done by almost 40 %. At the same time mean ozone concentrations at Berlin's monitoring station at the edge of a motorway with more vehicles per day rose by the same ratio. So, while NOx - emissions may have decreased conversion from NO to NO_2 has been accelerated. Another possible factor hampering a decrease in NO_2 – concentrations is the potential shift of the NO/NO_2 – ratio of diesel vehicle emissions towards more NO_2. Regardless of the relative importance of the two NO_2 enhancing factors, European action is needed, because neither the problem of rising mean ozone levels nor any unfavourable change in the NOx-emission characteristic of diesel vehicles can be tackled on a local level.

Gas combustion, one of the main non-transport sources of emissions of NO_2, is already a very clean fuel. In London the substitution of coal by gas for house heating brought a significant reduction of sulphur dioxide and total particulate concentration, but it is the sheer number of buildings using gas that makes it a problem. Heating boilers are often replaced less frequently than vehicles, and the NO_x emissions improvement per boiler replaced is often less. Airport-related emissions occur only at certain locations, and much of these are emitted at height. Airport-related emissions are only an issue for air quality at a few locations, and in fact very few airports, but one of these is Heathrow Airport on the edge of London, within the urban conurbation. Road traffic to and from airports also has as strong an impact on the exposure of people. While ground-based airport emissions can be 'relatively' easily tackled, local airports and nation states have less control over aircraft. International agreements are often constrained by other countries including non-EU member states.

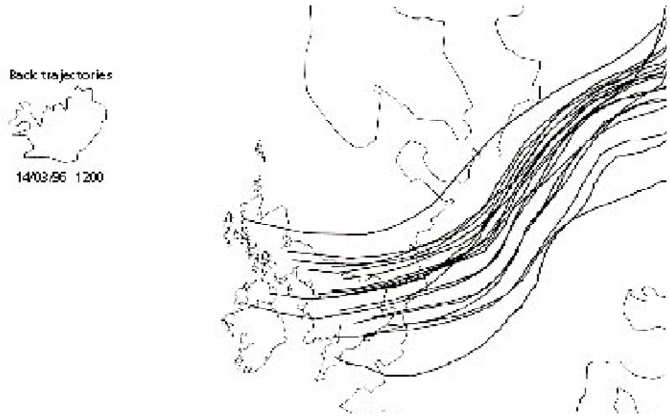
ORIGIN OF PM_{10} POLLUTION

PM_{10} is a particular problem. The indicative EU Limit Value is especially hard to achieve, yet the health research points to particles having by far the greatest health impact, especially the smaller particle fractions. It should also be noted that there are more methodology differences in the emissions estimation, monitoring and modelling of PM_{10}, between the different EU countries, than for NO_2.

The main contributors to PM_{10} other than road traffic exhaust emissions, are precursors of secondary PM_{10} (which are traffic as well as, industry, agriculture and natural sources), re-

[16] Only once a threshold is achieved when NO_2 reduction is no longer ozone limited, will reductions in concentrations be linear with emissions reductions. The rising levels of ozone also limit the ability to achieve these objectives due to the reaction of NO and ozone which in turn produces NO_2.

Figure 17. Long-range transport of PM_{10}[17]



suspended road dust, construction dust, gas use and annual bonfire or firework events. Re-suspended road dust is especially variable around the EU, from Sweden, with its studded tyres and very high levels, to the UK that at present assumes low contributions. As Figure 14 indicates, non-exhaust emissions make up almost half of what Berlin's transport sector contributes to the PM_{10} pollution at the roadside measurement sites. Unlike the traffic exhaust emissions, this coarse part of the PM_{10} load cannot be tackled by improving vehicles emissions. Whether enhanced road sweeping could be a solution is currently being investigated in Berlin. Preliminary results have not revealed a tangible effect, similar to recent studies in Stockholm.

