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DATA ORGANISATION AND MODELLING EXPERIENCES IN BUDAPEST AIR QUALITY MANAGEMENT

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In the Budapest Air Quality Management System programme the British Atmospheric Dispersion Modelling System (ADMS-Urban) is to be used. The integrated database demanded consists of different emission sources with their co-ordinates, meteorological data and surface data. Special pre-processing is needed in case of traffic emission where a traffic flow model and a set of emission factors are used. In case the number of sources exceeds 1500, a simplified approach is used by 1×1 km grids. A combination of grid and individual source impact assessment is also possible.
As general schemes are known in this field, the presentation puts emphasis on some major methodological considerations especially in data organisation.

Keywords: air quality; dispersion modelling; Budapest case study; emission inventory

Introduction

The Budapest Air Quality Management System is under development. It is supported by a management toolkit consisting of a dispersion model, an integrated database and a digitised map of Budapest. The project is financed by the Municipality, the Ministry of Environment, the National Committee for Technological Development and technical assistance is provided by the British Environmental Know How Fund. The project is co-ordinated by the authors.

The participating institutions from Hungary are as follow: *Institute of Public Health Officer Service (ÁNTSZ), Transport Ltd., NORG Ltd., Clean Air Protection Ltd., Institute of Atmospheric Physics and DASY Ltd.* Two departments are acting on behalf of the Municipality namely that of the Environment Management and Transport Management.

Air Quality Management is intrinsically a multi-disciplinary and holistic activity. Accordingly, a strong and multi-skilled UK team has been assembled for this project: this comprises international experts from *AEA Technology's National Environmental Technology Centre* (NETCEN), together with corresponding specialists from *Cambridge Environmental Research Consultants Ltd.* (CERC) and the *London Research Centre.* [1]

Within the British team the AEA Technology is responsible for the overall project management, and for ensuring that the technical input on monitoring, modelling and inventories is effectively co-ordinated and quality assured. LRC is responsible for ensuring inventory compilation and for inventory linkage to the selected ADMS modelling package. CERC is supplying the advanced ADMS-Urban model to be used in Budapest's Air Quality Management System. It will also adapt and optimise the model to local circumstances and validate using data from the Budapest air monitoring networks.

A conceptual scheme of the system is shown in *Fig.1*. Considering that the ADMS-Urban is the core of the planned toolkit, it is introduced briefly below.

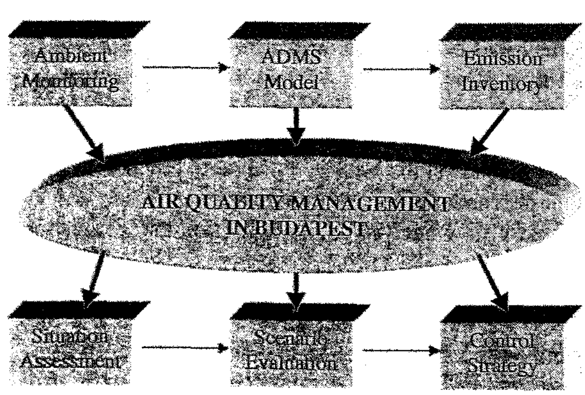

Fig.1 Conceptual Outline of Air Quality Management System in Budapest

Outline of the ADMS-Urban [2,5]

ADMS is an advanced "new generation" dispersion model, using the most up-to-date understanding of boundary layer physics to model dispersion of pollutants for industrial sources, traffic and other sources such as domestic heating. The model incorporates a semi-empirical photochemical scheme for NO_x reactions and links easily to an emissions inventory database.

ADMS-Urban, a version of the Atmospheric Dispersion Modelling System (ADMS), is a PC-based model of dispersion in the atmosphere of pollutants released from industrial, domestic and road traffic sources in urban areas. ADMS-Urban models these using point, line, area and volume source models. It is designed to allow consideration of dispersion problems ranging from the simplest (e.g. a single isolated point source or a single road) to the most complex urban problems (e.g. multiple industrial, domestic and road traffic emissions over a large urban area).

AMDS-Urban can be used as a stand-alone program, or in conjunction with ArcView, ESRI's desktop Geographical Information System (GIS), with which it is fully integrated. It is recommended to use the two programs together, as this allows the user to set-up problems visually using digital map data, CAD drawings and/or aerial photographs, and create output such as contour plots and produce hard-copy presentation layouts.

A significant difference between ADMS-Urban and other models used for air dispersion modelling in urban areas is that ADMS-Urban applies up-to-date physics using parameterisations of the boundary layer structure based on the Monin-Obukhov length, and the boundary layer height. Other models characterise the boundary layer imprecisely in terms of the Pasquill stability parameter. In the up-to-date approach, the boundary layer structure is defined in terms of measurable physical parameters, which allow for a realistic representation of the changing characteristic of dispersion with height. The result is generally a more accurate and soundly based prediction of the concentrations of pollutants.

