IMPLICATIONS FOR UK POWER STATIONS OF A MOVE TO A PARTICULATE MATTER STANDARD BASED ON $PM_{2.5}$

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INTRODUCTION

There is a growing consensus that fine particulate matter is more hazardous in relation to heath effects than larger particles and in response, the Clean Air For Europe (CAFE) Working Group on Particulate Matter proposed that $PM_{2.5}$ should be adopted as the principal metric for assessing exposure to particulate. The Second Position Paper on Particulate Matter (*CAFE*, 2004) included recommendations for an annual average standard in the range 12-20μgm^{-3} and a 24-hour 90th percentile standard in the range 20-35μgm^{-3}. The recommendations were subsequently revised to an annual average of 25μgm^{-3} and a 20% reduction in exposure in the proposed Directive on ambient air quality and cleaner air for Europe (*European Commission.*, 2005). Power stations contribute to ambient concentrations of $PM_{2.5}$ through both primary emission of particulate and through emissions of SO_2 and NO_x which are precursor species for secondary particulate matter, however toxicological studies provide little evidence for toxicity associated with the secondary component. This study was undertaken to assess the impact of power station emissions on $PM_{2.5}$ levels relative to both ambient concentrations and the proposed standards using modelled concentrations of $PM_{2.5}$. The implications of the distribution of primary and secondary particulate in the UK are also considered.

SHORT-RANGE MODELLING OF $PM_{2.5}$ EMISSIONS FROM POWER STATIONS

In order to assess the contribution to ground level concentrations due to primary $PM_{2.5}$ emissions from a typical coal-fired station a modelling study was performed using the Atmospheric Dispersion Modelling System, ADMS, for a generic 2000MW power station on full load. The $PM_{2.5}$ release rate assumed the station to be emitting at the maximum permitted dust emission limit of 50mgNm^{-3} with 40% of dust being $PM_{2.5}$. The stack characteristics used are detailed in Table 1 and five years of meteorology were used (2000-2004). The modelling was performed on a 30x30km grid centred on the power station at 1km resolution.

Table 1. Stack parameters used for ADMS modelling study

Stack Height (m)	Flue Diameter (m)	Number of flues	Exit Temperature (°C)	Exit volume flow rate (actual m^{3}s^{-1})	$PM_{2.5}$ emission rate (gs^{-1})
198	6.1	4	130	3039	41.2

The maximum annual average and daily average 90th percentile concentrations at any point in the grid across the five years modelled were 0.041 μgm^{-3} and 0.157 μgm^{-3} respectively, representing less than 1% of the lowest end of the ranges proposed by the CAFE Working Group. Given the assumption that the station operated at full load throughout the year and emitted at its dust emission limit, the assessment is very much a worst case scenario and it can be concluded with confidence that primary UK power station $PM_{2.5}$ emissions will not contribute significantly to ambient concentrations.

LONG-RANGE MODELLING OF $PM_{2.5}$ EMISSIONS FROM POWER STATIONS

Estimating the total contribution from power station emissions to fine particulate concentrations requires the long-range modelling of both the dispersion of the primary component and the atmospheric formation of the secondary component. A study was therefore performed using a UK version of the CMAQ model, developed by the UK power generators' Joint Environmental Programme, which is capable of simulating emissions, meteorology, transport, chemistry and deposition on an hourly basis and includes a detailed treatment of fine particulate matter. Validation studies for particulate matter simulation have been undertaken confirming that the model is able to simulate concentrations in reasonable agreement with measured data (*Griffiths, S.J. et al.*, 2005, *Cocks, A. et al.*, 2003, *Brooke*, D., 2003).

The model was run for a two week period in January 1999 and a two week period in July 1999 to assess the regional contribution from UK power stations to winter and summer levels of $PM_{2.5}$. Emissions data were taken from the EMEP WebDab inventory and the UK National Atmospheric Emissions Inventory. The model was run once incorporating all emission sources and a second time excluding emissions from the UK coal and oil-fired power stations. The difference between the two model runs formed the power station contribution. Model output over Southern Scotland, England and Wales was at 12km resolution.

