Results from Three Field Tracers Experiments at the Neighbourhood Scale in the City of Birmingham UK

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1. Introduction

In recent years much research has been devoted to the study of dispersion mechanisms in the urban environment. However, the physical processes governing flow and dispersion at the neighbourhood scale, which is intermediate between the local (street canyon) and the city scale, are not yet well understood. It is not clear yet whether a traditional approach using averaged characteristics such as the roughness length is sufficient to predict the concentration field at the neighbourhood scale. An analysis of full-scale experiments could improve our understanding of these processes and give suggestions to improve model performance. Field experiments at the neighbourhood scale are rarely available in literature.

Within this framework, three field experiments were designed within the UK Urban Regeneration and the Environment (URGENT) programme, sponsored by the Natural Environment Research Council (NERC) as a result of a collaborative effort between the University of Bristol, the University of Cambridge and Cambridge Environment Research Consultants (CERC).

The experiments were performed in the city of Birmingham using a finite duration release of perfluoromethylcyclohexane (PMCH) and perfluoromethylcyclopentane (PMCP). The combination of low background concentration of PMCH and PMCP, their non-depositing and non-reacting characteristics, as well as the ability of measuring very low concentration values with a newly developed gas chromatography/negative ion chemical-ionisation mass spectrometry (GC/NICI/MS) technique (Cooke *et al*, 2000a; Cooke *et al*, 2000b), allowed the realisation of nearly ideal fluid dynamic experiments in real urban environments.

2. Experimental Arrangement

The experiments took place in Birmingham in July 1999, February 2000 and August 2000. They were performed during the URGENT/PUMA campaign, which provided the necessary meteorological measurements. The source-receptor distance was initially chosen to be 3-4 km for the July experiment (see Britter *et al.*, 2000) and later reduced to 1 km for both the February and August experiments.

Each experiment was set-up with a box-like (top hat) temporal evolution of the tracer release rate. The spatial and temporal experimental design was determined using simple analytical models and the ADMS3 (CERC, 2000) operational dispersion model. Near-neutral stability conditions and wind speed about 4-5 ms^{-1} were chosen in order to satisfy the requirements for the simplest meteorological conditions for the experiment.

2.1 First Experiment

A release of perfluoromethylcyclohexane (PMCH) took place on 1st July 1999, from a heated chimney of 4.5 m height at 13:00, local time. The release rate was selected in order to make the most of the dynamic range of the analytical instrumentation. The release time was adjusted in order to record the total temporal evolution of the puff. The averaging time of the receptors was set at 15 minutes. The

release apparatus was situated at the University of Birmingham, Pritchatts Road (R1 in Figure 1.1) and the effective release rate was 4 gs^{-1} over a 40-minute period.

Five samplers were placed in an arc at approximately 3.5 km from the release point with a cross-wind spacing of about 500 m. The sampling height was 2 m above ground for four of the samplers while one sampler was positioned on a roof top at 40 m. The optimum spacing was deduced on the basis of the estimate of the plume width by means of simple analytical models (see Hanna *et al*. 1982). The samplers are referred to as Sites S1.1, S1.2, S1.3 (on the roof top), S1.4 and S1.5 (Figure 1.1). A secondary receptor Site SS1.1 (trap sampler) was placed on the outskirts of Birmingham at about 9 km from the release source. It was expected that measurements at a distance comparable with the city scale would be easily interpreted through standard plume dispersion models. A detailed description of the sites can be found in Cooke *et al*. 2000c.

