AIR POLLUTION ASSOCIATED WITH AIRPORTS

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(Received 7 November, 1983)

Abstract. Air quality in the vicinity of airports is examined with particular reference to a detailed study of Gatwick Airport (UK). Ambient air concentrations of carbon monoxide, hydrocarbons (total and non-methane), oxides of nitrogen, smoke and airborne particulate lead have been measured at seven locations around the airport. The results obtained have been compared with ambient air quality guidelines, where available, and with results from other monitoring sites in the UK. It is concluded that the airport cannot be considered to be a significantly more important contributor to average pollutant ground-level concentrations than other sources in the area.

1. Introduction

The rapid growth of air travel over the last twenty years has brought about a corresponding expansion of airport facilities in the vicinity of large connurbations. Activities conducted in and around airports may influence air quality in the immediate and surrounding areas, although it has been shown previously that, on a regional scale, such activities may contribute only 3% of the total emissions of air pollutants in surrounding urban areas (Cirillo *et al.*, 1975; Jordan, 1977). Major pollutants emitted from both stationary and mobile sources in the vicinity of airports include total (THC) and non-methane hydrocarbons (NMHC), carbon monoxide (CO), oxides of nitrogen (NO_x) and particulates (Bastress, 1973) together with lead emitted from petrol-engined vehicles.

Concern over the effects on ambient air quality of emissions from airports has prompted a number of studies in recent years at Heathrow (Parker, 1971; Nicholls *et al.*, 1981), Los Angeles International (Los Angeles Air Pollution Control District, 1971; United States Environmental Protection Agency, 1972), Washington National (Wang *et al.*, 1974), Orly and Roissy-en-France (Delsey *et al.*, 1978) and Osaka (Sawada and Nishi, 1974) airports. The majority of these surveys have indicated that concentrations of air pollutants measured were generally low and did not exceed current established ambient air quality standards or guidelines, with the exception, in a limited number of cases, of CO and NMHC, which were detected at relatively elevated concentrations for short periods in certain defined locations such as terminal buildings (Los Angeles Air Pollution Control District, 1971; Yamartino *et al.*, 1980). Monitoring studies alone are largely incapable of distinguishing between individual sources of particular pollutants and the problem of discriminating between airport and non airport-related air pollution may only be partially resolved by the judicious location of measurement sites. Complete resolution of the problem may only be obtained in combination with emission source inventories and atmospheric dispersion modelling.

Environmental Monitoring and Assessment **4** (1984) 361–377. 0167–6369/84/0044–0361$02.55.

The study reported here was carried out in connection with airport developments proposed by the British Airports Authority and consisted of monitoring at one fixed site within the airport boundary and at six mobile sites around the perimeter of the airport, forming the measurement component of a combined monitoring/atmospheric dispersion modelling study for the elucidation of current and future air quality in the vicinity of Gatwick Airport (Williams *et al.*, 1980).

2. Materials and Methods

2.1. Location of sampling sites

The measurement programme involved continuous monitoring of pollutant concentrations at one fixed site and measurement in rotation at six further sites around the airport, which were visited by a mobile laboratory. The locations of the sampling sites are shown in Figure 1. The sampling strategy for the mobile laboratory was designed with consideration of such factors as range of meteorological conditions experienced, time spent at the monitoring sites and data loss due to movement between sites. Owing to finite time constraints, it was decided to adopt a weekly schedule, which was considered to represent a best compromise case.

2.2. Analytical instrumentation

At the fixed site total hydrocarbons (THC) and methane (CH_4) were measured using a Meloy HC500-2C analyser, carbon monoxide (CO) was measured using a Philips PW9775 continuous coulometric monitor and oxides of nitrogen (NO and NO_x) were measured with a Thermoelectron 14/BE chemiluminescence analyser. Smoke concentrations were monitored by a standard 8-port sampler, identical to those used in the National Survey of Air Pollution. Airborne particulate lead was collected on a 0.8 μm millipore filter and analysed using a previously developed method (McInnes, 1976). The mobile laboratory was equipped with a Beckman Model 6800 Air Quality Chromatograph which was used to measure THC, CH_4 and CO. Total oxides of nitrogen and NO were measured with a Thermoelectron 14D chemiluminescence monitor. Airborne particulate lead was collected using a 0.22 μm millipore filter and was analysed by flameless atomic absorption spectrophotometry.

The instruments were calibrated and their zeros checked approximately once every two weeks using, in the case of the CO and hydrocarbons, standard gas cylinders. The NO_x calibrations were performed using, as a secondary standard, bottles of NO/NO_2 mixtures and calibrated against a NO_2 permeation tube primary standard.

Sampling was at a height of approximately 4 m above ground at all sites. Concentrations of the gaseous pollutants listed above were measured every five minutes and these data were then used to calculate hourly means, which is the basic unit of data for the gaseous pollutants discussed here. The design and execution of air quality monitoring surveys and a description of the mobile laboratory have been discussed previously (Clark *et al.*, 1983).

