ROAD TRAFFIC POLLUTION AND ITS EFFECT ON THE INTERNAL ENVIRONMENT OF BUILDINGS

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ABSTRACT

Indoor and outdoor concentrations of various pollutants were measured in a naturally ventilated building in the West End of Edinburgh during and after the period of the Commonwealth Heads of Government Meeting (CHOGM) to assess the effect upon indoor pollution levels of the closure of some streets in the city. The relationships between indoor and outdoor air qualities in respect of traffic-generated pollutants were studied and the building's relative attenuation of external pollution levels investigated. The peak concentrations of some of the external pollutants were attenuated by the building and the internal concentrations showed a reduction of up to 30% in some periods. During periods of reduced traffic, the early analyses indicate that the daily mean concentrations of the pollutants were not significantly different from those measured at other times.

KEYWORDS

Pollution, traffic, monitoring, air quality

BACKGROUND

The aims of the study were to:

- determine internal and external contaminant concentration levels of a building in normal traffic conditions;
- compare internal and external contaminant concentration levels of the same building when the road outside is closed to traffic;
- analyse the effect external contaminant levels have on indoor contaminant levels e.g. concentration gradients, diffusion rates, attenuation, time residency.

INTRODUCTION

In urban environments, traffic conditions have a large effect on the quality of the outdoor air, as vehicle emissions are a major source of urban pollution. Figures from a UK Royal Commission report on Transport and the Environment indicate that road transport emissions are responsible for the following percentages of total emissions in the UK: Carbon Monoxide 89%, Nitrogen oxides 52%, Particulates 41%, Volatile Organic Compounds 34%, and Sulphur Dioxide 2%. The effects that the quality of the indoor environment can have on an occupants health are widely recognised and, as a large percentage of the population spend up to 85% of their time indoors, it is important to consider the relationship between external pollution and internal climate. In many cases, particularly in city centres, the internal environment is perceived as being of a better quality than the outdoor environment, being a shelter from the outdoor, traffic-related, pollution. Recent studies have revealed that the situation is not so straightforward.

The quality of the indoor air in a commercial property is affected by climatic conditions an dits location relative to potential sources of pollutants e.g. busy roads. The extent to which such pollutants enter the building and migrate to individual rooms will be determined by the building's fabric and internal geometry as well as natural and mechanical ventilation and their associated supply and distribution systems. This study concentrates on what is essentially a naturally ventilated building, where it is the combination of pressure forces and pollutant levels around the building that generate the internal contamination process. Externally-generated contaminants can enter the indoor environment through the building fabric, i.e. both proprietary and adventitious ventilation openings or small gaps in construction, such as between windows and the surrounding structure or occupants opening the windows. It is important to consider whether or not these externally pollutants are of significance in terms of their ingress into buildings and presenting potential health hazards indoors.

CASE STUDY

Two refurbished commercial buildings in Edinburgh, of similar construction but different occupancy levels, were selected for study. The monitoring period chosen covered the period of the CHOGM in order to examine the effects of street closures and hence attempt to isolate some of the traffic-related pollutants. The following discussion is based on one of the buildings, which was located on a street closed during the CHOGM.

The building is a four storey, stone-built Georgian terraced property situated in the West End of Edinburgh and consists of a basement plus ground, first and second floors which are all used as offices. The front elevation of the building faces a busy street, at the rear there is a small area with private car parking spaces. All the windows are single glazed with traditional, vertical sliding, timber sashes. The building is naturally ventilated, but there is one window-mounted, mechanical extract/supply fan in one of the ground-floor offices, but this is not generally used by the occupants as it faces the street. There was one potential source of indoor pollutants, a gas-fired low pressure hot water boiler, located in an out building to the rear of the property.

