Source Apportionment of Airborne Particulate Matter in the United Kingdom

Prepared on behalf of the
Department of the Environment, Transport
and the Regions, the Welsh Office, the Scottish Office
and the Department of the Environment (Northern Ireland)

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Report of the
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Airborne particulate matter has well recognised adverse effects upon health. Consequently, the UK government has adopted an air quality standard for particles measured as PM_{10}* of 50 micrograms per cubic metre (µg m^{-3}) expressed as a 24 hour running mean (the average of any consecutive 24 hourly measurements at an individual site), and the objective in the National Air Quality Strategy is a 99% compliance of daily maximum running 24 hour means with the air quality standard by 2005. The European Union has recently agreed limit values for PM_{10} of 50 µg m^{-3} measured over fixed 24 hour periods, not to be exceeded more than 35 times per year (equivalent to a 90th percentile compliance with 50 µg m^{-3}), and an annual average limit value of 40 µg m^{-3}, both to be achieved by the Year 2005. Indicative Stage II limit values have been set at 50 µg m^{-3} not to be exceeded more than seven times per year (equivalent to 98 percentile compliance of 50 µg m^{-3}) and an annual average of 20 µg m^{-3} PM_{10}, to be achieved by January 2010. Currently, there are widespread exceedences of both the UK National Air Quality Strategy objective and the EU Stage I limit values at urban sites across the UK. This report is concerned with identifying the sources of airborne particulate matter and in predicting the future changes in concentrations arising from controls applied to the various source categories.

Airborne particulate matter has both a primary component, which is emitted directly from sources such as road traffic and industry, and a secondary component which is formed in the atmosphere by chemical reactions of gases, most notably sulphur dioxide, oxides of nitrogen and volatile organic compounds. Knowledge of emissions alone provides valuable insights into the sources of primary particles, but gives little insight into the contribution made by secondary particles to airborne concentrations of PM_{10}. The report therefore relies heavily upon receptor modelling techniques which use measurements of the chemical and physical properties of airborne particles to assign them to different source categories. The various receptor modelling methods are consistent in indicating that there are three predominant contributors to PM_{10} mass in the UK atmosphere. These are respectively road traffic, secondary particles (largely sulphates and nitrates, but with a significant organic component in the summer months) and coarse particles arising from a number of sources including resuspension of surface soils and dusts, sea spray and construction activity. National emissions inventories attribute an important proportion of primary particle emissions to road traffic, but a number of other sources including industry and power stations, commercial, institutional and residential combustion, and industrial activities such as mining, quarrying and construction also contribute significantly, the contribution of road traffic becoming proportionately greater as the size of particles considered is reduced. Inventories of urban emissions attribute a relatively greater proportion of primary emissions to road traffic, and city centre concentrations of primary particles are largely explicable in terms of road traffic emissions and coarse particles. Local sources such as construction, quarrying and certain industries can, however, have an appreciable impact at some sites. Projections of future emissions of primary particles are available for the road traffic sector and indicate a reduction of 49% in emissions by 2005 from a 1996 baseline. This reduction will have a marked impact on future PM_{10} concentrations, especially at roadside sites where road traffic can contribute up to 15 µg m^{-3} of PM_{10} above the local background. A very significant proportion of the local elevation is however in the form of coarse particles attributable to resuspension of dusts from the road surface, which are unlikely to benefit from controls on exhaust emissions.

Secondary particles are much more spatially uniform across the UK than primary particles, although there is a general reduction in concentrations moving from a maximum in the south-east to a minimum in the north-west of the British Isles. Numerical models of the atmosphere indicate that both UK and mainland European

**PM_{10}* to a good approximation describes particles smaller than 10 micrometres diameter, determined by mass.*

sources of precursor emissions contribute substantially to secondary PM_{10} and the best estimate of the Group based on the EMEP model is that concentrations of secondary particles will decrease by 30% by 2010 from a 1996 baseline.

The relative contributions of the various source categories to airborne particle concentrations vary substantially on a day-to-day basis. A novel technique has been developed which disaggregates the daily average PM_{10} concentration into three components, a primary combustion-generated component, a secondary component, and "other" particles representing coarse particles as well as some other primary non-combustion emissions. Using data disaggregated in this way, the Group has applied reduction factors from a 1996 baseline to the primary combustion-related and secondary components in order to predict future concentrations. It is assumed that 75% of the primary combustion component is due to road traffic which will decrease by 49% by 2005 and 63% by 2010; the other 25% is assumed to remain constant. The secondary component is assumed to decrease by 19% by 2005 and 30% by 2010. The "other" particle component is assumed to remain constant, although given the considerable number of contributing sources, this assumption is uncertain.

The resultant predictions indicate reductions in annual mean PM_{10} as measured by TEOM monitoring instruments at London Bloomsbury from 28 µg m^{-3} in 1995 to 23 µg m^{-3} in 2005 and at Birmingham Centre from 23 µg m^{-3} in 1995 to 19 µg m^{-3} by 2005. The 99th percentile of daily average concentrations declines from 80 µg m^{-3} to 69 µg m^{-3} at London Bloomsbury and from 77 µg m^{-3} to 65 µg m^{-3} at Birmingham Centre. Higher concentrations would be anticipated in years with adverse meteorology. Thus, on the basis of these predictions, current policy measures will not achieve compliance with the National Air Quality Strategy objective for PM_{10} at urban background locations and further measures will be needed. An additional complication is provided by bonfire night celebrations which often continue over several nights, and can be associated with up to four days exceedences of 50 µg m^{-3} PM_{10}. This number is likely to decrease due to a fall in the primary and secondary particle background upon which the bonfire and firework emissions are superimposed, but bonfire night activities alone will in some years bring PM_{10} concentrations close to exceeding the strategy objective.

Comparison of the UK monitoring data determined with TEOM instruments with the European Union Directive limit values is not straightforward since the EU limits are based upon measurements of PM_{10} by other instrumental techniques which yield higher data. The difference between the methods is typically 10-30% and the Group has therefore taken a conservative approach of increasing the UK TEOM measurements and associated future projections by 30% for comparison with the EU limit values. The results indicate likely compliance with the EU Stage I limit values for 2005 at urban background locations with the possible exception of Central London in years with adverse meteorology. However, predicted concentrations for 2010 based upon currently planned emission reductions exceed the indicative EU Stage II limit values by a considerable margin in urban background locations in most major cities.