Integrating health and air quality information for use in a health telematics project

H. Crabbe, R. Hamilton and N. Machin

Urban Pollution Research Centre, School of Health, Biological and Environmental Science, Middlesex University, U.K.

Abstract

This paper presents the progress to date on a feasibility study to integrate health and air quality information for a group of asthmatics enrolled on a health telematics project. The MEDICATE (Medical Diagnosis, Communication and Analysis Throughout Europe) project is an EC TEN-TELECOM funded project for the development and feasibility of using a health telematic system for asthmatics. A trial study is being conducted with the use of a remote lung function monitoring device linked to a Disease Management System (DMS). Asthma patients are recruited from two hospitals, one in North London, UK and one in Manresa (Barcelona), Spain. Air quality information is linked to this by relating lung function measurements with modelled personal exposure and ambient air quality measurements.

Environmental factors are collected about the patient such as work and home locations, commuting routes, modes of travel and home-environment sources of allergens and pollutants. By using this information, patients’ personal exposure is modelled by time-weighted estimates of their exposure to ambient air quality at each defined location and journey to work. This involves modelling with the ADMS Urban dispersion system by placing receptors with the use of a GIS for both study areas. Emission inventory information on point and line sources in the area determines sources of pollutants that could affect patient respiratory health. Lung function data is compared on a time-wise basis with both modelled personal exposure and measured ambient air quality to see if there is a relationship on an
hourly, daily or lagged-day basis. The methodology of integrating respiratory health and air quality information in this context is discussed.

1 Introduction

The MEDICATE (Medical Diagnosis, Communication and Analysis Throughout Europe) project is an EC TEN-TELECOM funded project for the development and feasibility of using a health telematic system for asthmatics. A trial study is currently being conducted with the use of a remote lung function monitoring device linked to a disease management system (DMS). Asthmatics admitted into hospital are recruited onto the feasibility trial, subsequently discharged and are instructed to use the monitor to record lung function measurements electronically. They then send this data to the hospital using a modem base station at home. Clinical consultants have access to this data through the DMS and thus have knowledge about the patient’s symptoms and wellbeing after discharge. The monitor is able to record all lung function parameters, symptoms, medication use and location of readings. Patients are instructed to make four readings a day during the first week of the trial, and two recordings a day on the following week, for a total of 14 days. The data is kept in secure databases on servers for subsequent research analysis.

One aim of the project is to assess the impact of environmental factors on respiratory health, namely lung function response. In the future, one objective is to enable clinical consultants to have access to environmental information in the DMS such as air quality, to be able to ‘manage’ patient’s symptoms and medication with some knowledge of the patient’s environmental responses. At present in this feasibility stage, information gathering and developmental systems are being set up and tested. Two hospitals are currently in the trial, with study areas in Manresa (Barcelona, Spain) and North London, U.K. It is envisaged that the project will be extended in the future to several other European countries and the U.S. involving several thousand patients. Epidemiological studies can then use this methodology to assess the effect of pollution using real-time lung function measurements.

The aim of this paper is to discuss the integration, practicalities and success of using air quality assessment tools in a health telematics project. Progress to date will be presented, with an emphasis placed on developing the methodology of integrating respiratory health and air quality information in this context. The objectives and transferability of the system to other health and environment applications will be discussed. Fig 1 below demonstrates the methodology and object behind this task.
2 The effect of air pollution on respiratory health

It has been known for many years that air pollution can have an effect on health. Asthma is predominantly an allergic disease of the human airways. It is found that individuals with asthma have changes in lung function, increased symptoms and increased use of asthma medication after periods of higher air pollution and also at moderate air pollution levels. Many studies performed over various parts of the world have shown supporting data, with health effects occurring at lower levels than the World Health Organisation (WHO) guidelines, although the
apparent causative pollutant has varied. Numerous UK Governmental reports produced recently have examined the impacts of air pollution on health, presenting data on the number of deaths or hospital admissions resulting from respiratory and cardiovascular diseases caused by episodic levels of air pollutants (e.g. DoH, 1997, COMEAP, 1998). AGMAAPE (1995) also draw attention to the long-term effects of mixtures or ambient concentrations on health.

The MEDICATE project provides the ideal opportunity to study the effects of air pollution on health on a day-to-day basis. A variety of respiratory symptoms and lung function parameters are measured for a panel of asthmatics by a novel personal automatic monitor. Ideally, this provides real time information on lung function that can be related to the patient’s personal exposure to air pollution. One of the main aims of the project is to develop a methodology for integrating air quality and respiratory health information using a variety of data gathering techniques in a health telematic system.