MEASUREMENT

The monitoring was carried out using a Brüel and Kjær Multi-gas Monitor Type 1302 which works on the photoacoustic infra-red detection principle. A multi-channel sampling system was used to sample eight points both inside and outside the building. The gases monitored were Carbon Monoxide (CO), Sulphur Dioxide (SO_2), Carbon Dioxide (CO_2), Nitrous Oxide (N_2O) and Total Volatile Organic Compounds (TVOCs). Three offices were monitored at the front of the building, where windows faced the main road, at basement, ground floor and first floor levels. External levels were measured at window height outside these offices. Measurements were recorded with four minute intervals between each sampling point.

Data have been analysed from three, separate, uninterrupted periods. The first measurement period was for six days during the CHOGM in October 1997. During this period the road outside the building was closed to through traffic for security reasons. The second and third monitoring periods were in the following weeks with normal traffic conditions on the road outside.

During unoccupied periods, the decay of CO_2 generated by the occupants previously in the building was used as a measure of the air change rates. The ventilation rate was found to range from 0.24 to 0.75 air changes per hour in the basement and the ground floor offices. These rates are very low when compared to CIBSE recommended air changes for offices of 4-6 changes per hour. Weather data for the period was obtained from the Meteorological Science Department at Edinburgh University and the calculated rates could not be correlated with changes in external wind velocities, however, prior to any studies it was appreciated that general weather data is notoriously difficult to correlate with that experienced at micro-building scale. Krüger (1994) points to the importance of wind direction on influencing pollution levels on facades and work is still underway on investigating the relationships of air change rates and pollutant levels with changes in external climatic factors and to further examine the potential canyon effects within the street and the air flow patterns around the building and the surrounding properties.

RESULTS

Outdoor CO levels fluctuate rapidly depending on the density of traffic. As the traffic levels reduce the CO concentration externally reduces as it is dispersed into the atmosphere. During the CHOGM there were still peak concentrations of CO at certain times. Although the road outside the building was closed to traffic, congested traffic conditions on nearby roads were expected to contribute to the peak concentrations of pollutants, depending on wind speed and direction.

Figure 1 shows one example of the attenuation using values of CO recorded over the second monitoring period. The values are the average internal levels within the first floor office and the corresponding levels externally. In general, the external peak concentrations of CO are followed by lower internal peak concentrations; the pattern was replicated both during and post CHOGM. The internal peak concentration is normally well below the external peak concentration, which shows the building can attenuate external levels and therefore reduce the risk of short term exposure to pollutants, in this case CO. As the building's air exchange rate is 0.75 or less the concentration reduces at a much slower rate than it does outdoors. This pattern of results can be compared with those described by Green*et al* (1998) and by Kukadia and Palmer (1996) for similar, naturally ventilated, buildings. Attenuation values in those studies are generally of the order of 50% whereas the peak internal concentrations in this case show reductions of between 25% and 30% of the peak external concentrations. Only simplistic analyses have been carried out to date and bivariate time-series analysis of the data is being undertaken to further understand the attenuation factors associated with the building's fabric and internal geometry.