Some principal features of ADMS-Urban:

- A meteorological pre-processor which calculates the boundary layer parameters from a variety of input data: e.g. wind speed, day, time, cloud cover or, wind speed, surface heat flux and boundary layer height. Meteorological data may be raw, hourly averaged or statistically analysed.
- Advanced dispersion model in which the boundary layer structure is characterised by the height of the boundary layer and the Monin-Obukhov length, a length scale dependent on the friction velocity and the heat flux at the surface.
- A non-Gaussian vertical profile of concentration in convective conditions, which allows for the skewed nature of turbulence within the atmospheric boundary layer that can lead to high surface concentrations near the source.
- An easy to use interactive graphical interface.
- A direct link to an Emissions Inventory database.
- Integration with a commercial GIS.
- An integrated street canyon model.
- The modelling of chemical reactions involving NO, NO_2 and Ozone.
- The calculation of emissions from traffic count data, using a database of emission factors.
- The realistic calculation of flow and dispersion over complex terrain and around buildings.

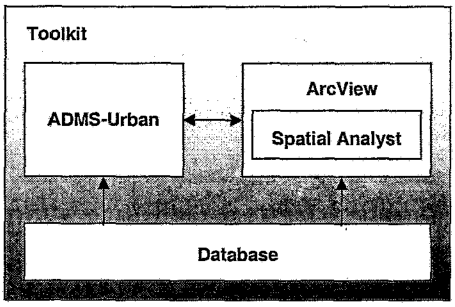

Fig.2 Block diagram of the toolkit

The toolkit to be applied is shown in *Fig.2*.

A pre-requisite to use any numerical modelling as a powerful tool is to compile an appropriate input dataset that is an emissions inventory to the model hence some methodological questions related to emission inventories have to be considered.

Emissions Inventory and Data Pre-Processing [4,5]

There are two sets of data to be used in the model. One is describing the air quality on monitoring, the other is the emissions inventory. While monitoring data show air quality near the given monitoring station, model results can provide more detailed but estimated/calculated data for areas not covered by monitoring stations. Emission inventories form a means by which local sources can be identified and quantified as an input to models providing these "missing" data.

An air pollution emissions inventory is a schedule of the sources of an air pollutant or pollutants within a particular geographical area. The inventory usually includes information on the amount of the pollutant released from major industrial sources, average figures for the emissions from smaller sources, and from transport throughout the area. Emission inventories are an essential tool in the management of local air quality. Whilst monitoring shows the concentration of air pollution, emission inventories identify the sources and help in preparing abatement strategies.

Compilation of an emissions inventory is a complex task involving diverse inputs from many different participating organisations. In case of Budapest these data are provided by authorities (ÁNTSZ, KDV-KF and OMSZ) and calculated by others like Transport Ltd. providing traffic flow data as well.

A complete inventory for a city will need to include emissions from:

- point sources, primarily industrial,
- area sources such as domestic emissions,
- mobile (mostly traffic) sources- sometimes referred to as line sources.

The purpose of an emissions inventory is to quantify and organise data describing emissions from identifiable sources across the *study area.* Such an inventory can then be used: (a) in general terms, to examine the main causes of observed poor air quality and to develop remediation measures, or (b) in a more specific sense as one of the basic inputs to an atmospheric dispersion model, such as the ADMS model being used for the Budapest air quality management system.

For the purpose of air quality management, sources of emissions are typically categorised into the following main types:

- Line or mobile sources – are emissions occurring along line-of-route, primarily from road traffic but also other transport-related sources such as aircraft flight paths, railway lines or shipping routes.
- Point or stationary sources – are emissions occurring at a discrete point in space, typically a factory chimney, and therefore mainly relating to industrial, power generation or incineration activity.
- Diffuse, low-level or area-sources – are emissions arising from low-intensity activities across areas of varying sizes, such as domestic fuel combustion, industrial solvent use, and waste disposal.

Of these listed emissions from mobile sources that means the calculation of line sources is the most critical in the case of urban emission inventories.

The most significant source of emissions for urban pollutants is traffic on major roads. Two primary sources of road traffic data are 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, rather than area wide information. On the other hand, transportation models are available for most of the main urban areas and are comprehensive. (In Budapest the EMME-2 model is used by the Transport Ltd.)

In order to estimate the annual fuel use and emissions along each link and within each grid square, it is necessary to know the proportion of the links within a particular grid square, the link lengths, the annual flows, speed, and the composition of the traffic (heavy goods vehicles, light goods vehicles, buses and cars). The model does not contain all the information required, for example, on the composition of the traffic flows on the individual links in the road network. Traffic surveys carried out in Budapest provide information on four categories of heavy goods vehicles, light goods vehicles, buses and cars. Using these data, a traffic fleet composition can be ascribed to each link in the road network. The proportions of the vehicle fleet within each of these categories, which are petrol, and diesel engines, and the proportion of cars fitted with catalytic converters, are estimated from the vehicle licensing records. The total annual vehicle kilometres travelled for each category of vehicle can then be combined with emission factors in order to calculate the total emissions for each link. These can then be aggregated for each grid square.