Table 2 details the contribution from all-sources and from UK coal and oil-fired power stations alone at the locations of the maximum concentration arising from the two sectors. It can be seen that maximum impacts from all sources are well below the proposed $PM_{2.5}$ concentration cap, though above the 12μgm^{-3} lower end of the range proposed by the CAFE Working Group. The UK power station contribution is minimal at the all-source maximum impact relative to both the ambient total and the proposed standards and it is evident that sources other than power stations are driving the high concentrations. It is also evident that even at their maximum point of impact, the UK power stations contribute very low levels of fine particulate. Although power stations make a modest contribution of 5-10% of the ambient concentration, the corresponding all-source contribution is below even the 12μgm^{-3} level and sources other than power stations are clearly still dominating.

Table 2. Maximum modelled $PM_{2.5}$ concentrations in January and July 1999 for all-sources and power stations only

	At location of all source maximum		At location of power stations only maximum	
	January 99	July 99	January 99	July 99
All source contribution (μgm^{-3})	14.5	16.3	9.98	6.74
Power station contribution (μgm^{-3})	0.09	0.33	0.58	0.71
% power station contribution	0.6%	2.0%	5.8%	10.5%
All source as % of 25μgm^{-3} cap	58%	65%	40%	27%
Power stations as % of 25μgm^{-3} cap	0.4%	1.3%	2.3%	2.9%

Figures 1 and 2 show the modelled January primary and secondary $PM_{2.5}$ concentrations arising from UK power stations. It can be seen that the primary concentrations are minimal relative to the secondary concentrations. Secondary $PM_{2.5}$ comprised over 98% of the concentration for both the January and July periods at the point where the power station $PM_{2.5}$ concentration was greatest. It can be seen in Figure 1 that the highest primary concentrations are generated in the Midlands and Yorkshire where a substantial proportion of the UK coal-fired power stations are located. By contrast, secondary concentrations are at a maximum some distance away over East Anglia and in south-west England. Examination of the modelled emissions showed that these areas are associated with high ammonia emissions from farming and that the secondary concentrations were being generated through the interaction of power station plumes with these ammonia sources.

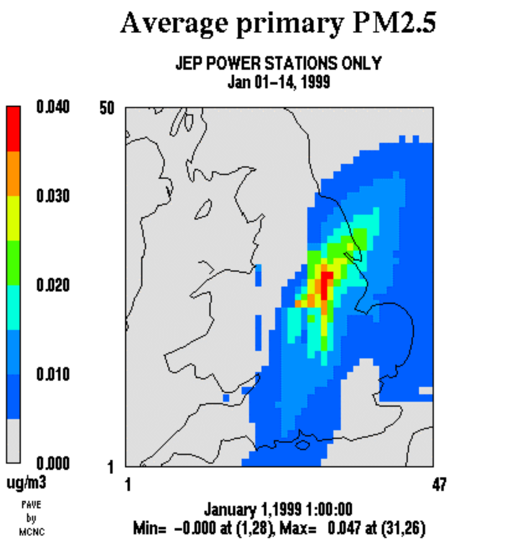

Figure 1. Average modelled primary $PM_{2.5}$ from power stations for January 1999

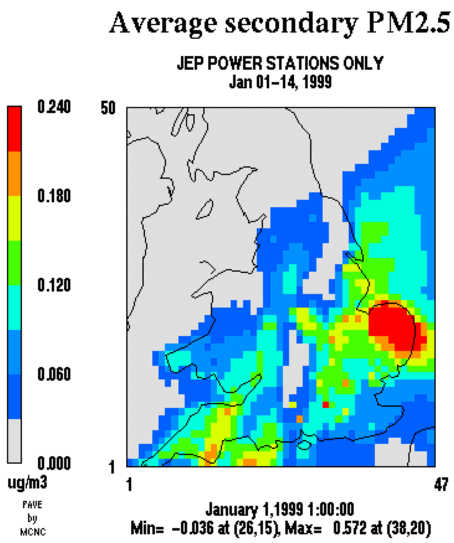

Figure 2. Average modelled secondary $PM_{2.5}$ from power stations for January 1999