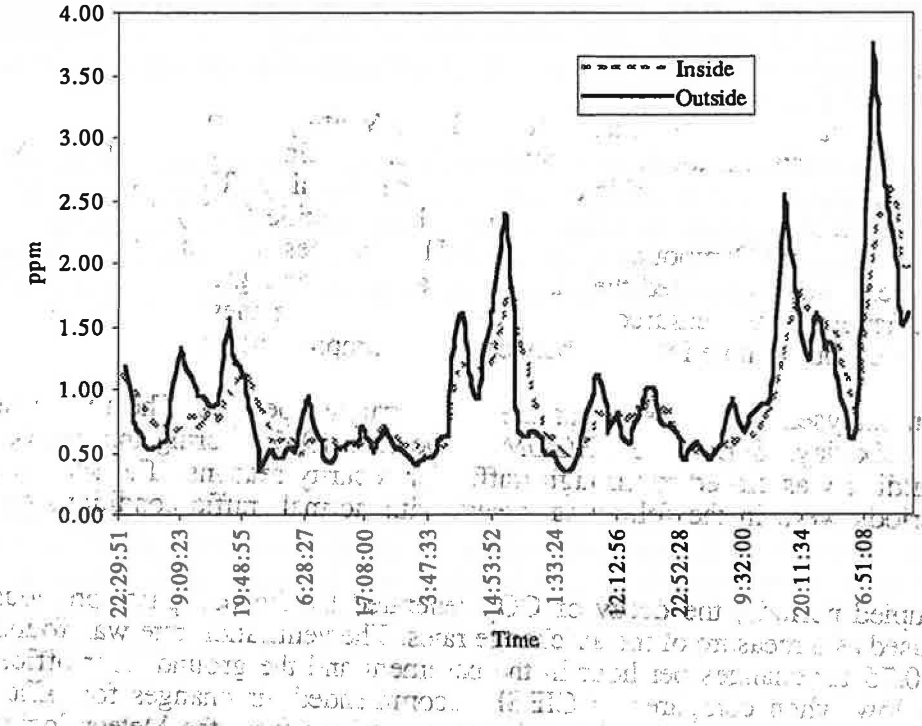

Figure 1. Attenuation of external levels of CO over a five day period

Table 1 shows the mean values of CO within the three front-facing offices in the building. The contrast between external and internal values can be seen and the reduction afforded by the building fabric. The values in parentheses are the standard deviations, showing considerably more variation in external concentrations. There is little difference shown in concentration levels between the three internal rooms or any significant vertical gradient externally.

TABLE 1
Mean CO levels (ppm) (with Standard Deviation) over a five day period

	Outside Concentration (ppm)	Inside Concentration (ppm)	% reduction
First Floor	0.96 (0.70)	0.93 (0.47)	3.1
Ground Floor	1.03 (0.76)	0.99 (0.48)	3.9
Basement	1.09 (0.86)	0.98 (0.53)	10.1

Table 2 shows similar results for the third monitoring period. Overall the concentrations are higher, but again there is little internal variation or vertical differences. The percentage reduction external/internal is approximately 8%.

TABLE 2
Me n CO levels (ppm) (with Standard Deviation) over a six day period

	OutsideConcentration (ppm)	Inside Concentration (ppm)	% reduction
First Floor	1.90 (1.15)	1.74 (0.58)	8.4
Ground Floor	2.00 (1.72)	1.83 (0.63)	8.5
Basement	1.96 (1.10)	1.82 (0.64)	7.1

The health issue associated with CO is its combination with hæmoglobin in the blood and the consequent reduced capacity of the blood to transport oxygen. The reaction is however reversible and exposure to unpolluted air removes most of the gas from the body. The World Health Organisation (WHO) (4) recommends a carboxy-hæmoglobin (COHb) level of 2.5-3% for the protection of the general public and suggest guidelines for limiting exposure to CO in order to maintain COHb below that level. Overall the levels of CO measured in the study are very low in comparison with the guidelines. Maximum internal values in any of the rooms did not exceed 7 ppm for any periods of time, the guidelines indicate values of up to 85 ppm for periods not exceeding 15 minutes. The mean values of between 1 and 2 ppm, given in the above Tables are significantly lower than the WHO recommended safe threshold exposure level of 10 ppm averaged for an 8 hour period.

For the other gases measured, analyses are still underway. This is being concentrated around correlation of the relative source strengths and their relationship to vehicular modal mix. By way of observation; the measured levels of SO_2 were found to be consistently below the threshold for the instrumentation, and levels of Nitrous Oxide found during CHOGM and post CHOGM were low, both indoors and outdoors - the highest eight-hour concentration was 0.81 ppm.

CONCLUSIONS

This study presented a rare opportunity to examine the effects of major road closures in a city centre and their consequent impact upon indoor air quality in a commercial property. The preliminary results show that the naturally ventilated building does attenuate the peak concentrations of some of the traffic-related pollutants. Further work is required to assess the effect of wind speed and direction and to model air flows and consequently pollutant flows in the street and around the building.

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