With regard to the problem of a high-level regional PM background, many other cities are similar to Berlin, with a significant contribution from secondary PM_{10} sources. London, Berlin and Paris all have around one third of their PM_{10} concentrations coming from sources outside the city[18], although this varies significantly from year to year and seems to be higher in those parts of Europe with a more continental climate. The secondary PM_{10} is often brought in from a particular wind direction. This long-range transportation of particles for the UK is illustrated by Figure 17. In both London and Berlin this is greatest in years with winds predominantly from the south-east, such as during London's particularly poor year for PM_{10} in 1996 and in a number of recent episodes with elevated PM_{10} levels covering whole eastern Germany.

Figure 18 below indicates this recent upward trend in the PM_{10} levels in Berlin. The two bottom trend lines reflect the PM_{10} concentrations recorded rural sites outside Berlin and at the city boundary stations. It can be seen that the upward trend in the PM load originating from areas outside Berlin triggered a similar increase of the urban PM_{10} background (the line with circle markers) and the PM_{10} load measured at traffic sites (the line with square markers). Hence, the worsening of the PM_{10} situation in Berlin between 2001 and 2003 is largely due to regional scale transport of particulate matter, which is a major obstacle to the achievement of the Limit Values by 2005 (and even more so for the indicative 2010 standard). This conclusion is supported by the downward trend of black carbon concentration (line with triangles) recorded at kerb sites stations in the city, which would not have been observed if the surge in PM_{10} were of local origin.

As mentioned above, PM_{10}, with its large secondary component is significantly affected by the weather, and some years can be much worse than others (see Figure 3 and Figure 4 above for London). Whether the recent surge in the regional PM_{10} background around Berlin is primarily due to poor weather conditions or imported emissions is difficult to substantiate.

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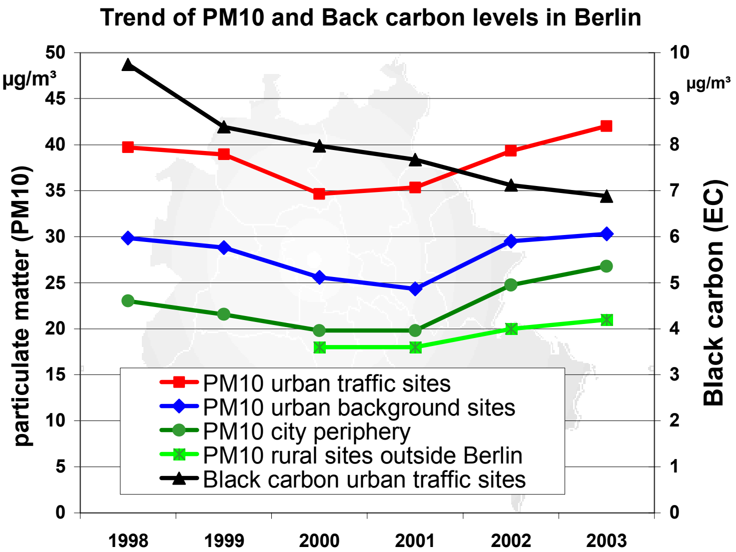
[17] Source: UK DEFRA

[18] For London see the Mayor of London's Air Quality Strategy, and for the other cities from workshops at an environment conference held in London in July 2001 with London, Paris, Berlin and Moscow, and the proceedings of the city conference in Berlin in November 2003 (see http://www.stadtentwicklung.berlin.de/umwelt/luftqualitaet/staedtekonferenz/index_en.shtml)

