LONDON ATMOSPHERIC EMISSIONS INVENTORY

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INTRODUCTION

The London Atmospheric Emissions Inventory (LAEI) is a schedule of the sources of eight key pollutants (oxides of nitrogen, sulphur dioxide, carbon monoxide, non-methane volatile organic compounds, carbon dioxide, benzene, 1,3-butadiene and particulate matter less than 10 micrometres aerodynamic diameter) and three 'subsidiary' pollutants (black smoke, methane and total suspended particulates) within the 32 London boroughs and the City of London as well as parts of 19 districts in the counties of Kent, Surrey, Berkshire, Buckinghamshire, Hertfordshire and Essex, which lie between the M25 motorway and the Greater London boundary. The LAEI covers a total area of 2,466 km^2 with a population of 7.31 million people.

The LAEI includes information on the amount of pollutants released from road traffic and other modes of transport, major industrial sources, and smaller sources throughout the London area, and it is an essential tool in the management of London's local air quality. Whilst measurements of pollutant concentrations in the atmosphere, carried out by many national governments and cities around the world, show the extent of air pollution, the LAEI facilitates the estimation of each pollutant emitted in the London area, and the assessment of the relative significance of the different sources of air pollutants and their geographical distribution. The LAEI also helps in the development of London's air quality improvement strategies.

DEVELOPMENT OF INVENTORIES IN THE UK

Two of the earliest inventories prepared in the UK were for Sheffield [1] and Reading [2]. London's first inventory, of sulphur dioxide (SO_2) emissions, was prepared at the former Greater London Council in 1979 [3]. As part of the UK Government's continuing programme of air pollution studies, the Department for Environment, Food and Rural Affairs (DEFRA) has developed a national inventory of air pollution sources and the type and quantity of the pollutants they emit. This is known as the National Atmospheric Emissions Inventory (NAEI) [4]. The coverage of this inventory has been expanded as emissions of pollutants have grown or as evidence of their adverse effects has accumulated. Initially only emissions of black smoke and SO_2 were estimated but now many more pollutants are covered. The NAEI is maintained for DEFRA by the National Environmental Technology Centre.

Although the first urban atmospheric emissions inventories in the UK had been prepared in the 1960s (see above), it was not until 1994 that the then Department of the Environment (now DEFRA) initiated a comprehensive programme of urban inventory preparation. The first urban inventory to be commissioned was for the West Midlands area covering the city of Birmingham and the adjacent urban areas [5]. This was followed by inventories covering other major urban areas. Concurrently, the former London Research Centre (LRC) also prepared an emissions inventory for the Greater London area with funding from the European Commission and the London local authorities [6]. The primary purpose of all these inventories was to assist the local authorities in managing air quality and particularly in meeting their obligations under the Environment Act 1995 to review air quality within their

areas. Following the creation of the Greater London Authority (GLA) in 2000, the LAEI has moved towards an annual cycle of review and up-dating [7] and it is intended to add additional pollutants in the next cycle of review and up-dating (see below).

EMISSION INVENTORY PROCEDURE

There are two main approaches that can be followed in estimating emissions, which are often referred to as the 'top-down' and the 'bottom-up' approach. The top-down approach means that emission estimates are derived from national data on, for example, the amount of fuel used or the distance travelled by road vehicles. National data is scaled to the area covered by the inventory using some measure of activity thought to be directly or indirectly related to the emissions in the area of study. Population figures and employment statistics are often used. In the alternative bottom-up approach, estimates are made of emissions from individual sources and these are then summed for the inventory area. As far as possible the bottom-up approach has been adopted in compiling the LAEI.

The sources of air pollution emissions included in the LAEI are grouped into:

- **Point emission sources**. These are stationary sources identified individually on the basis of the quantity or nature of their emissions. These are:
  - Part A processes (i.e., large regulated industrial processes);
  - Part B processes (i.e., smaller regulated industrial processes); and
  - Boilers (i.e., large boiler plants).
- **Area emission sources**. These encompass a large number of diverse emission sources - everything from bakeries and breweries to asphalt paving and degreasing operations. They include facilities whose individual emissions do not qualify them as point sources (individually they emit smaller quantities of pollutants) but collectively they can release significant quantities of pollutants. This category also includes those emissions sources for which data does not exist to locate the emissions more precisely. These are:
  - Gas (domestic, industrial and commercial combustion and gas leakage);
  - Oil (domestic, industrial and commercial oil fuel combustion);
  - Coal (domestic, industrial and commercial combustion);
  - Agriculture and natural sources;
  - Sewage treatment; and
  - Solvent use in buildings (e.g., paints and adhesives)
- **Mobile sources**. These are emission sources along a defined line. They include all on-road mobile sources (these are vehicles operated on the streets and highways, such as cars and trucks) and non-road mobile sources (consisting of all vehicles and equipment not routinely operated on streets and highways, as well as trains, ships and aircraft). These are:
  - Road transport;
  - Rail;