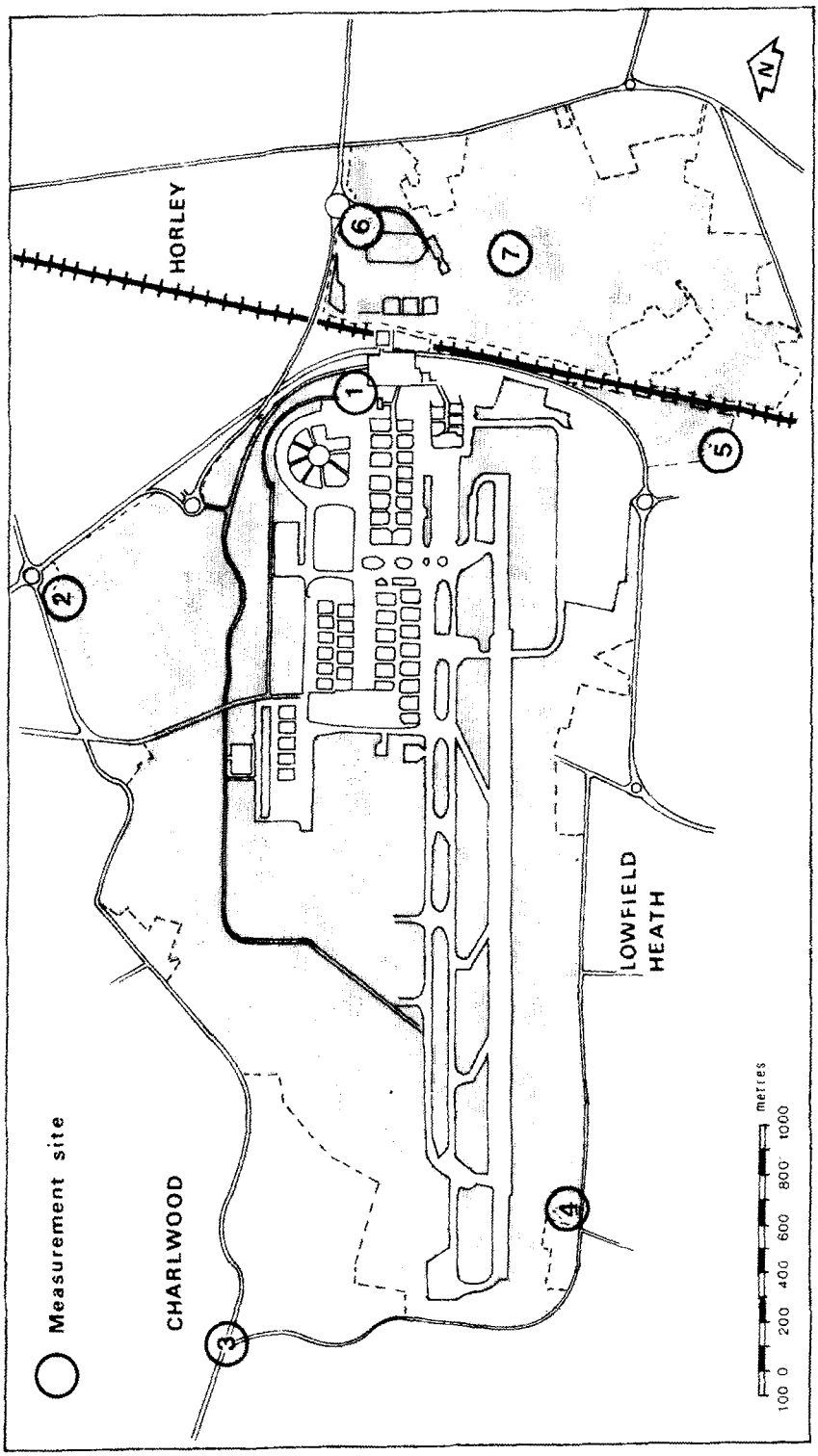

Fig. 1. Location of sampling sites at Gatwick Airport.

3. Results

The data accumulated for gaseous pollutant concentrations at the fixed site over the period 8 February to 30 June, 1979 (a total of 3400 hr monitoring) are summarised in Table I as arithmetic means and percentiles, together with data from London kerbside and off-street locations for comparative purposes. For those pollutants where a comparison is feasible, it is evident that concentrations measured at Gatwick Airport are lower than those recorded at the central London off-street site and markedly lower than those at the kerbside location.

Air quality criteria for gaseous compounds have been established by the United States Environmental Protection Agency (USEPA) and the World Health Organisation (WHO).

For carbon monoxide the US Federal Regulations state that an 8-hr mean of 9 ppm or an hourly mean of 35 ppm is not to be exceeded more than once per year. During the period of monitoring the values recorded at Gatwick were well below these standards.

TABLE I

Summary of gaseous pollutants measured at Gatwick Airport (fixed site) and comparison with other sites in the U.K.

Pollutant and site	Arithmetic mean	Percentiles of distribution of hourly means		
		50	90	99
THC (ppm)				
Gatwick	2.7	2.6	3.5	5.1
London off-street		3.0	6.0	10.0
London Kerbside		4.6	8.7	16.5
CO (ppm)				
Gatwick	0.4	0.2	0.7	1.6
London off-street		2.4	4.8	7.9
London Kerbside		3.9	8.5	14.1
NO (pphm)				
Gatwick	1.8	0.9	3.4	13.3
London off-street		2.9	8.4	17.5
London Kerbside		5.5	22.8	54.0
NO_2 (pphm)				
Gatwick	2.3	2.0	3.5	5.1
London off-street		2.8	6.7	12.8
London Kerbside		Similar to off-street site		
NO_x (pphm)				
Gatwick	4.1	3.2	6.7	16.7
NMHC (ppm)				
Gatwick	0.2	0.2	0.4	0.7

In the case of nitrogen dioxide the World Health Organisation criterion is that an hourly mean of 10–17 parts per hundred million (pphm) should not be exceeded more than once per month; these levels have not been exceeded at all at the Gatwick fixed site during the period of measurement. The nitrogen dioxide standard in the United States is expressed as an annual average 5 pphm, not to be exceeded, and although the measuring period did not extend over a year the average concentration of nitrogen dioxide at the Gatwick fixed site over the 5 months measurement period was 2.3 pphm, with a 99th percentile of 5.1 pphm, so that it would seem most unlikely that the United States standard would be exceeded.