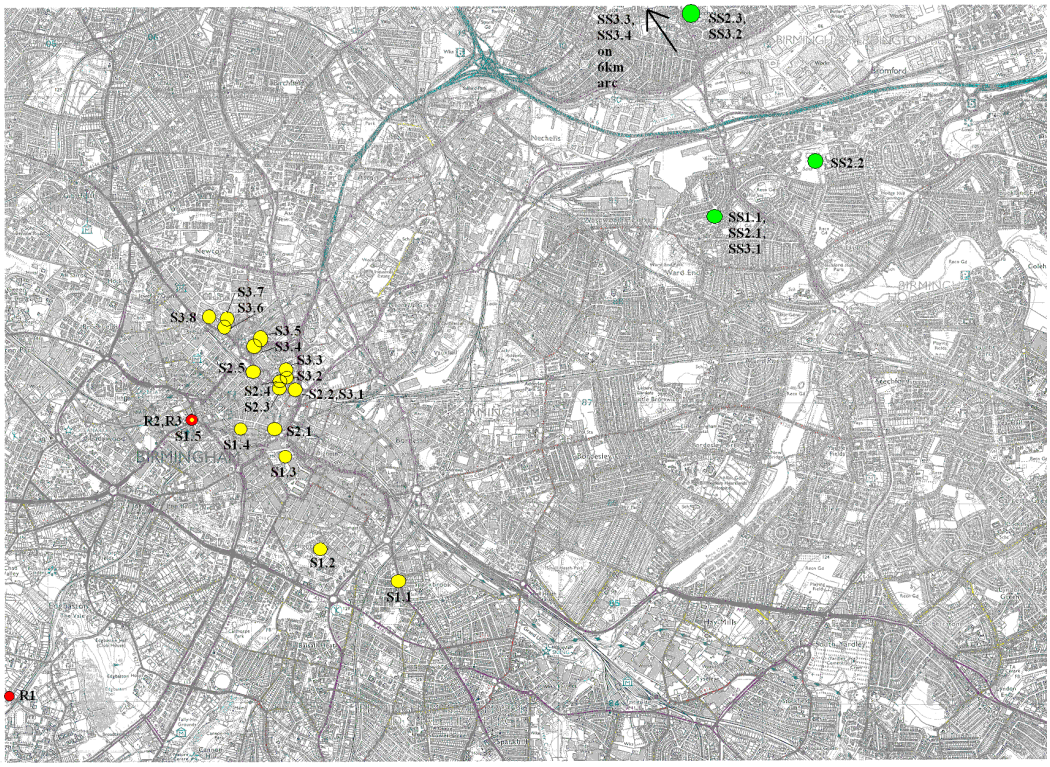

Figure 1.1 Overall map of the three Birmingham experiments. Rx, Sx.n and SSx.nn represents the release site, the site in the main arc and the secondary sites respectively, where x stands for experiment 1 (July 1999), 2 (Feb 2000) or 3 (Aug 2000) and n, nn are the number of receptors used for each experiment.

2.2 Second Experiment

The second experiment took place on the 1st February 2000 at 13:00, local time. It was decided, on the basis of the results obtained in the previous experiment, to perform this experiment in an area where the plume depth would be more comparable with the building heights.

Five samplers, of which one was on a 30 m high roof (S2.4), were placed on an arc at about 1 km from the release site (R2; see Figure 1.1). The optimum cross-wind spacing between receptors was determined to be around 300 m. The averaging time for the samplers in the main arc was set at 3 minutes. This shorter time resolution was expected to give more data during the rise and the decay which, at this distance from the source, was expected to be quicker. Three secondary receptors of which only one (SS2.3) gave results, were placed at about 6 km from the release site. The release rate was 0.23 gs^{-1}over a period of 35 minutes.

2.3 Third Experiment

The third experiment performed on the 2nd August 2000, was designed on the basis of the results from the first and the second ones.
Eight samplers, of which three were on the roof (11 m and 20 m high), were placed at 1 km from the release site with a cross-wind spacing between the receptors of about 250 m. A second tracer PMCP was used in this experiment in conjunction with the first tracer PMCH. The secondary tracer release was delayed by half the sampling period (averaging time). The averaging time was set at 6 minutes. The primary tracer, PMCH, was released on 2nd August at 13:00, local time, while the secondary tracer, PMCP, was released at 13:03. The motivation for this was to obtain the same time resolution as in the February experiment over a longer measuring period without using more samplers. The effective release rate was 0.22 gs^{-1} for PMCH and 0.18 gs^{-1} for PMCP over a period of 20 minutes.

3. Results, Discussion and Conclusions

Concentration measurements taken from the main arc for the three experiments are shown as a function of time in Figure 3.1, Figure 3.2 and Figure 3.3. From the analysis of the figures it appears that the July and August experiments worked successfully while the plume was partially missed for the February experiment as it turned out that the most important receptor (S2.5) failed.

A comparison of the maximum measured concentration values with results from simple analytical Gaussian plume models was performed in order to verify that those values were broadly consistent with expectations. Atmospheric thermal stratification was estimated from the available meteorological data to be near neutral. The comparison was done for both Pasquill stability class C and D. Vertical and lateral standard deviation of the concentration distribution σ_z and σ_y where calculated using Briggs curves for urban conditions (see Hanna *et al*. 1982). Results from this comparison are reported in Table 3.1.

Table 3.1 Measured and modelled maximum concentrations.