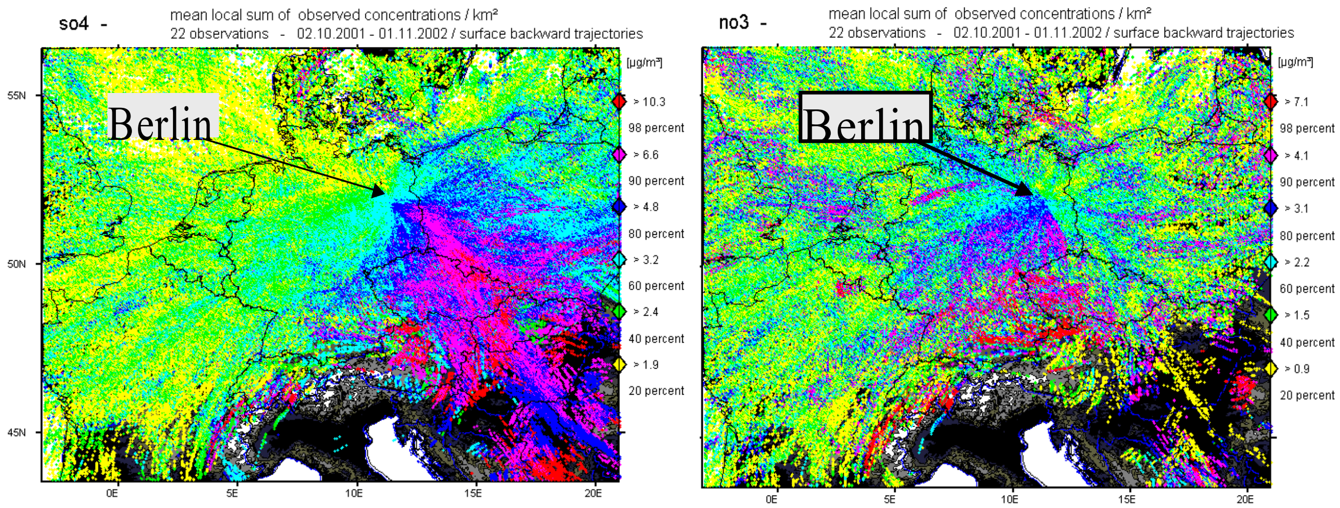
Figure 18. Recent trend of the annual average PM_{10} and NO_2 concentrations at the periphery, urban background and traffic hot spot locations in Berlin



However, a recent evaluation[19] of PM-episodes[20] in Germany, revealed that meteorology favouring accumulation and large-scale transport of atmospheric aerosol, such as those with low mixing height combined with moderate (south-)easterly winds and continental air masses, occurred much more frequent in 2002 and the first half of 2003 than in the years before. The worst example was a four-week episode in February 2003 which contributed to already half of the 35 days of allowed exceedances of the 50 µg/m³ PM_{10} threshold in north and eastern Germany. The following hot and dry summer acerbated this year's results of the highest PM_{10} concentrations for more than 5 years. However, in the second half of 2003 and the first half of 2004 meteorological conditions were less stagnant and dominated by easterly winds so that PM_{10} pollution has now dropped to the levels comparable with those in 2001.

This long-range transport was also modelled in Berlin using a statistics of 3-dimensional backward trajectories (Figure 19). Surface layer contacts of all trajectories are added up in a 1x1 km² grid over one year. For every grid cell concentrations of particulate matter or PM species measured in Berlin at the time of the arrival of each trajectory are stored and

Figure 19: Spatial distribution of potential source areas for sulphate (left) and nitrate (right) aerosol imported into the Greater Berlin area based on backward trajectory calculations[21]



[19] Source Umweltbundesamt (German Environment Agency)

[20] an episode has been defined as a situation with more than 10% of all German monitoring sites recording more than 50 µg/m³ PM_{10} on at least 2 consecutive days

eventually averaged over all those trajectories which met the surface layer in the said grid. As an example, the area in Figure 19 (left) appearing in red colours has been touched by all those trajectories which arrived in Berlin at a time when relatively high sulphate concentrations (i.e. more then 6.6 µg/m³ SO_4 which is the 90th percentile of the whole annual series) had been measured in the sampled PM_{10}. So, the red area gives an indication of the spatial distribution of the main sources for secondary sulphate aerosol imported into the Berlin area. It coincides well with the industrialised region in Southern Poland and in Slovakia where emissions of sulphur dioxide from industry and power plants are still relatively high. The spatial distribution for nitrate aerosol sources (right map in Figure 19) is quite different. Given the high traffic volume in Germany and the subsequent nitrogen oxide emissions the high nitrate levels in Berlin come from within Germany. This highlights the need for stricter control of industrial sulphur emissions in the new Member States, as well as of NO_x road transport emissions within Germany to reduce the imported secondary inorganic component of PM_{10} in north eastern Germany. Both measures cannot be pursued on a local level but rather by national and European activity.