The US Federal standard for non-methane hydrocarbons (0.24 ppm 6 am – 9 am average) was promulgated, not to protect the populace from adverse health effects due to the hydrocarbons themselves but rather in an attempt to reduce secondary photochemical pollution, of which non-methane hydrocarbons are a precursor. The timescales of reactions of individual hydrocarbons vary from minutes to days so that the phenomenon of photochemical pollution tends to be regional, covering distance scales of the order of hundreds of kilometres. It is clear that NMHC emissions at Gatwick Airport, inasmuch as they affect the regional photochemical pollutant burden, should be considered in a regional context although they are only in total, roughly 6% of those in Greater London.

With the length of time involved in data accumulation, trend analysis can be performed over the period of study. An example of this is shown in Figure 2 where daily average pollutant levels have been plotted, together with the daily total aircraft movements (ACM) at Gatwick, for the monitoring period. The ACM plot displayed a pronounced upward trend beginning around 1 April and continued through the rest of the period as the summer peak of aircraft traffic was reached. The daily movements in June were typically 1.5 times those in February. Turning to the trend plots for the gaseous pollutants, it is clear that no similar upward trend was discernible. An analysis of the meteorological data indicated that the wind direction was from a sector from 180° (due South) to 240° for 50% of the time from April to June compared with 35% in February and March. (The average wind speeds in each sector were also very similar for both periods). This arc broadly represents those wind directions for which airport sources were likely to contribute to concentrations at the fixed site, so that despite the lack of upward trend, the potential for contribution by the airport was rather greater on average during the latter period. On the other hand, it is possible that atmospheric dispersion conditions could have been worse during the former period. Therefore, all that can really be concluded from the measured data is that the potential increased contribution from increased aircraft movements was obscured by the variation in concentrations arising from other sources and by the variations in dispersion conditions.

To illustrate the averaged behaviour of pollutant levels with time of day, Figures 3 and 4 show the diurnal average variation of the measured gaseous pollutant concentrations. These plots were generated by averaging, over the whole period, the measured hourly means for each hour of the day in turn. The graphs show that on average CO and NO, and to a much lesser extent THC, peak at roughly the same time, namely

