EVALUATION OF VENTILATION PERFORMANCE IN PUBLIC SPACES

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ABSTRACT

Smoking restrictions in the workplace and increased health consciousness at home have seen a sizable reduction in the number of spaces where smoking is permissible. The aim of this study was to investigate the effects of ventilation in public houses, one of the few remaining public spaces where smoking is still socially acceptable. Little is known about the situation with shared occupancies, where relatively large areas are intended to accommodate both smokers and non-smokers. This study clearly identifies potential problems with a simplistic design approach to ventilation and it's effectiveness in the context of shared occupancy spaces. A computational fluid dynamics code has been used to model airflows with the aim of identifying inefficiencies in existing ventilation systems.

KEYWORDS

Public Spaces, Smoking, Ventilation, ETS, Monitoring, Modelling, CFD

BACKGROUND

A proportion of public opposition to exposure to Environmental Tobacco Smoke (ETS) stems from its potential for causing irritation and annoyance but, for the most part the passive smoking debate relates to the health risks of exposure and the presence of several known or suspected human carcinogens in tobacco smoke (Walsh et al., 1984; Weetman, 1992).

The possible health effects of exposure to ETS have been subjected to considerable investigation. Analysis of smoke generated from a standard cigarette shows it is made up from three main physical classes of chemicals: a gas phase containing nitrogen, nitrogen oxides, carbon monoxide (CO) and Carbon Dioxide (CO_2), and unused oxygen; a vapour phase containing a large number of volatile organic molecules produced by burning; and an aerosol of particles (containing all the tar).

For most buildings the only practical way of limiting the airborne concentration of the pollutants is by dilution with fresh air from outside the building. In public houses this is normally done by using mechanical ventilation, typically by the use of extract fans through windows and walls. If the systems are more complicated then there is a risk of introducing additional hazards due to duct contamination by viable organisms such as bacteria and fungi. The introduction of fresh air will also dilute the persistent smell associated with ETS.

Previously reported work (Currie and Capper, 1994) identified problems in respect of the traditional design approach to ventilated spaces and showed where improvements could be made to accommodate best environmental practice. The studies demonstrated the weaknesses of the traditional approach to perceived air quality problems, where mechanical extract ventilation is installed and operated on an ad-hoc basis.

At present, it is estimated that ventilation accounts for 15% of the total energy overhead for a typical public house (BRECSU, 1990). Any strategy to improve indoor air quality, typically increasing ventilation rates, must therefore be carefully analysed. The basis of this study was to examine shared occupancy spaces and to evaluate the suitability of computational fluid dynamics (CFD) modelling as a tool both to consider existing systems of ventilation and optimise any proposals for retrofit "improvements".

MONITORING

In order to monitor ETS levels it is normal to consider surrogates. The most commonly used surrogate, and the one monitored in this study, is CO; ETS resulting in about 2 ppm CO has been shown to lead to irritation and discomfort amongst 20% of those exposed (European Concerted Action Report, 1992). CO_2 levels were also measured, generally being regarded as a good indicator of overall indoor air quality relating to occupancy. Levels greater than 800 parts per million (ppm) are considered to be an indicator of poor air quality in other property types (Potter and Booth, 1994).

Premises were continuously monitored over a number of days. Sample data measurements were taken at various locations in a number of public houses, including the working area of the bars, any seated areas and any areas intended for eating. An investigation was also made to assess the extent of vertical distribution within the spaces.

The equipment used to measure the gas concentrations was a Brüel & Kjær Gas Analyser Type 1302, whose detection principle is based on photoacoustic absorption. It allows unattended monitoring of gas concentrations for up to 6 gases simultaneously and provides qualitative analysis measurements on-site. This was connected to a Brüel & Kjær 1309 multi-point sampler unit. A notebook computer provided control and data logging functions using proprietary software. Compensation was made for barometric pressure and temperature fluctuations, water vapour interference and interference from other known gases.

The following discussion is centred on the CO_2 and CO profiles for one of the public houses.