2.1 The suitability of lung function measures

The relationship between peak flow and other measures of airway obstruction and air pollution could vary depending on the variable and technique measured. Sherwood-Burge (1997) suggests that peak flow (PEF) is more discriminating than forced expiratory volume in one second (FEV1) or maximal expiratory flow at 50% vital capacity (MEF50), although in older patients, peak flow may be a less relevant measure of lung function where other causes of breathlessness exist.

Dockery and Pope (1994) in their review of respiratory effects of particulate pollution found slight differences in dose-responses depending on the variable measured. A decrease of 0.05 to 0.35% (weighted mean of 0.15%) decrease in FEV1 was associated with each 10 μg/m3 increase in daily mean PM10, while peak flow measurements ranged between 0.04 to 0.25% (weighted mean of 0.08%) for the same dose. Therefore relatively larger changes in FEV1 were recorded than in PEF for responses to particulate pollution.

The MEDICATE project can help to study this question of the responses of lung function parameters to pollution exposure. The feasibility trial uses a new novel Jaeger electronic monitor to perform full spirometric tests measuring PEF, FEV1, FVC, FEF25, FEF50, FEF75, and FEF25-75. The appropriateness of the parameters to measure responses to environmental conditions can be assessed in this project using the telematic devices.

2.2 Limitations of using ambient air quality concentration data

Most previous studies have determined health effects occurring at levels of air pollution measured within the local environment of the population. It is questioned whether exposure to air pollution is adequately characterised by fixed-site ambient air concentrations, since people spend a large proportion of their time indoors. The resulting misclassifications of exposure would probably
result in a downward bias of the observed association between air pollution and health endpoints (Romieu et al. 1996).

This project attempts to use a more representative value of personal exposure that is modelled using various methods (see section 4). A number of data gathering exercises were conducted for this to collect environmental information on each patient on the trial.

3 Collecting environmental information in the MEDICATE project

To compute each individual’s exposure to air pollution and other environmental factors (allergens and irritants), a series of data gathering exercises were necessary. Questionnaires were devised to collect this data and were executed or given to each patient on the MEDICATE trial. Three different data gathering steps were devised; describing here the data collection measures, parameters and methods of two of these questionnaires. An asthma quality of life questionnaire (AQLQ) was also administered to the patients on the trial at the end of the two-week period.

3.1 Environmental factors questionnaire

In order to identify the patient’s exposure to allergens and irritants, an ‘environmental factors’ questionnaire was designed. Its primary aim is to identify patient lifestyles, activity patterns and collect information for personal exposure modelling such as indoor and outdoor conditions in a spatial context. The questionnaire identifies;

- The patient’s home and work locations,
- other significant places where time is spent on a regular basis
- the time spent per week at each location defined above
- modes of travel undertaken, for commuting and other purposes, identifying routes and noting any trafficked or industrial areas passed through
- journey lengths by each mode of transportation.
- the use of domestic fuels in the home, for heating and cooking.
- smoking: whether the patient currently smokes, has smoked in the past, or if anyone smokes in the home or workplace.
- the patient’s perception of what affects their respiratory health, i.e. irritant or allergen such as; cleaning products, pets, pollen, dust, smoking, the weather, house dust mites, moulds or fungus, traffic or industrial pollution, exercise, food allergies or other.
- Occupation and income

The aim is to identify environmental factors that could be detrimental to patient’s respiratory health. A home visit to the patient is conducted to collect this information and assess their home environment.
3.2 Daily health diaries and use of an EVENT Button

An electronic record of the patient’s location is also recorded at the time of each lung function measurement. Patients have the choice of pressing a button to record one of four categories of location to describe where they are. The categories are: home, work, commuting/travelling or outdoors/other. As there can be some overlap between the classifications, a written daily health diary allows for an explanation of the precise location of the reading. This was devised to confirm when and where the readings took place and specify locational details about the readings for personal exposure analysis. It asks patients to identify any activities, locations and possible irritants, both immediately and within the last 3 hours, which may affect each recording of lung function. In the event of a low reading of lung function being recorded, the precise location can be retrospectively identified and analysed to see if poor air quality or irritants in the vicinity of the location contributed to the reason for the low flow or asthma attack.