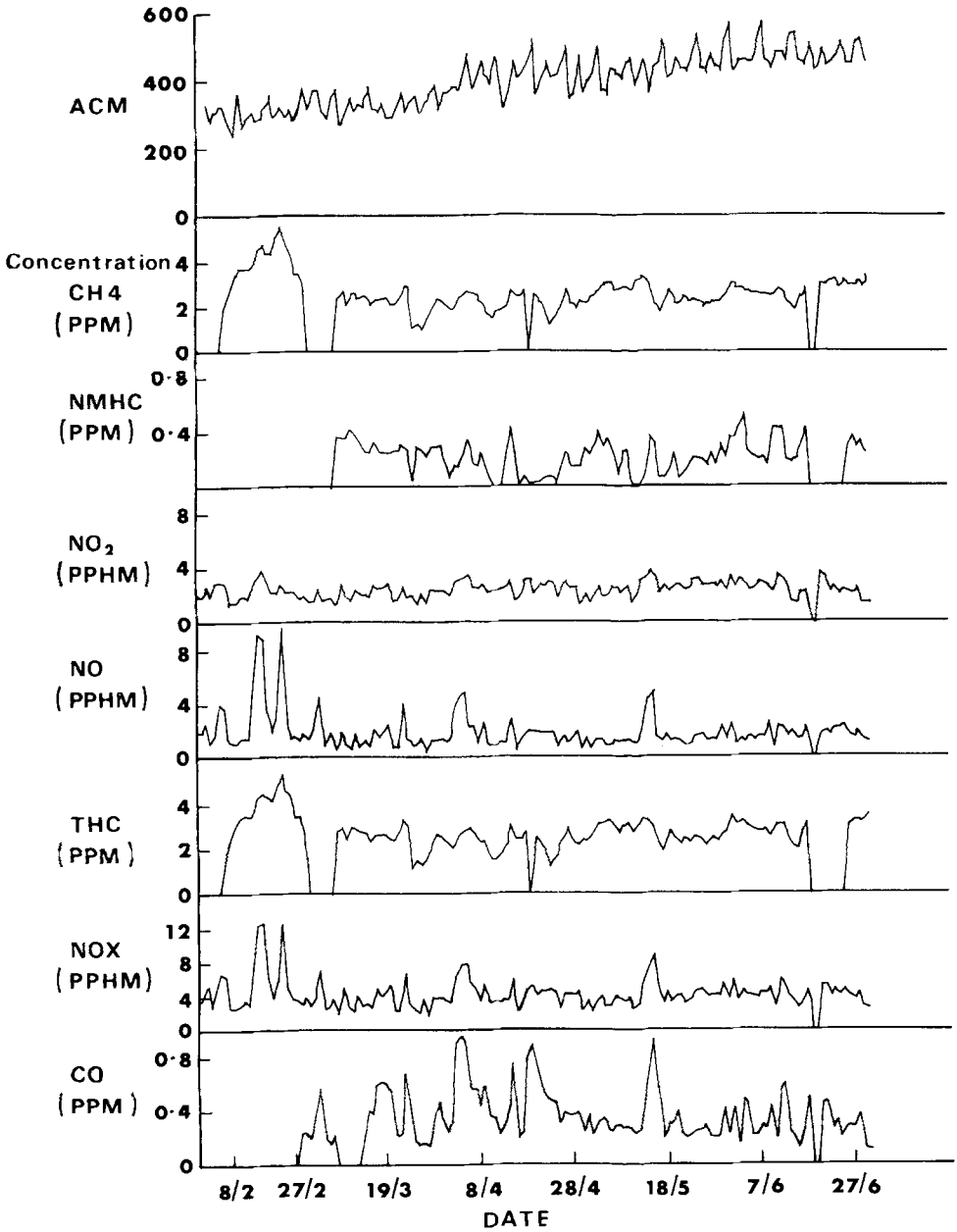

Fig. 2. Daily aircraft movements (ACM) and air quality data for the fixed site (1).

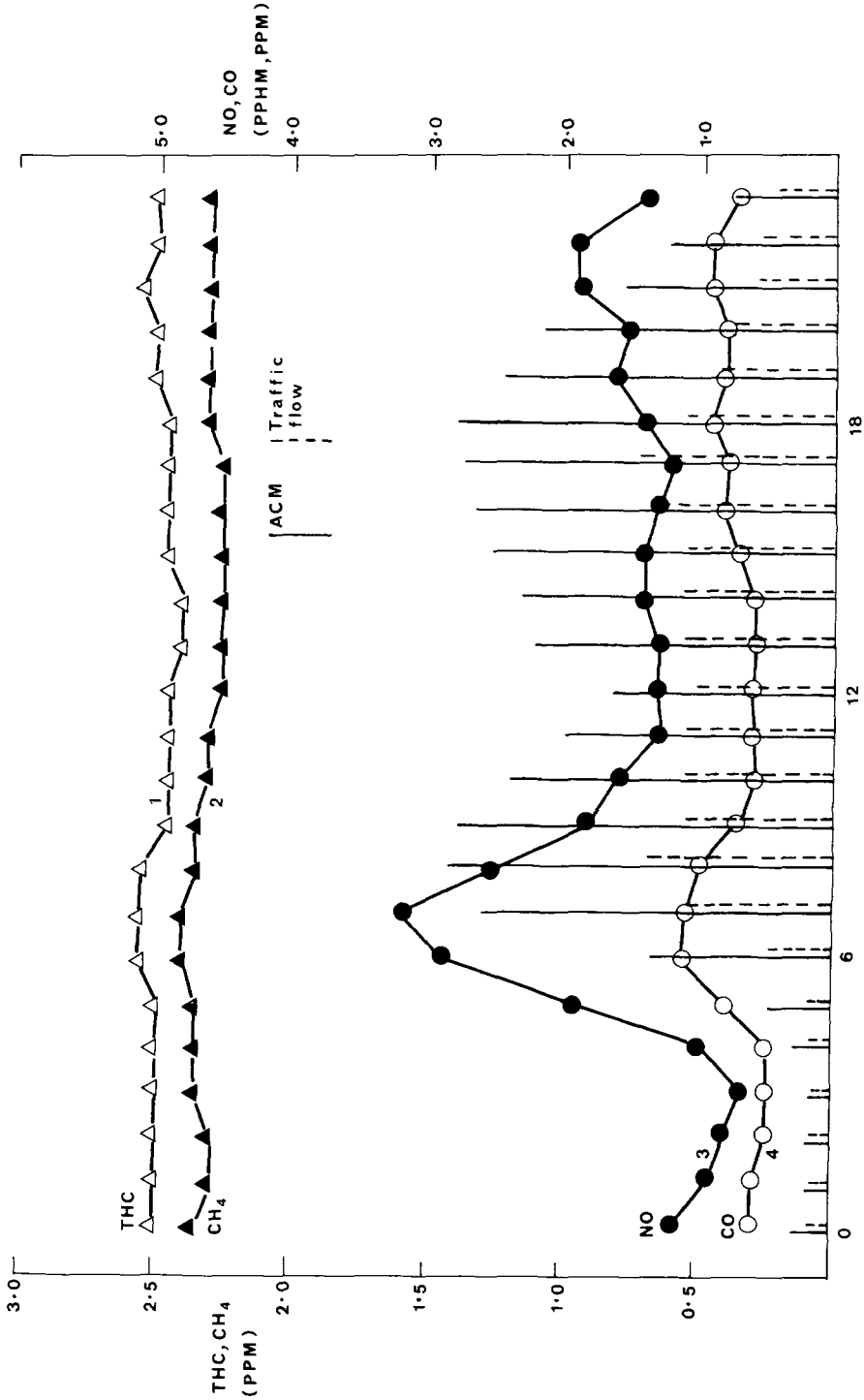

Fig. 3. Average diurnal variation with aircraft movements (ACM) and traffic flow of concentrations of THC, CH_4, NO, and CO at the fixed site.