PUBLIC HOUSE

The public house is a typical and traditional Scottish pub in the centre of Edinburgh, with a substantial catering operation. It is located on the ground floor of a stone construction tenement block with single glazed windows to the front facade. The pub was completely refurbished in 1994/95 and has a large open area for dining at two levels, one bar and a kitchen to the rear. The refurbishment was undertaken to create one of the ever-increasing theme pubs. The pub is generally open from 1100 in the morning until 0130 the following morning. The nominal seating capacity of the pub is 75, but it is busy in the evenings and at weekends, when the occupancy can rise to over 400.

Ventilation is by means of extract fans fitted in the windows on the front facade of the building with a supply fan above the entrance to the kitchen area and a cooker extract canopy. The kitchen extract fan is switched on at approximately 1100 hrs each morning and remains on until about 1700 hrs. In general the supply fan is not used. Main extract fans are only used during evening periods and on a reactive basis to perceived air quality problems by staff and customers. Heating is provided by a low-pressure hot water system with mixed convective and forced convective heat emitters.

Mechanical ventilation rates were measured at 5.13 ach. Natural ventilation rates were calculated at an average value of 0.26 ach by examination of the CO_2 decay characteristics after the mechanical ventilation had been switched off and the building left unoccupied.

RESULTS

Continuous samples were taken from seven different points in the pub; hree measurements were taken in a vertical plane adjacent to one of the extract fans and four other points were monitored to assess the horizontal distribution from the bar to the seated, eating, area.

Figures 1 and 2 give the profiles at a mid point in the seated area of the pub over a full week, from a Tuesday afternoon through to the following Tuesday morning.

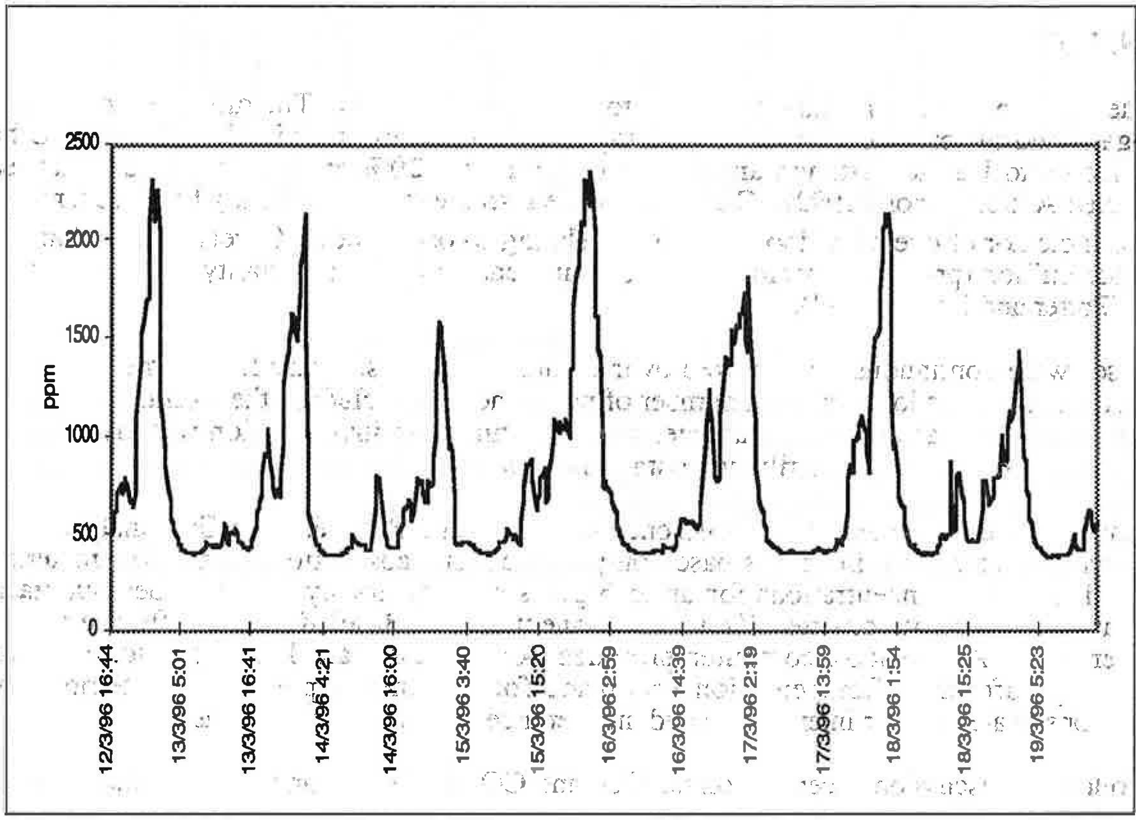

Figure 1. Carbon Dioxide Profile

The CO_2 profile indicates, as expected, an occupancy related pattern with increased levels at lunchtime, an early evening peak and a build-up towards late evening / closing time.