Another example of quite how important it is to co-operate on reducing pollution is illustrated by modelling in the Netherlands that estimates that of the total 16.4µg/m^3 of anthropogenic PM_{10}, only a third came from the Netherlands and the rest from other countries. Table 1 shows this in more detail, with the annually averaged primary and secondary inorganic concentrations of PM_{10} for the Netherlands by source.

Table 1 Sources of PM_{10} in the Netherlands (based on 1995 emissions)[22]

Dutch sources	Primary PM_{10} (µg/m^3)	NH_x (µg/m^3)	NO_y (µg/m^3)	SO_x (µg/m^3)	Summed concentration (µg/m^3)
Industry	0.4	0.0	0.1	0.1	0.6
Energy	0.0	0.0	0.1	0.1	0.2
Transport [1)]	1.5	0.0	1.0	0.1	2.6
Agriculture	0.5	0.9	0.0	0.0	1.4
Others	0.5	0.1	0.1	0.0	0.7
Total	**2.9**	**1.0**	**1.4**	**0.2**	**5.5**
Other countries					
Industry	0.9	0.0	0.1	0.1	1.0
Energy	0.4	0.0	0.7	1.9	3.0
Transport [1)]	0.9	0.0	2.1	0.3	3.3
Agriculture	0.1	1.2	0.0	0.0	1.4
Others	0.7	0.0	0.5	1.1	2.3
Total	**3.0**	**1.2**	**3.3**	**3.4**	**10.9**
All sources					
All anthropogenic sources	**6.0**	**2.2**	**4.6**	**3.6**	**16.5**
Non-modelled other sources[2]					**18**
All sources					**34.5**

1) Including international shipping
2) Non-modelled part of the PM (18 µg/m3): sea salt, crystal and biogenous material and the northern hemisphere background.

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[21] Source: Reimer, E., Free University Berlin, 2004
[22] Source: RIVM report of the Netherlands Aerosol Programme "On health risks of ambient PM in the Netherlands", October 2002, RIVM report 650010 033. Editors: Eltjo Buringh and Antoon Opperhuizen

LOCAL ACTION IN EU MEMBER STATES

Different member states are at different stages in their work towards meeting the EU Limit Values. This section describes by example measures taken forward by London, Berlin and Paris

London has produced its first London-wide air quality strategy, combining national and local measures considered necessary to achieve the Limit Values. The Mayor of London's Air Quality Strategy focuses on road traffic – both the largest source, and both where the most impact can be made and the Mayor has most powers. The air quality strategy links together with the transport, land use planning, noise, energy and other Mayoral strategies[23]. The transport and land use planning strategies take forward traffic reduction measures, and the air quality strategy concentrates on the cleaner vehicle issues. These all work together with UK national measures such as giving fuel duty concessions, tax incentives and grants for alternative fuelled or retrofitted vehicles.

Measures in the Mayor of London's (2002) air quality strategy include:

- cleaning the public vehicle fleets – these include buses (minimum of Euro II and particle trap by 2005, water diesel emulsion, selective catalytic reduction (SCR) and exhaust gas re-circulation (EGR) trials); taxis (introducing their first emissions standards), fire engines and police vehicles
- specific guidance for the 33 London local authorities to clean their vehicles and undertake other measures to reduce pollution, which is raising the standard of local action
- traffic reduction – aiming for a 15% reduction in traffic in central London, reducing the growth in traffic to zero in inner London, and halving the growth in outer London, through measures including the central London Congestion Charging scheme
- encouraging businesses to clean their vehicles by facilitating the uptake of government grants, and providing objective information on how operators can clean their fleets
- roadside testing of vehicle emissions
- using the planning system to reduce the impact of new developments
- incentives through the central London Congestion Charge scheme for the very cleanest alternatively fuelled vehicles
- feasibility study into a London low emission zone (LEZ).