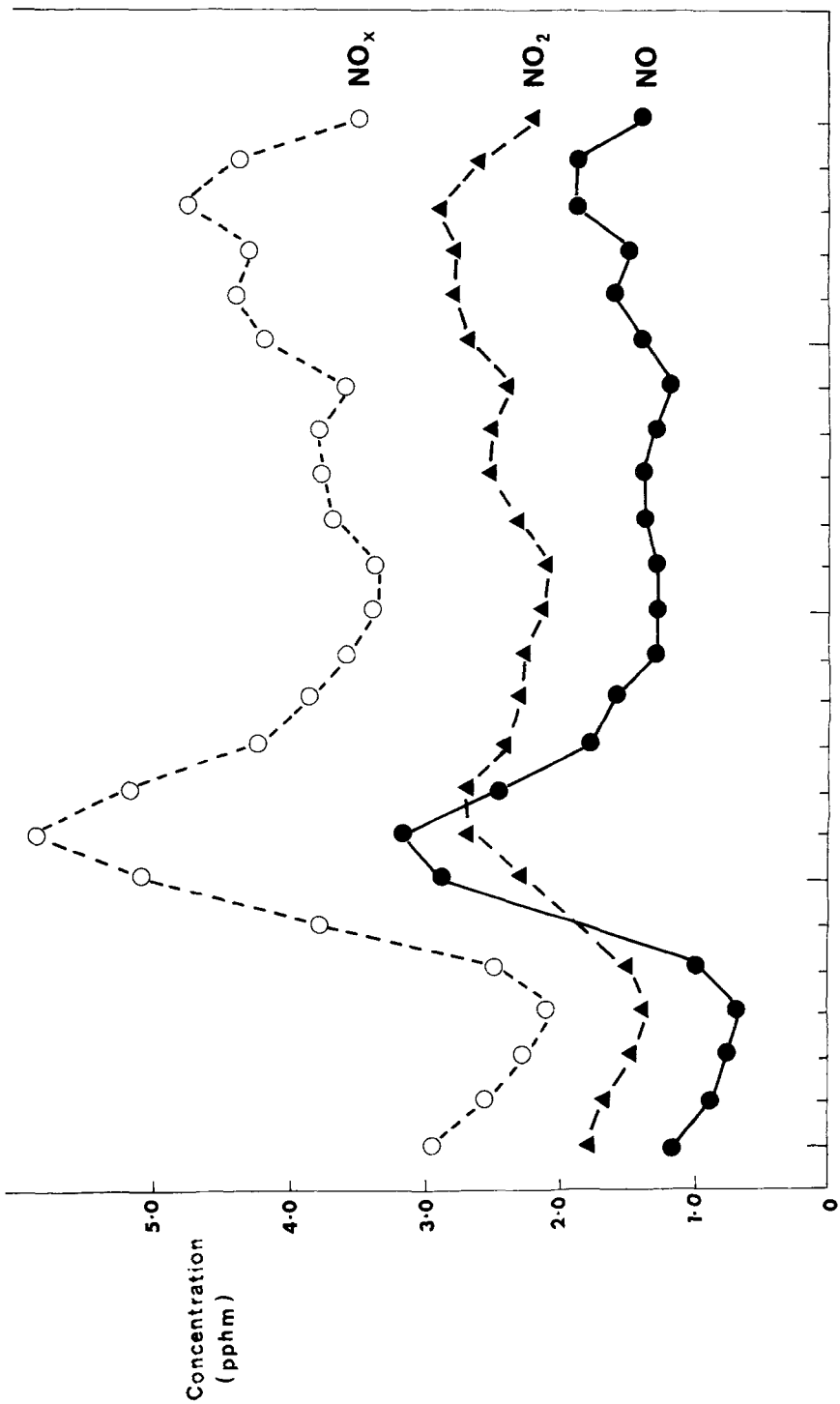

Fig. 4. Average diurnal variation in oxides of nitrogen concentrations at the fixed site.

between about 6 am and 8 am, with some evidence of a rather broader maximum later in the evening whose magnitude is less than the morning peak. Such a profile is fairly typical of urban patterns of pollution behaviour and arises from a variety of causes. Also shown in Figure 3 are typical patterns of hourly aircraft movements at Gatwick and hourly road traffic flows on the A23 road south of the passenger terminal, based on data provided by BAA. Both patterns show marked increases at roughly the time that the pollutants show a morning peak. It is tempting to draw the conclusion from these plots that these two types of sources are solely responsible for the observed pollutant levels. However stationary sources of the pollutants (space heating emissions from domestic, commercial and industrial sources), particularly NO and NO_x, are also beginning to increase at roughly the same time so that it is not possible to attempt to quantify the contributions from the various possible sources from measurements alone. The reason for the less well defined evening concentration peak is probably that dispersion conditions were on average poorer in the 6–8 am period than in the 5–6 pm period and also the fact that the evening traffic peak is flatter. Further insight into the meteorological factors affecting pollutant concentrations at the fixed site is afforded by an analysis of the measured concentrations in terms of wind direction. Pollution roses, obtained by averaging all the hourly mean concentrations measured when the wind blew from each of 12 30° sectors, have been derived and an example for CO is included in Figure 5.

It was evident that the CH_4 concentrations displayed no significant directional dependence. This is consistent with an ubiquitous natural source and it seems likely that such differences in levels on different wind directions, as are apparent, arose from differences in wind speed and atmospheric stability in these directions. The THC rose was very similar to that for CH_4 since the latter accounts for the majority of the THC, so that variations in THC are very much dominated by variations in CH_4. The NMHC rose displayed more pronounced directional dependence with slightly higher concentrations being observed with winds in the 240°–330° and 30°–120° directions. The airport sources would be expected to contribute in an arc from roughly 180° to 240° so that it would appear that, on average, NMHC concentrations were lower on winds from this sector than on the easterly (30°–120°) and westerly (140°–330°) directions, although the airport could contribute to the westerly arm of the pollution rose.

The CO rose shows distinct bias towards the east-south-easterly sector centred roughly on a wind direction of 105° and also to the north-north-westerly sector (345°). Average concentrations from these sectors were respectively 1.6 and 1.4 times those from the airport sectors.