4 Procedures to estimate personal exposures

For some citizens, exposure to air pollution may have major health effects. However the exposure depends on much more than the local air quality level; it requires an integration of the individual’s movements and the pollution concentration at the location of the citizen. As many health impact studies of air pollution are based on measurements made from outdoor monitoring sites, recent attention has turned to personal exposure of pollution, being more representative to the inhaled dose of a pollutant and the effects it may have on health. Personal exposure monitoring relies on the sampling inlet being in the breathing zone to be representative, but monitoring equipment for this purpose is relatively expensive. Characterisation of human exposure and dose assessment techniques can be used to model personal exposure measurements.

Personal exposure of air pollutants is modelled for this purpose based on the following equations.

\[ E_p = \sum_x \bar{C}_{(x,t)} \]

(1)

where:
\[
\bar{e}_{(x,t)} = \frac{\int_{t_0}^{t_1} c_{(x,t)} \, dt}{t_1 - t_0}
\]

Where:
\[ x = \text{home, work, other, etc, locations} \]
\[ t = \text{time spent at each location identified from the environmental factor questionnaire.} \]
\[ e = \text{the exposure to air quality at that location, either measured or modelled.} \]
\[ c = \text{concentration of air quality at that point} \]
\[ E_p = \text{total personal exposure} \]

The following pollutants can be considered on this basis for this study: SO\(_2\), CO, PM\(_x\) (particulate matter of various sizes and total suspended particulates), NO\(_2\), VOCs (Volatile Organic Compounds) and O\(_3\), using the following methodology.

5 Methodology for integrating air quality, personal exposure and respiratory health information

For each patient enrolled on the trial various data gathering techniques are carried out, involving conducting the questionnaires already described. The following steps are then carried out to integrate the various types of information.

1. The patients home, work and any other significant locations are spatially identified on the GIS for preparation for use in dispersion modelling scenarios and to identify proximity to air quality monitoring stations. ESRI's ArcView is used to locate the spatial information needed to integrate environmental factors for both the London and Manresa (Barcelona) study areas.

2. Fixed site air quality monitoring stations are identified in the study areas. Hourly time series data are collected from these sites for the period of concern, retrospectively, when the patient was enrolled on the trial. Table 1 describes the fixed sites identified as providing suitable air quality monitoring data for this purpose.

3. Emissions data are compiled for the study areas, incorporating all available road and point sources that are likely to affect air quality in the identified locations. An emission inventory GIS is compiled for each study area. For London, data from the London Research Centre's (LRC) database on the London Atmospheric Emissions Inventory (LAEI) (LRC, 1997) was utilised to compile information on point sources (industries), road sources and area sources. Information on the industries polluting to air in the Manresa area is
being compiled based on data from the Ajuntament de Manresa (1999) using the Catáleg d’Activitats Potencialment Contaminadores de l’Atmosfera (CAPCA) database, and the Generalitat de Catalunya (2000). Background emissions data are also added at an appropriate spatial level using the EC EMEP European emission inventory.

4. The new generation ADMS Urban dispersion model is utilised to model concentrations of air quality at patient locations where ambient levels are not measured. This provides concentration estimates to be used in the estimation of time weighted exposures. An emissions inventory database is prepared for direct inclusion into the model.

5. Model scenarios are prepared using the above emissions data and location information for receptors placed at patient’s locations and air quality monitoring sites. Site specific information on street canyon morphology (road and building dimensions) is also added at this stage. The model is run under different meteorological conditions to obtain hourly averages, daily averages and maximum levels that are likely to be experienced at the locations defined in 1 and 2 above.

6. Meteorological parameters are collected for each study site to include wind speed and direction, surface temperature and cloud cover (as a minimum). It is ideal to model air quality under the same meteorological conditions that the patient trials are carried out. This involves obtaining hourly meteorological parameters for the time periods concerned from the nearest meteorological site.

7. The data from the model runs are compared to the measured air quality data. The validated modelled data are weighted to represent air quality at each receptor location using the equation show above (2). These levels represent personal exposure at each location. Patient’s total exposure on a daily basis are calculated using the equation (1). Hourly exposures are calculated based on weighted hourly emission variations.

8. Patients’ total calculated hourly, daily and lag-day personal exposure levels are compared to the various lung function variables measured by the monitor. This is represented by time series graphs and statistical analysis involving multiple correlation analysis of individual exposure to pollutants against respiratory function parameters.

9. The results of the comparison are displayed on an Intranet/WWW when analysis is complete. The aim is to show examples of correlations after a completed trial for selected patients at each study location giving information for both the patients and consultants involved.