Distance from release km	Measured concentration μgm^{-3}	Briggs curves class C μgm^{-3}	Briggs curves class D μgm^{-3}
3.5	2.16 (Site S1.3)	1.0	3.0
9	0.08 (Site SS1.1)	0.09	0.15
1	0.003 (Site S2.4)	0.4	0.9
6.6	0.017 (Site SS2.3)	0.015	0.05
1	0.69 (SiteS3.4)	0.5	1.0
6.6	0.008 (SiteSS2.3)	0.02	0.07

From the table it can be observed that the measured maximum concentration for both July and August experiments are comparable with values obtained by the analytical model. For the February experiment (Site S2.4) the maximum concentration is about one order of magnitude less than analytical model predictions. According to this result, Site 2.4 was about 30º off the centreline of the plume. Looking at Figures 3.1, 3.2 and 3.3 it can be observed that the experimental concentration history is asymmetrical: the rise occurring much faster than the decrease. Measurements were compared with ADMS3 model predictions. Results for Site S3.4 are reported in Figure 3.4. Only PMCH measurements are reported. It can be observed that the maximum value of the concentration is predicted within a factor of two by ADMS3. The slow decrease is also well predicted by ADMS3 and can be fitted by an exponential curve with a well definite time constant. This time constant for the concentration decrease of the July experiment was estimated to be about 7 minutes (Britter *et al*. 2000).

The good agreement between the measurements and the model predictions support the experimental techniques and procedures. However, a long-lived plateau at low concentration is observed for both the July and August experiments, but is not predicted by the model. We believe that this long-lived plateau might be due to material trapped inside the complex urban canopy.

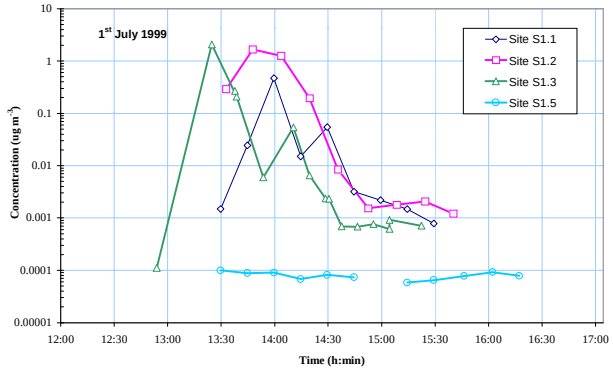

Figure 3.1 PMCH concentration measurements for the July experiment.

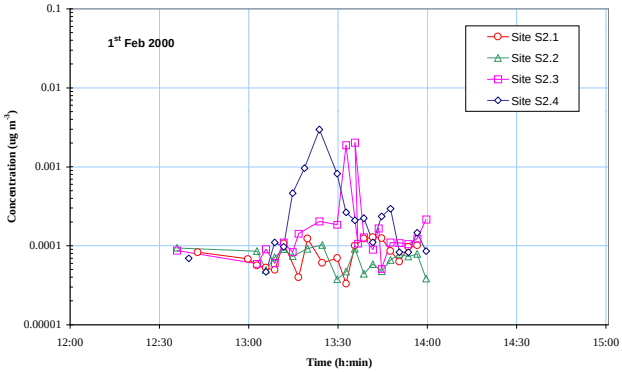

Figure 3.2 PMCH concentration measurements for the February experiment.

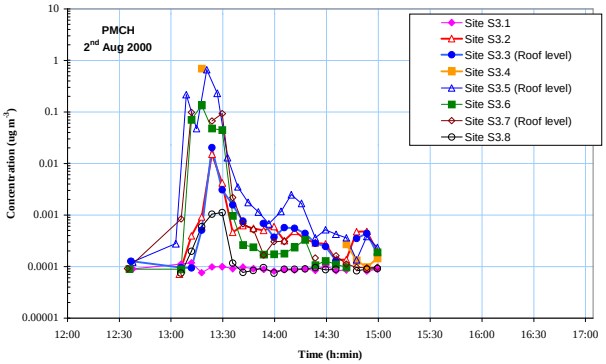

Figure 3.3 PMCH concentration measurements for the August experiment**.**

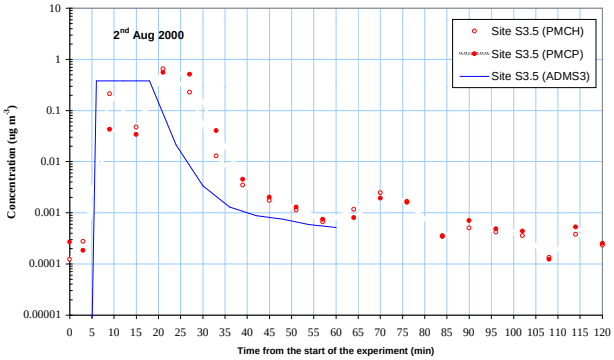

Figure 3.4 Comparison between measured concentration and ADMS3 model predictions for Site S3.5.

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