The overall pattern of the NO rose was similar to that of CO in that the highest concentrations appeared on east to south-easterly winds, with the difference that the north-easterly sector showed a greater relative contribution than was the case for CO. Possible sources over and above background levels in the area, giving rise to these directional biases, are the airport car parks and associated minor roads to the east of the site, the A23 and M25 spur to the north and east and also the urban area of Horley. In the case of CO emissions for the UK as a whole, motor vehicles account for 88% of the total (Apling *et al.*, 1979) so that it is probable that the motor vehicle emissions

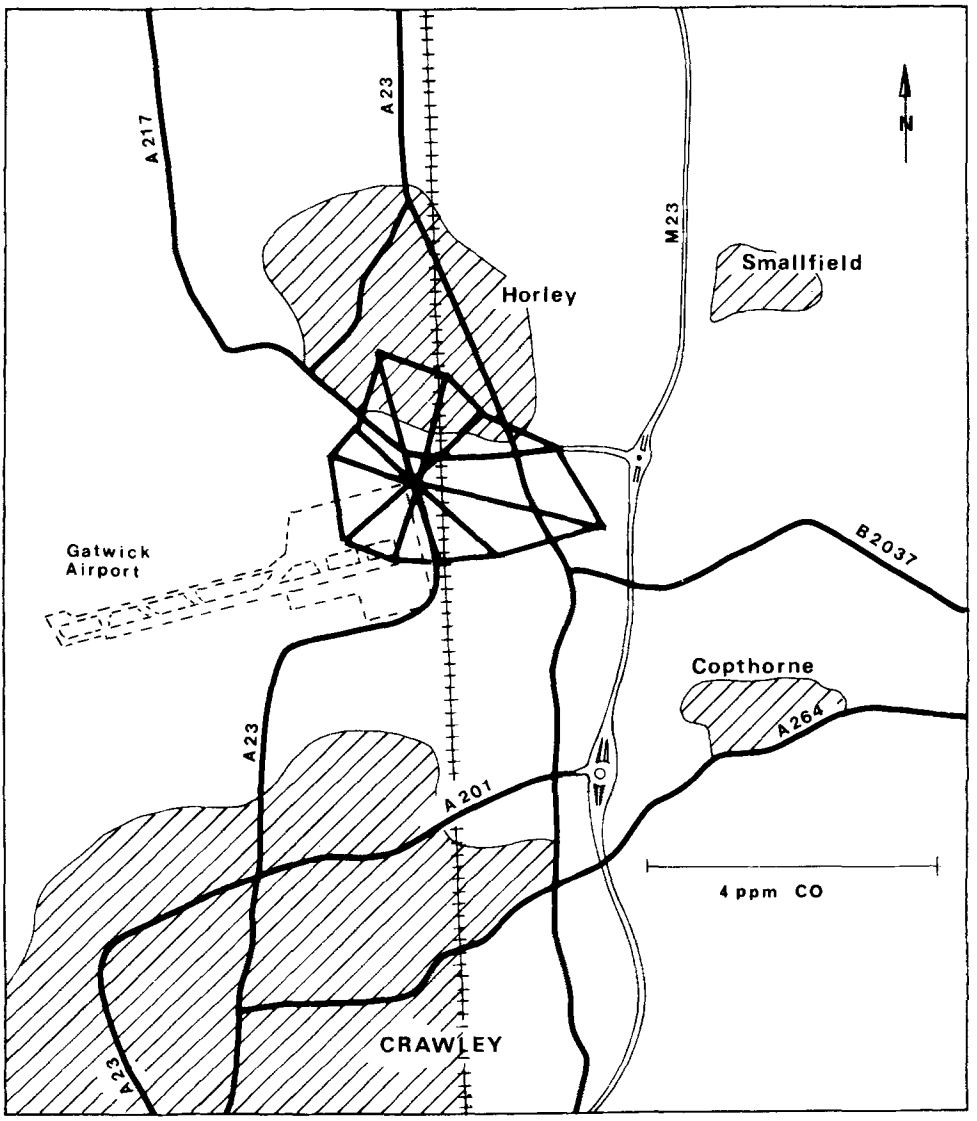

Fig. 5. Pollution rose for carbon monoxide.

from the above areas were responsible for the greater part of the observed CO concentrations from the north to east sectors. The situation as regards NO is not so straight-forward, particularly in relation to the northern sectors, since there was likely to be a significant contribution from stationary sources in the Horley area for this pollutant.

The NO_2 rose was more nearly isotropic than those of the primary pollutants CO and NO, which is consistent with the fact that NO_2 is produced by reactions involving NO from both local and more distant sources. The results of the lead measurements at the Gatwick fixed site are shown in Table II where they are compared with concentrations observed at five UK urban sites, the EEC standard and with the United States standard. From these results it is clear that lead levels at the Gatwick fixed site were very similar to concentrations in other UK urban areas, and that levels did not exceed the United States standard or the EEC guideline. Since modern jet aircraft do not burn fuel which contains lead, the major source of this pollutant will be from road traffic in the vicinity of the airport.

TABLE II

Comparison of lead concentrations measured at Gatwick Airport (fixed site) with other sites in the U.K.

Site/comparison	Lead concentration (ng m^{-3})
Gatwick	430
Five sites mean 1976/7	510
Five sites mean 1977/8	180
US standard[a]	1500
EEC Standard[b]	2000

[a] Mean over a calendar quarter.
[b] Annual mean.