The typical background level, overnight, is approximately 450 ppm. For the occupied periods the levels rose to values in excess of 2000 ppm, clearly above the WHO control level of 1000 ppm and indicating not an inadequacy in the ventilation system capacity but ineffective and/or impracticable operation of the system. This is the typical scenario that has demonstrated in most of the studies conducted to date by the authors

For CO, given in Figure 2, the profile is again clearly occupancy related, absolute levels are not high in relation to measurements in other similar properties, with only occasional peaks rising above a level of 10 ppm.

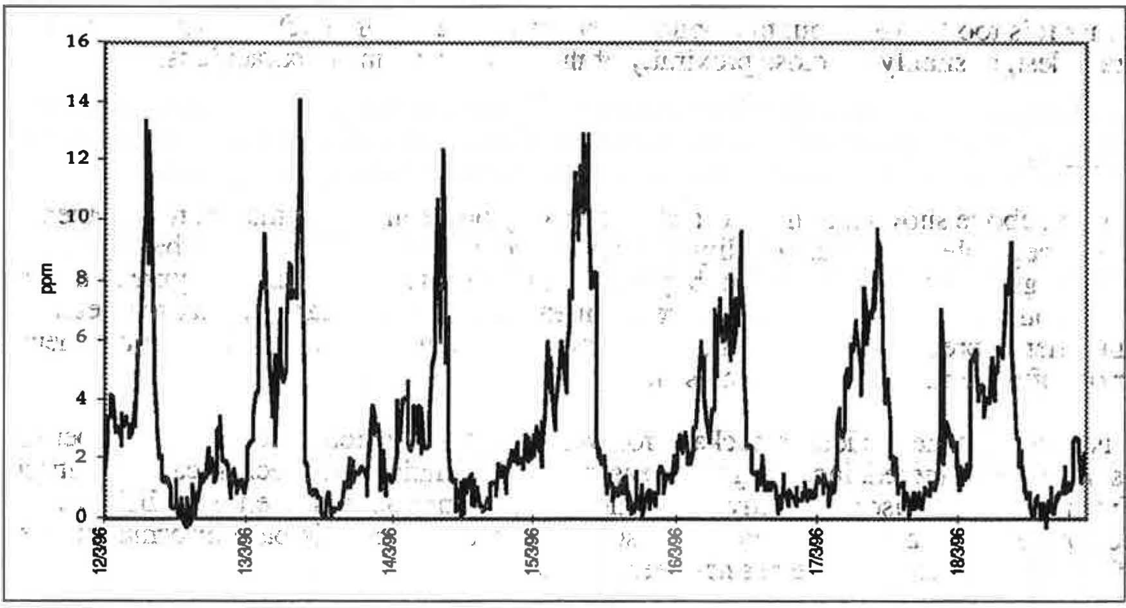

Figure 2. Carbon Monoxide Profile

It is important to consider not only the time-based variance in pollution levels but also the spatial distribution throughout an occupied area. This will be determined by the pollutant source(s) and the physical geometry of the space and will be affected by the installed ventilation system(s) - their capacity and operating strategy.

Figure 3 shows, in more detail, a typical daily profile for two of the areas in the pub.