An Low Emission Zone (LEZ) is an area from which older, more polluting vehicles are excluded, thereby increasing the proportion of cleaner vehicles in the area. The London Mayor is intending to introduce a Low Emission Zone by 2007 aimed at lorries, buses, coaches and taxis, covering the whole of Greater London. The London LEZ feasibility study reported in July 2003[24], and concluded that a LEZ would significantly reduce air quality exceedences. It recommended that the LEZ standard should be set at Euro II plus particulate trap (or equivalent) for lorries, buses and coaches, and would get more stringent in 2010.

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[23] More information on all of these can be found on www.london.gov.uk, and following prompts for the Mayor's publications, then strategies.

[24] Further information on this study completed can be found on www.london-lez.org, further information on the Mayor's announcements can be found on www.london.gov.uk. Also covered by another paper given at this conference.

Berlin is in the process of updating its local air pollution abatement plans. At the same time, noise mitigation plans are being developed in three districts. Measures already in place in Berlin include:

- substitution of coal by gas, oil and district-heating for house heating purposes
- industry is to apply best available technology, e.g. de-NOx equipment on all power plants and larger industrial installations.
- particle filters for all public buses
- investment in a network of refuelling stations for compressed natural gas (CNG)
- grants for enhanced use of CNG-vehicles for taxis and driving schools
- similar programme for light duty vehicles and heavy duty vehicles powered by CNG
- containment of traffic flows by huge investment in public transport

A recently adopted transport development plan aims to reduce motor traffic flows in the city centre, *inter alia* by

- considerably enlarging the area with parking fees in several city centre districts
- re-routeing through traffic in the city centre on tangential roads
- extension of the tram network
- enhanced investment in cycling infrastructure

Additional measures are being considered, like

- the setting of tighter environmental standards for public bus services and the municipal vehicle fleet
- optimised traffic management aimed to ameliorate air and noise pollution in sensitive areas

Options for additional action are being investigated covering

- variants of a LEZ for diesel vehicles, which would reward vehicles with particle traps and lower NOx emissions
- enhanced street cleaning, in order to reduce re-suspension of road dust

The Federal Government pledged to introduce a tax discount for diesel cars equipped or retrofitted with a particle trap.

In France, air quality management has not been devolved at a local level, as it has in many other EU countries. The Atmospheric Protection Plans (PPA) are produced and implemented by national government, and their local administrators - and ***not*** by the cities and local authorities. The **Paris** PPA is behind schedule and was published in mid-2004, following public consultation. Decentralisation is an issue being pursued by the Paris authorities with the national Government to try to improve this.

While a 50% reduction in NO_x emissions is needed to meet the EU Limit Values in Paris, only 33% is expected from the measures currently in place. The PPA is estimated to reduce emissions by around 10%, and includes

- tighter controls on factories and industry
- low-NOx boilers introduced on all individual boilers replaced between 2000 and 2010,
- requiring all petrol stations over $1000m^3$/year to have vapour recovery on the pumps
- between 2000 and 2010 a reduction of 30% of emissions from diesel vehicles in the Ile-de-France by traffic management - includes introducing bus lanes and car free day
- reduce traffic through urban planning

Measures already in place include:

- measures to keep emissions from airports static, and;
- replacing the engines of 30 of the diesel trains
- speeding the replacement of better technology in the vehicles by 11%,
- replacing the kilometres at present travelled in slow utility vehicles and road maintenance vehicles by motorised two wheeled vehicles,
- use of water diesel emulsion in the city's buses.