In addition to the method outlined above and used in the case of the main roads, minor road traffic has to be considered as well but in a simplified way, namely treating it as area emission sources.

It has to be mentioned here that a line source emission is calculated on the base of the traffic outlined and the vehicle emission factors of the given composition of vehicles.

The emission sources are geocoded, hence an emissions inventory is usually held in a Geographical Information System (GIS), to allow normalisation of the different geographies involved (usually in the form of 1 kilometre grid squares), and to allow easy data retrieval and manipulation. Outputs of the emissions inventory can then be fed into a dispersion model.

Quality Assurance/Quality Control

The quality of the data in the emissions inventory is fundamental to the overall performance of the air quality management system. It is also one of the most difficult elements of the system to compile accurately. This is because of the sheer range of input data required, which is compiled by originators to different levels of space, time and quality (accuracy). It is also a product of the basic methodology used, which relies on the application of emissions factors to some measure of the activity giving rise to the emission (e.g. emissions from domestic combustion would be estimated with reference to statistics of fuel consumption). Some specific reasons constraints to the development of an accurate inventory include [2]:

- Lack of ability to obtain measurement of actual emissions (e.g. it is not possible to monitor every vehicle travelling on the roads) and reliance on secondary or surrogate data (activity data and emissions factor) to arrive at an emissions estimate.
- Use of emissions factors which have a large measure of uncertainty associated with them, either through being based on observations of inappropriate or obsolete technologies or on a small, possibly statistically non-robust, number of observations.
- Short-period measurements being used to estimate long-term averages, such as weekday peak hour traffic flows extrapolated to daily or annual totals.

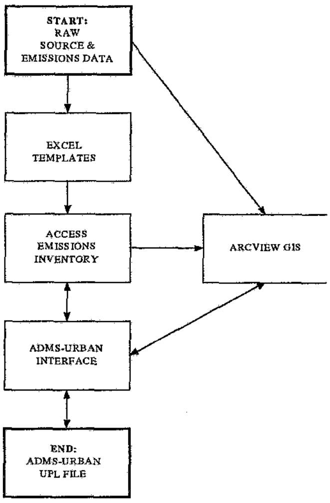

Fig.3 The steps involved in manipulating raw source and emissions data into an ADMS-Urban file

- Inability to obtain the ideal range and depth of activity data required for using the most accurate emissions factors (such as speed of traffic flows, type and efficiency of combustion unit).
- Uncertainties in the geographical resolution at which activity data is available: for instance, data only available at the level of the city administrative unit, or even pertaining to the entire city, province or country.
- Uncertainties associated with primary activity data, including: errors associated with traffic model vehicle flow estimates, under-reporting in fuel sales data, specific deficiencies in the reporting of emissions data from industrial processes.

Sources and emissions data thus must be in a specific format for entering the Emissions Inventory, the ADMS-Urban.

Three Excel templates are supplied with ADMS-Urban. These illustrate the format that the raw data must be in before it can be entered the Access Emissions Inventory. The first is therefore to manipulate the raw data in Excel so that it is in the form of the Excel templates. Each worksheet corresponds to a particular table in the Access Emissions Inventory. *Fig.3* shows how raw data are processed to be made applicable by the model. [5]

Preliminary Results

During the inception phase of the BAQMS programme it was realised that the dataset required is sparse, fragmented and maintained by different organisations furthermore some (traffic) data are not even available. Therefore it was recommended and generally accepted that a spatial subset of data has to be produced and enter into the "pilot" inventory. For this approach, a representative pilot area was selected. (The area is shown in *Fig.4*).

Based on the guidelines given in the frame of the Know How Fund technical assistance the first version of

Fig.4 Pilot area for modelling Budapest (dark solid line: district, light solid line: road network, shaded area: study area)

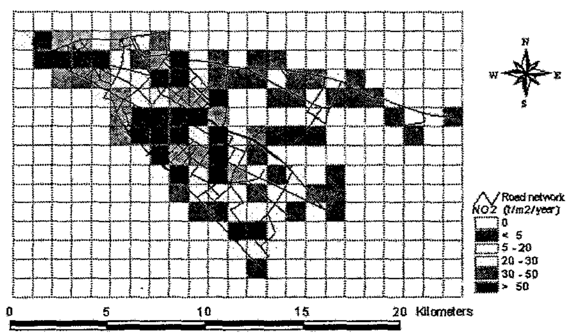

Fig.5 Budapest pilot area for modelling. Emission of oxides of nitrogen from road traffic

the inventory for the study area was compiled (*Fig.5* shows a sample of database on a map).

During the conference, the first results of modelling are being presented as well.

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