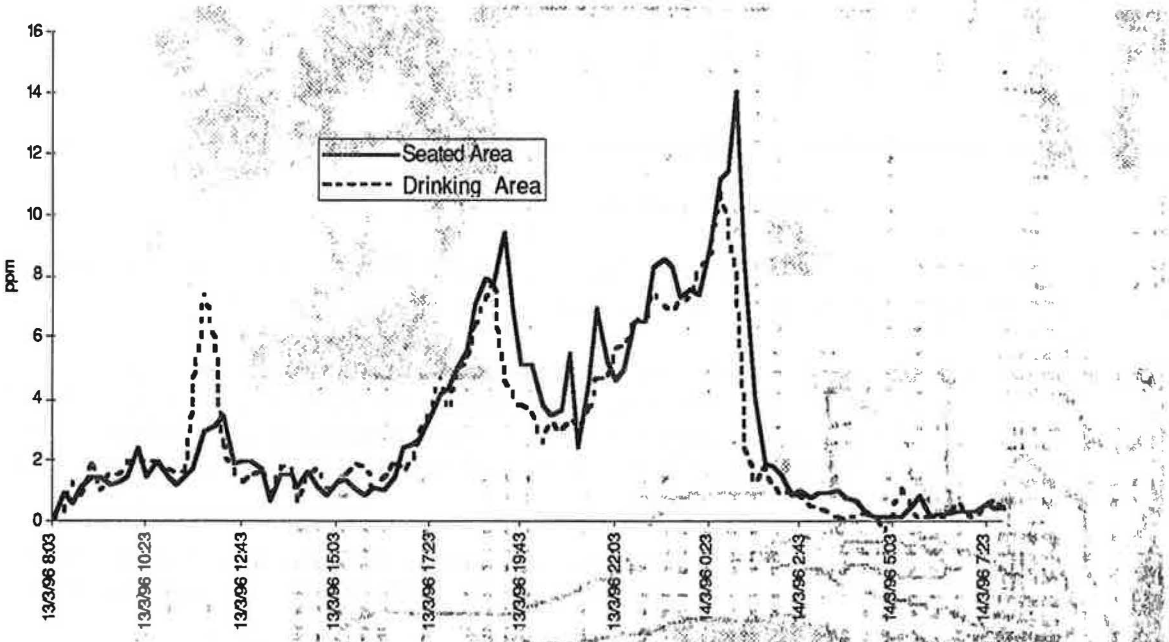

Figure 3. 24-Hour Carbon Monoxide Profile

The monitoring exercise showed a small CO distribution gradient in the vertical plane but more significant variations horizontally, as would be expected. Variations between floor and ceiling level were of the order of 9% whereas horizontal plane variances were up to 17% on average.

The bar area is consistently one of the least 'smoky' areas in this pub which, from an occupational health viewpoint, may be advantageous (visitors to a pub may choose to leave if they feel that it is too 'smoky', but this option is not available to bar staff) but is not the result of deliberate design, simply the close proximity of the window mounted extract fans.

MODELLING

The discussion above shows that there is a clear disparity between the ventilation requirements to achieve acceptable indoor air quality in certain premises and those prescribed through legislation as a generic standard for all pub types. The net result is an increased requirement for fresh ventilation air with a consequent increase in energy use particularly during the heating season. In order to predict the impact of the required increase in ventilation energy requirement a number of software models have been used.

CYMAP is a steady state modelling package for which the construction details for a number of pub types have been entered, including the measured air infiltration and mechanical ventilation rates. From this the seasonal steady state energy consumption has been established and compared (quite favourably) with actual consumption data. From this base information the impact of various ventilation strategies has been evaluated.

ARIA, a CFD package, is currently being used to optimise the location of mechanical intake/extract points with the aim of achieving a better distribution of dilution air and the identification of potential 'dead-spots' thus moving away from an ad-hoc solution to this type of problem. The model is currently being validated for different pub types and geometries and a typical solution profile of air distribution within a pub is shown in Figure 4. This profile depicts an horizontal 'slice' showing the air velocity vectors and velocity contours at approximately 2m height. Good mixing of the air is really only achieved in one corner of the pub with significant stagnation evident in the remaining (mainly seated) area of the Figure.