EFFECTS OF LOCAL MEASURES

The impact of local measures are limited by the tools and funding streams provided by the EU and national governments and, by the affect of the large-scale PM background in Europe. Without the EU introducing the ‘Euro Standards’ and the cleaner, lower sulphur fuel Directives, the massive reduction in vehicle emissions would not have been possible. Government tax and duty incentives, as well as grants, reduce the cost of action to reduce emissions, and enable businesses, local authorities and others to adopt the cleaner technology options. It should be noted, however, that economic incentives for innovative vehicle emission control technologies are difficult to set unless the EU framework of emission standards has been adapted to technological progress. So, at least a Commission proposal for tightened vehicle emission standards is needed for national and local authorities to become active in this field.

Businesses, with the exception of a few companies that wish to promote their environmental profile, generally do not undertake measures that add to their costs. Therefore, to get the large majority of the businesses to reduce their emissions (and therefore the large proportion of the emissions reduced), the measures must either be legally required or financially beneficial. Expecting significant take-up of measures that are even cost neutral is optimistic, unless legally required.

Studies in both London and Berlin into Low Emission Zones (LEZs) suggest that this is the most effective measure to achieve air quality improvements. Estimates of the likely effect on PM_{10} traffic emissions of a London LEZ requiring at least EURO II plus particle trap for lorries, buses and coaches in 2007 shows a reduction of 9% from what would occur without intervention. If the zone is tightened in 2010 to a minimum of EURO III plus particulate trap for heavy vehicles, and ten year age limits for vans and taxis, a reduction of 23% from that which would occur without intervention.

However, even with the most ambitious zone, pollution would be reduced but the EU Limit Values would not be achieved. Whilst investigations in London suggest that the relatively new technologies such as selective catalytic reduction (SCR) has an opportunity to improve this situation further, the EU Limit Values will still not be met without further action. Bringing forward the production of Euro IV compliant heavy vehicles and Euro V compliant light vehicles could also have a significant impact[25].

For Berlin and other cities in continental Europe, a tangible reduction in the PM_{10} background needs to be achieved. While the tightening of European vehicle emission standards will achieve some of the reduction needed, additional reductions in secondary aerosols, especially in the accession countries, will be necessary.

[25] Further information on the SCR and Euro standard issues can be found on the Greater London Authority Website, www.london.gov.uk, under Mayor’s publications - environment.

The scope for local measures aimed to achieve the EU Limit Values in many large cities is small – even with 'good' weather. Achieving the value even at a later date will also require action beyond the local level. Achieving the NO_2 and the indicative PM_{10} Limit Values for 2010 will also take further assistance on a wider level.

ISSUES THAT ARE BEING RAISED FOR ACTION AT DIFFERENT LEVELS

As explained above, local action is largely dependent on the tools and incentives provided by EU and national governments. A cost-effective balance between national, EU and local action is needed. Action at a local level to encourage take-up of cleaner vehicle technology is only going to be effective on a significant scale if it is slightly less, or at least no more, expensive to adopt the cleaner option. If the cleaner option is more expensive, then only public organisations and a very few of the most environmentally aware operators will adopt it - unless it is mandated, and many local authorities themselves may struggle to fund these options.

It seems that the EU Limit Values will be harder to meet than was originally expected. One of the reasons for this is that the later 'Euro Standards' are having less impact at low speeds and under stop-start conditions - i.e. in the urban areas where pollution is greatest. The 'Euro standards' are an essential tool in reducing air pollution. Euro I vehicles have made a huge impact. However between Euro II and Euro III the improvement has been far less, particularly for NO_x emissions. Indeed, under some duty cycles, such as for London buses, there is actually an increase in emissions[26]. It appears that manufacturers are meeting the 'Euro Standards' by reducing emissions where it is technically easiest, under steady-state extra-urban conditions, rather than under the more arduous stop-start slow speed conditions of urban areas. This is known as 'cycle-beating'. This means that the later Euro standards are not achieving emissions reductions where they are needed, in urban areas where there is the most problem in meeting the Limit Values. Greatest emissions benefit is being achieved on motorways, where generally fewer people are exposed to the pollution and where the pollution is often dispersed more easily. It is hoped that the Euro IV transient test cycle will help reduce this problem, but this remains to be seen, and needs to be ensured by the European Commission.