- Ship; and
- Airports and aircrafts.

The number of emission sources that are continuously monitored is very small in relation to the total number of sources in London. The majority of emissions must therefore be estimated from other information such as fuel consumption, vehicle kilometres travelled (VKT), or some other measure of activity relating to the

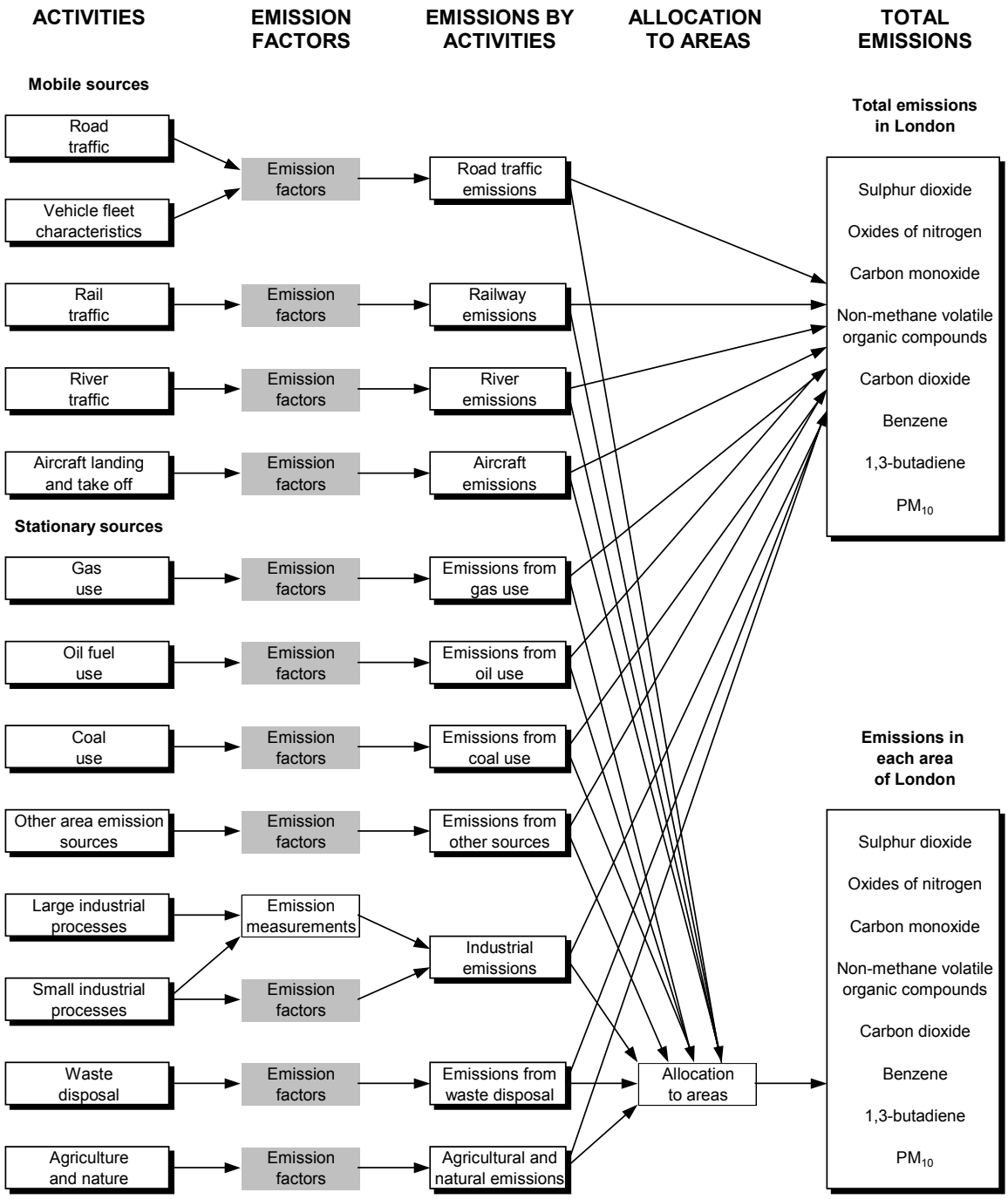

Figure 1 London Atmospheric Emissions Inventory compilation procedure

emissions. Emission factors, derived from the results of the monitoring which has been undertaken, are then applied to the activity data in order to estimate the likely emissions:

$$\text{Activity rate} \times \text{Emission factor} = \text{Emission}$$

The procedure for applying emission factors to information on activities in order to estimate total emissions and emissions by area is illustrated in Figure 1.

For the UK, a great deal of useful information on emission sources, emission factors and procedures is provided on the NAEI website [8]. Further guidance is provided

by DEFRA for local authorities that need to prepare inventories as part of their work under the Environment Act 1995 [9]. Where there is no UK information available, other sources used include:

- EMEP/CORINAIR Atmospheric Emission Inventory Guidebook [10];
- Compilation of Air Pollution Emission Factors, generally known as AP-42 prepared by the US Environmental Protection Agency and many related documents and software available via the CHIEF website [11];
- IPCC Guidelines for National Greenhouse Gas Inventories [12].

When factors developed elsewhere are used, there may be some doubt as to how appropriate they are. One example is dust on road surfaces, which becomes re-suspended as a result of air turbulence caused by passing traffic. Emissions vary with the 'silt loading' of the road surface as well as the average weight and volume of traffic. There is at present very little UK data and the emission factors given in AP-42 result in improbably high emissions when applied in the UK. Work is now being undertaken in London to try to improve our understanding of this source.

ROAD TRAFFIC

There are two primary sources of road traffic data currently in use for preparing urban emission inventories: traffic surveys and transportation models. Information from traffic surveys is attractive because it relates to real traffic on real roads whereas transportation models are a computerised reflection of the actual conditions. However, traffic surveys have the disadvantage that they only provide information relating to the specific survey points. The London traffic model contains a geographical representation of the major roads with approximately 13,000 individual links (discrete sections of road) within and including