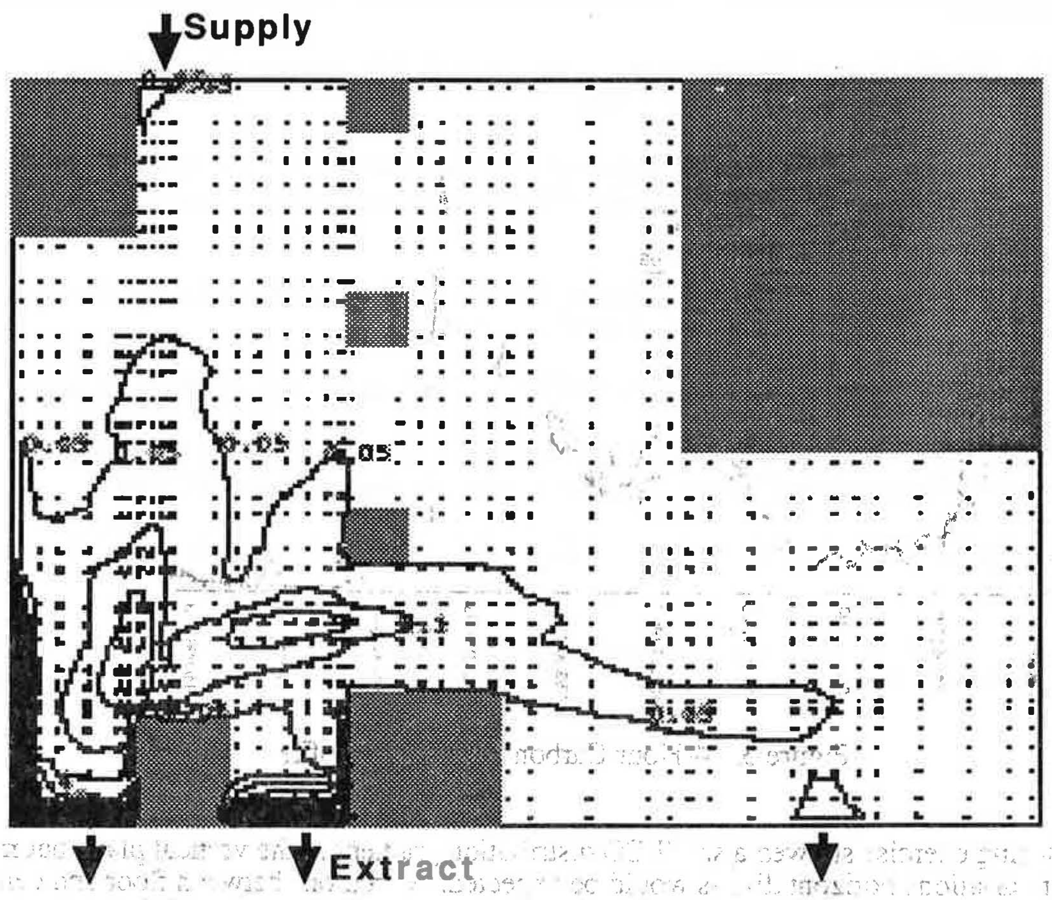

Figure 4. Horizontal velocity profile through public house.

CONCLUSIONS

Public concern about the exposure to higher levels of ETS is further justified by the results from this survey. Although improved ventilation strategies are the only practicable means of alleviating this situation and maintaining general indoor air quality, the situation clearly exists where traditional ad-hoc designs do not achieve airflow distributions which mitigate the effects of ETS. The use of techniques such as CFD help considerably in understanding the effectiveness of any such strategies employed.

In some premises where food is served and eaten it may be necessary to place a greater emphasis on complete physical separation between smoking and non-smoking areas, this is of particular relevance to the current guidelines governing the granting of children's licences. Better design, in terms of the positioning and capacity of supply / extract systems may be a short term step in managing smoke levels but this is a trade-off against increased energy consumption.

Overall, current legislation in the UK in respect of ETS contamination within public spaces is limited to the protection of employees and places a duty of care upon employers under general health and safety provision. There has been little stimulus for investment in effective ventilation systems or in the more sophisticated HVAC design tools now available. These factors, together with a lack of maintenance, can result in the scenarios outlined above within a few years of a complete refurbishment of a property such as a public house. As health problems associated with ETS become more apparent and precedents are set in the UK courts then increased pressure will be put on employers, local authorities and central government to start to address such issues.

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