A summary of the distribution of smoke concentrations is given in Table III, together with the WHO acute effects threshold and the EEC directive limit value (Commission of the European Communities, 1980). The smoke concentrations measured at the fixed site are well below these criteria and, though monitoring was only conducted over a period of 5 months, it is most unlikely that these criteria would be infringed over the period of a year.

TABLE III

Percentiles of the distribution of daily mean smoke concentrations at Gatwick

Site/ standard	Arithmetic mean ($\mu g\ m^{-3}$)	Percentiles of distribution ($\mu g\ m^{-3}$)		
		50	90	99
Gatwick	21	17	30	38
WHO	100			
EEC	68			

TABLE IV

Concentrations of gaseous pollutants measured at the mobile sites

Site	Carbon monoxide ppm			Non-methane hydrocarbons ppm			Nitric oxide pphm			Nitrogen dioxide pphm		
	Mean	Percentiles		Mean	Percentiles		Mean	Percentiles		Mean	Percentiles	
		50	99		50	99		50	99		50	99
2	0.2	0.1	0.9	0.5	0.3	1.9	1.5	1.3	7.1	1.5	1.2	4.5
3	0.9	0.5	4.0	0.4	0.3	1.2	1.5	0.9	7.3	1.3	1.1	2.8
4	0.3	0.2	1.3	0.7	0.6	1.3	2.0	1.6	4.8	1.5	1.2	3.2
5	0.4	0.3	2.2	0.3	0.2	0.9	2.8	1.2	18.6	1.5	1.2	4.3
6	1.0	0.7	4.7	0.7	0.5	2.0	3.1	1.9	16.0	2.3	1.8	6.9
7	0.3	0.2	1.6	0.2	0.1	0.3	1.1	0.7	4.4	1.8	1.4	6.0

The results of air quality monitoring for gaseous components at the six mobile sites are summarised in Table IV.

Overall concentrations of all pollutants were low and, as was the case at the fixed site, site I, none of the standards discussed were exceeded for any of the gaseous pollutants, other than NMHC, measured at any of the mobile sites during the period of monitoring.

CO concentrations were low and in terms of arithmetic means, site 6 and site 3 with values of 1.0 ppm and 9.0 ppm respectively, exceeded the level of 0.4 ppm at the fixed site. These two sites also exhibited higher upper percentiles than the other sites including the fixed site. In the case of site 6 this is almost certainly due to the influence of motor traffic (*c.f.* NO). Total hydrocarbon concentrations are of comparable magnitude for all the sites, since the major proportion is naturally generated methane.

The non-methane hydrocarbon concentrations displayed rather more variability among the sites, with 2, 4, and 6 exhibiting the highest levels, which were also greater than those measured at the fixed site. It seems likely that motor vehicles are the source of the higher levels of NMHC at sites 4 and 6 although some contribution from the runway to site 4 is possible. At site 2 the higher levels of NMHC were observed on wind directions from the north-west (300°–330°) and from the east to south-east direction (90°–120°) which would tend to rule out the airport as being the source of these higher levels. The source of these relatively high NMHC levels is not clear. The US standard of 0.24 ppm was exceeded at all mobile sites.

A further summary of the results of monitoring at the mobile sites is given in Figure 6 which includes the time series of daily mean concentrations for the gaseous pollutants at the various sites. This shows clearly that, overall, site 6 exhibited the highest levels. The higher than average concentrations observed at site 5 during the last week of monitoring coincided with some activity in the car park associated with the removal of some Portakabin structures. Figure 6 also indicates that there was little or no correlation

TABLE V

Airborne particulate lead concentrations measured at the mobile sites

Site	Lead concentration (ng m^{-3}) (arithmetic mean over monitoring period)
2	200
3	447
4	373
5	588
6	333
7	290
US Standard	1500[a]
EEC Standard	2000[b]