the M25 orbital motorway. The LAEI uses traffic survey data where this is available (this accounts for the majority of traffic) and model output elsewhere. NAEI emissions factors (see above) are then applied to calculate the emissions from each vehicle type, at each speed, in order to produce an annual total for each road link and for the entire network. These results can be displayed in a variety of ways, such as on a link-by-link basis, or allocated to the individual areas, such as the 1 x 1 kilometre grid squares in which they fall.

Although the traffic model gives relatively complete coverage of the more important roads in London, between 10% and 15% of vehicle-kilometres is driven on the remaining 'minor' roads. These roads tend to be overlooked in traffic surveys, that usually concentrate on the busier parts of the network. London is fortunate, however, to have an alternative source of data, the Rotating Traffic Census undertaken by the Department for Transport, which provides an estimate of total VKT on both major and minor roads. It is possible to subtract the total major road VKT estimated by the traffic model from this total to give a 'residue', which can be considered to be the traffic on the minor roads, and the emissions from these minor roads estimated.

In addition to normal vehicle running, there are additional 'cold start' emissions, which occurs at the start of a trip, and 'hot soak' emission, which occurs at the end of a trip once the vehicle engine has been switched off. When vehicles are first started they take some time for the engine to reach its full operating temperature, and during this 'cold start' period, emissions are substantially higher than normal. Evaporation of hydrocarbons from the engine and fuel system occurs continuously,

both when the vehicle is in use and also when it is parked, but is particularly pronounced when a hot engine is switched off and the heat of the engine promotes evaporation. The geographic distribution of trip starts and ends is derived from the traffic model and used to allocate the 'cold start' and 'hot soak' emission.

EMISSIONS FROM OTHER TRANSPORT MODES

Heathrow Airport is major source of emissions in west London. BAA plc is responsible for preparing an emissions inventory for the airport, which includes:

- emissions occurring within 1,000 metres of the ground as a result of the aircraft landing, taxiing and taking-off as well as engine test and auxiliary power units;
- ground support equipment, including aircraft tractors, aircraft servicing vehicles and baggage handling vehicle;
- road traffic delivering or collecting passengers, baggage and freight, or otherwise serving the airport, car parks and taxi queues;
- stationary sources including the airport heating system.