Light goods vehicles also account for an increasing proportion of urban emissions, and further Euro emissions standards for these vehicles would make a significant contribution to reducing pollution.

In terms of replacing the vehicle fleet to assist in achieving the EU Limit Values (mainly for 2010), the timing of the introduction of 'Euro Standards' (Euro V start from in late 2008 for light duty vehicles and 2009 for the more important heavy duty vehicles) lags behind what is needed. Encouraging early uptake of Euro V technology particularly for heavy duty vehicles would therefore be very effective in terms of achieving the Limit Values. Low Emission Zones, which the London study concludes could not be introduced before late in 2006 but would then become increasingly stringent, would have more impact if the higher Euro standards could be introduced earlier. An LEZ could be something that would encourage vehicle manufacturers to achieve the standards earlier, as when replacing vehicles, operators would want to buy vehicles that would be compliant for as long as possible. European wide co-operation on this issue would be of great benefit.

[26] This is also discussed in the London Low Emission Zone study available at: http://www.london-lez.org

For PM_{10}, a large proportion of the problem is secondary, over which the local authority has no control and which often limits the effectiveness of action at a local level. Many countries and cities have these same problems, and find that secondary emissions account for around one third of the concentrations (although in some years it is more and some years it is less, as discussed above). It is therefore essential that all Member States take action to reduce the particulate pre-cursors, to enable the Limit Values to be achieved, and improve the effectiveness of local action. While each city reducing its emissions to achieve the Limit Values will contribute to the reductions required, reductions from other areas are also needed. In the absence of a no-effect level for PM any reduction of the regional background level would pay off in reduced health effects, even and in particular in cities.

For $PM_{2.5}$, about which there is increasing health concern and discussion of further EU Limit Values, local transport emissions as well as secondary sources are particularly important. However, when focusing on smaller particles, the question arises whether to put more emphasis on certain PM components with greater health risk, like carbonaceous exhaust particles, in relation to secondary aerosol, like ammonium nitrate, which seems to be less toxic. If so, local action and setting of European emissions standards aimed to control such primary PM components would gain importance in comparison to combat precursors of secondary PM. Hence, this aspect needs more consideration when designing future air pollution control policies, not least because of its implications on the burden sharing between the local level and the European Union or the CLRTAP, respectively.

FURTHER ACTION AT THE EUROPEAN LEVEL

As discussed above, local action by cities will not be sufficient to achieve the EU air quality Limit Values. Additional larger scale measures are needed. It is essential that the Member States play their part in providing these additional measures. However, there are many issues that the individual state has great difficulty to tackle on its own, including actions affecting vehicle manufacturers, oil companies or aircraft, for which the EU and/or UN-ECE is better placed to act, but can only do so with the co-operation from Member States and countries. Whilst not an exhaustive list, some of the issues that cities, countries and the EU could work on together are outlined below. For some of these, discussions are already underway and where this is the case, cities need to be more closely involved and informed. While it may be difficult to achieve, it is important that all efforts possible are undertaken towards achieving the EU Limit Values.

With the automotive industry:

- Further Euro standards, especially for light duty diesel vehicles
- Encouraging manufacturers to produce vehicles meeting Euro IV and V standards earlier, or to ‘leapfrog’ Euro standards as some manufacturers did for Euro III/ IV petrol cars.
- The EU to ensure that transient testing means that emissions reductions are achieved under stop-start and low speed driving conditions, typical of in urban areas, as well as over the total test cycle
- To ensure that technologies are encouraged that reduce CO_2 emissions at the same time as reducing local air pollutants. This could well favour SCR over exhaust gas re-circulation (EGR) as a method of achieving the 2010 Euro standards.
- Encourage manufacturers to produce a greater variety of gas and electric vehicles, especially vans and lorries, together with adequate supporting infrastructure.