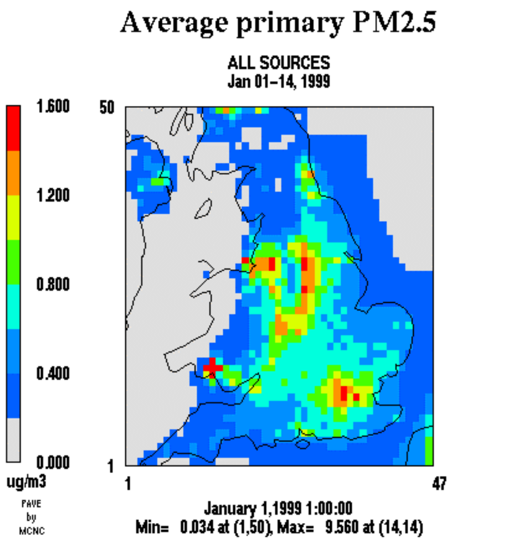

Figure 3. Average modelled primary $PM_{2.5}$ from all sources for January 1999

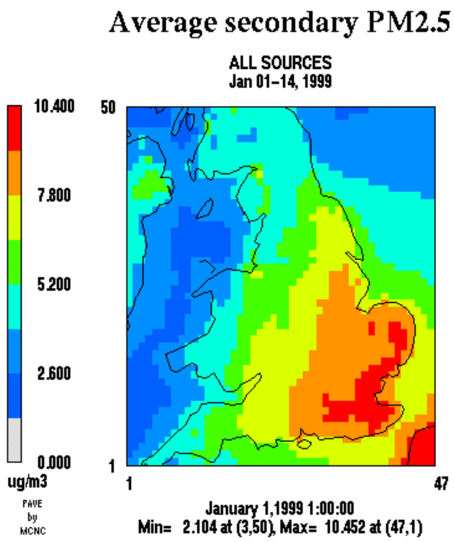

Figure 4. Average modelled secondary $PM_{2.5}$ from all sources for January 1999

Figures 3 and 4 show the January primary and secondary concentrations arising from all sources. It can be seen that secondary concentrations dominate the primary concentrations across the majority of the UK. The primary concentrations are focussed on the major urban and industrial areas, whereas the secondary concentrations are more regional in nature. The concentration decrease from north-west to south-east derives partly from higher pre-cursor emissions around London and lower emissions in Scotland, and partly from the import of secondary $PM_{2.5}$ and its precursors from the European mainland. The difference between the spatial distribution and the absolute concentrations of primary and secondary particulate has important consequences depending on whether the toxic component of particulate matter lies within the primary or the secondary fraction. Whilst there is little evidence for toxicity associated with the soluble inorganic species present in fine particulate (*Schlesinger, R.B. and*

F. Cassee, 2003, *Kelly, F.J, et al,* 2005), the most compelling evidence for particle toxicity lies with species associated with primary emissions, such as metals and insoluble carbon ultrafines (*AQEG*, 2005).

CONTRIBUTION OF EMISSIONS FROM EUROPEAN MAINLAND

Increased concentrations during south-easterly winds are seen at measurement sites across the UK, suggesting that transport of $PM_{2.5}$ from Europe may make a significant contribution to UK concentrations. Both modelling and measurement studies indicate that central mainland Europe does have substantially higher $PM_{2.5}$ concentrations than the UK (*EMEP*, 2003, *Van Dingenen, R.V. et al*, 2004). The results suggest that reducing fine particulate concentrations in the UK may be hampered by concentrations originating in mainland Europe, which would be outside direct control of the UK regulatory agencies. South-easterly wind patterns in the UK are also associated with warm sunny anti-cyclonic conditions when higher rates of pollutant oxidation may lead to elevated levels of fine particulate at ground level.

CONCLUSIONS

This study has assessed the contribution of UK power station emissions to both primary and secondary $PM_{2.5}$ concentrations. Short range modelling of primary $PM_{2.5}$ emissions indicated that even for a power station operating on full load, the impact on local concentrations would be well below 1% of proposed the $PM_{2.5}$ standard. The long range modelling study suggested that emissions from the UK coal and oil-fired power stations make a minimal contribution to regional concentrations of $PM_{2.5}$ when considered against the proposed CAFE standards and only a modest contribution in terms of overall UK fine particulate levels. Secondary particulate showed a very different concentration pattern to primary particulate, the latter being focussed on urban and industrial areas with high populations. This has important implications for population exposure if, as toxicological studies suggest, the toxic component lies predominantly with the primary fraction. Overall, the study suggests that in general, emissions from coal and oil-fired power stations make a minimal contribution to UK concentrations of $PM_{2.5}$. A copy of the full JEP report many be obtained from the author (*Griffiths, S.J. et al*, 2005).

The study demonstrates the benefits of utilising regional scale 'one atmosphere' modelling to address regulatory issues where the maximum impacts may not be localised to the emission source and may be significantly influenced by secondary atmospheric processes.

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