Shipping is a relatively small source of emissions in London. Nevertheless, emissions from ships and smaller vessels on the River Thames and the London canals are included in the inventory. Railway emissions have not been up-dated since the first LAEI was completed in 1997 and are currently being reviewed.

STATIONARY EMISSION SOURCES

The Pollution Prevention and Control Act 1999 require operators of specified industrial installations to obtain specific authorisation, to monitor the release of pollutants, and to submit information in order to demonstrate compliance with the standards set by the Environment Agency. Information on the actual releases of air pollutants reported to the Agency is used in compiling the point source data for the LAEI and is also available on the Agency's website [13]. Smaller industrial plants, which come under local authority control, are required to obtain specific authorisation and to meet specified emission limits, but they are not at present

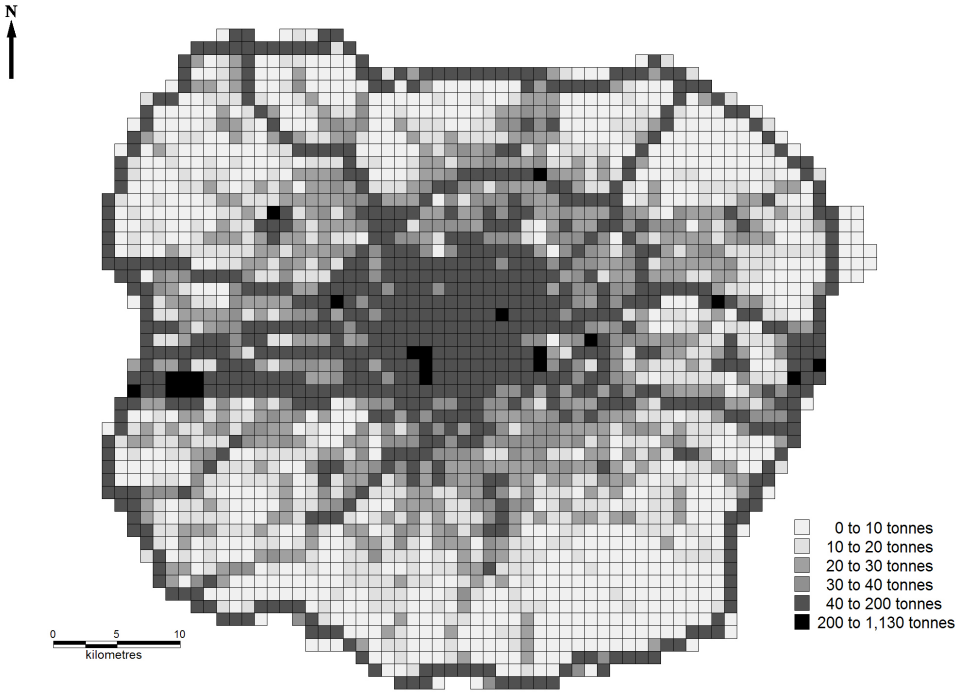

Figure 2 Emissions of oxides of nitrogen in Greater London in 2001

required to report the actual amounts of pollutants released, so emissions factors are used to estimate the emissions from these processes.

FURTHER DEVELOPMENT

In consultation with the LAEI users, the GLA is putting in place a programme for the continued development of the LAEI. Current priorities are to up-date the railway emission estimates, and to include estimates of both resuspended road surface dust and dust from building construction. It is planned to include ammonia in the next LAEI because this is likely to become more important as selective catalytic reduction (SCR) using ammonia or urea is fitted to vehicles to reduce NOX emissions. It is also planned to include polycyclic aromatic hydrocarbons (PAHs), primary NO, and $PM_{2.5}$. In future we plan to synchronise the production of the LAEI more closely with the NAEI. The inventory is at present distributed on CD-ROM but it is hoped that at least summary data can be made available on the GLA website in future.

CONCLUSIONS

The LAEI has undergone significant development since it was first produced in 1997. It is an essential tool for both GLA air quality policy development and London borough air quality work. Nevertheless, it is constantly being improved and developed in response to improvements in our understanding of atmospheric science and evolving concerns over the effects of particular pollutants.

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