With the oil industry:

- Bring forward the introduction of sulphur free vehicle fuels.
- Look to faster introduction of lower sulphur limits for all other fuels, including rail and shipping
- Ensure that incentives designed to encourage the use of biodiesel do not result in negative impacts on local air quality.

With other transport sectors:

- Have an ever more sustainable European transport policy - i.e. more rail freight, and keeping the TEN under review.
- Seek reductions in aircraft emissions, both in terms of each aircraft and to encourage the use of cleaner aircraft. To move towards a technology stretching strategy in the International Civil Aviation Organisation (ICAO) 'Chapters' emissions system as used in the road vehicle 'Euro standards' rather than the present technology following system.

With other industry:

- Encourage or require Best Available Technique (BAT) emissions control in industry
- Further reduce emissions from large combustion plants.

With regulation:

- The Gothenburg protocol and the national emission ceilings Directive (NECD) is a good first step to assist in reducing secondary emissions. To reduce the secondary contribution which is such a great influence on the abilities of many states to achieve the Limit Values, this process needs to continue with further agreements to reduce the secondary PM_{10} pre-cursors by setting lower national emissions ceilings in the NEC Directive
- Avoid long transition periods for new EU member and accession countries meeting emissions standards, NECD ceilings and Euro Standards.
- A draft $PM_{2.5}$ Limit Value to be identified as soon as possible, as action to achieve the $PM_{2.5}$ limit would be different to that for PM_{10}. For example, by placing more emphasis on vehicle tailpipe and secondary sources, and less on re-suspended road dust or quarrying sources.
- Ensure that the regulation aimed at road user charging allows the type of congestion charge implemented in London to be implemented.

In terms of funding:

- Enhance the possibilities for EU Member States to grant economic incentives for users of “green” technology
- Interpretation of state aid and other rules that limit the ability to focus funding at the problem areas
- It should be considered to enhance regional funding for the implementation of environmental legislation, at least for a transitional period.

In terms of research:

- Clarify which pollutants should be tackled in the most cost-effective way in order to maximise health benefits. Where there is a choice, should NO_2, PM_{10} or $PM_{2.5}$, or any toxic PM component be prioritised? Also decide how this should affect present and future policies.

- Achieve greater harmonisation across Europe in assessing the achievement of Limit Values, so the same standards are being achieved. At present different countries - and even areas within countries - often have assessment methods that differ in practice, and lead to different conclusions on attainment.
- At present, it is not clear where the Limit Values are required to be met, eg is it dependent on exposure? The EC should clarify where the Limit Values are to be met.
- Given the need for compliance on a city or even street canyon scale, how can this scale be taken properly into account by the tools used within the Commission's Clean Air for Europe Programme or by the CLRTAP to set the next generation of environmental objectives and the requisite air pollution control strategy for Europe?

Timing of Directives for Limit Values and emissions reduction is also an issue, as is the length of time issues take to resolve at an EU level. Some of these measures have been discussed as possibilities within the review of the EU thematic strategy and CLRTAP protocols, and it is hoped that this will paper will provide a useful input from London, Berlin and Paris to this review. This workshop is part of this process. The cities of London and Berlin would be interested in discussing the topics considered in this paper with other cities, the EU and the CLRTAP[27].

ADDITIONAL ISSUES AT THE NATIONAL LEVEL

While the main focus of this paper is the additional measures at an EU level, it is important to also recognise the national issues that limit city-level action. These issues vary from country to country, and each country needs to find its own answers to these, and other issues. Some of the issues are highlighted below:

- Sufficient funding for local and city authorities adequately to implement emission reduction measures
- Allowing funding and other support to be focused at the problem areas
- Governmental support for EU initiatives and proposals aimed at reducing emissions
- Availability and stability of incentives and grant schemes
- Insufficient delivery of national measures
- Air quality has not always a local issue in all countries
- Pollution imported from other issues within the country
- More joined up Government policies.

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