5.1 Limitations of this method

Ideally, air quality will be compiled on a hourly temporal scale basis, along with the appropriate hourly meteorological data for the patient activity and monitoring areas. But, there are limitations the cost and availability of obtaining suitable meteorological data on an hourly basis for the modelling study. Time activity
patterns are also temporally limited to the collectable data given on the health diary sheets. In practice, variations in the patients’ compliance in recording lung function measurements also limit the amount and use of this data. So, in this case it is more appropriate to focus on daily values (averages and maximums) to relate to the day’s lung function measurements or lag-days effects. The use of this data in the modelling assessments will take the most appropriate and available time resolution to compute personal exposure.

6 Conclusions and future directions

Although many factors will influence respiratory health, including other environmental parameters, this project tries to determine the effect of air pollution on measured lung function and respiratory symptom parameters. The project aims to integrate environmental factors recorded about asthmatic patients on a feasibility trial using a new health telematic system. The environmental emphasis in the project focuses on air quality and the short-term impacts on health. The development of a methodology for integrating this data involving remote lung function measurements is discussed here. The results from this project and its suitability for use will be available towards the end of 2000.

By collecting this data it will be possible to make an assessment of the health outcomes and impacts that the MEDICATE patients could experience at ambient pollution levels. Comparisons will be made of exposure levels and ambient levels (both monitored and modelled) with the National Air Quality Strategy (UK), EU Framework Directive and WHO health based air quality standards. The project will also consider measures to limit individual’s exposures to elevated pollution levels such as abatement of indoor sources, travel options, lifestyle choices, telecommuting, health telematics and public information measures.

The response of lung function to pollution levels can ultimately be fed into the Disease Management System (DMS). A series of decisions made by algorithms on whether to act upon this information can be made, for instance if high pollution levels affect patients’ health, the clinical consultants and patient can be advised of this fact.

Future investigations will have to address the effects of the shortest exposure times and the minimum does of specific pollutants required to have adverse effects on humans, especially in realistic relevant combinations, due to their possible additive effects (Devalia et al. 1994). People with respiratory diseases can be helped to manage the affects of air pollution by increased awareness of the problems that can arise from exposure to highly polluted air. Publicity of forthcoming pollution episodes via the media is essential and full use of information dissemination techniques and health telematic systems such as described here should be encouraged.
<table>
<thead>
<tr>
<th>Location (address and grid reference)</th>
<th>Site type</th>
<th>Parameters measured</th>
<th>Measurement timeframe</th>
<th>Source of data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Placa de Espanya, Manresa (402462)</td>
<td>Urban background</td>
<td>SO₂, NO, NO₂, PST, O₃, H₂S, CO, NMHC, MHC, HCT, wind speed and direction, temperature, relative humidity, pressure, precipitation.</td>
<td>30 Minute averages</td>
<td>Generalitat de Catalunya, Barcelona.</td>
</tr>
<tr>
<td>A41 Great North Way, Swiss Cottage (TQ267843)</td>
<td>Kerbside</td>
<td>NO₂, PM₁₀</td>
<td>Hourly averages</td>
<td>NAQA, NETCen, UBA</td>
</tr>
<tr>
<td>Tottenham High Road, Tottenham (TQ339906)</td>
<td>Roadside</td>
<td>NO₂, PM₁₀</td>
<td>Hourly averages</td>
<td>NAQA, NETCen, UBA</td>
</tr>
<tr>
<td>Priory Park, Crouch End (TQ300892)</td>
<td>Urban centre</td>
<td>O₃</td>
<td>Hourly averages</td>
<td>NAQA, NETCen, UBA</td>
</tr>
<tr>
<td>Russell Square Gardens, Bloomsbury (TQ302820)</td>
<td>Urban centre</td>
<td>O₃, NO₂, CO, SO₂, PM₁₀, PM₂.₅</td>
<td>Hourly averages</td>
<td>NAQA, NETCen, UBA</td>
</tr>
</tbody>
</table>

Details of the air quality monitoring stations providing data for the MEDICATE environmental study.
7 Acknowledgements

The authors wish to thank the Hospitals and individuals involved in this study in recruiting patients onto the trial. This includes Senga Steel and Sara Lock of the Whittington Hospital, London and Yolanda Martinez, Emili Marquilles, Len Winfield and Gemma Carné of the Hospital General de Manresa, Barcelona. Thanks also go to the patients who agreed to take part in this study along with the other partners of the MEDICATE project involving Cable and Wireless, Licore Associates, Erich Jaeger Tonnes, UCL and colleagues at Middlesex University. This project is funded by the EC, contract No. TEN 45608 (FS).

References

COMEAP (Committee on the medical effects of air pollutants) (1998) Quantification of the effects of air pollution on health in the UK. London, Stationary Office.