[a] Mean over a calendar quarter
[b] Annual mean

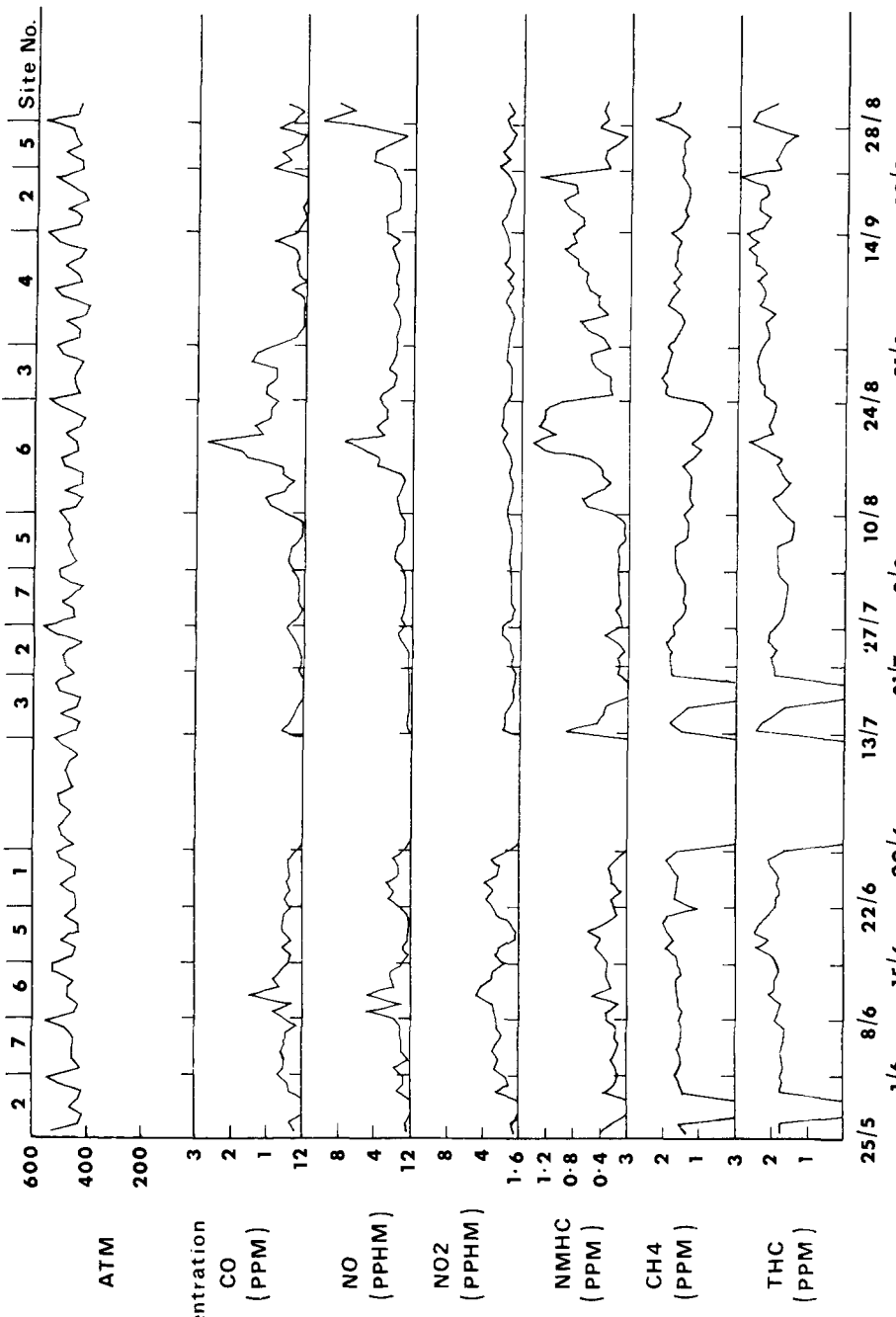

Fig. 6. Daily aircraft movements (ACM) and air quality data for the mobile sites (2–7).

between total aircraft movements and pollutant concentrations, a result which was also demonstrated for the fixed site.

Concentrations of particulate airborne lead measured at the mobile sites are presented in Table V, and are compared with the US and EEC standards.

4. Discussion

An overall assessment of the gaseous pollutants measured in the vicinity of Gatwick airport during the course of this survey revealed that concentrations were generally low in comparison to those measured at other urban locations in the UK and also low when compared with established ambient air quality guidelines. Smoke and particulate lead concentrations were also low in comparison to the US, WHO, and EEC guidelines. An exception occured in the case of NMHC, where measured concentrations exceeded the US standard at all of the sites monitored. These occurences are not, however, considered to be significant in a public health context, for the reasons discussed previously.

The pollution roses, derived from data accumulated over the period of continuous monitoring at the fixed site (1), revealed that, within the limitations of the technique, greater quantities of the pollutants considered were emitted from sources on wind directions away from the airport complex than when the wind blew across the airport in the direction of site I. It is concluded from these data that sources such as nearby roads, emissions from urban areas in the vicinity and general background concentrations of air pollutants greatly influenced air quality. The importance of background concentrations in relation to general air quality has been underlined by the results of studies at Stansted airport (Williams *et al.*, 1981) and at Washington DCA (Yamartino *et al.*, 1980). In the latter case, 70% of the mean total NO_x emissions were accounted for by background concentrations. Similarly, data acquired from monitoring studies at Williams Air Force Base (U.S.A.), demonstrated that the maximum concentrations of CO occurred at sites heavily influenced by traffic on nearby roads (Daley and Naugle, 1979).

The problem of discrimination between individual sources of the same pollutants, in order to distinguish between airport and non-airport related air pollutants, was addressed during this survey by means of spot-sampling of individual aromatic hydrocarbons (Tsani-Bazaca *et al.*, 1982). By comparison of characteristic gas chromatographic hydrocarbon profiles of petrol and common aviation fuels with ambient hydrocarbon profiles obtained from samples taken at the six mobile sites, it was possible to identify three sites (2, 4, and 5) which were, at the times of sampling, influenced by aircraft operation. It should be emphasized that the results of these analyses do not imply that air quality at sites 2, 4, and 5 was always influenced by aircraft operations, but rather than these sources could, at certain times, given correct wind direction and dispersion conditions, contribute to NMHC concentrations at all the sites monitored here. Although aircraft operations *per se* contribute to pollutant emissions, the marked increase in aircraft movements over the period February to June 1979 was not

accompanied by any discernible trend in pollutant concentrations at any of the sites, which is perhaps suprising when the associated increase in vehicular traffic activity is considered. It is likely that an overall increase in vehicular activity in the general area of Gatwick may have obscured any possible trend in pollutant concentrations.

On the basis of the results of this monitoring exercise, the airport cannot therefore be considered to be a significantly more important contributor to ground-level concentrations of air pollutants than other sources in the general surrounding area. The modelling study, which was performed in parallel with the monitoring survey reported here, has indicated that, within the limitations of the techniques employed, should the airport be developed, current ambient air quality standards and guidelines would not be infringed, with the exception, as is presently the case, of NMHC. It is further concluded that ground-level concentrations of air pollutants in the future will be lower than typical London background concentrations, with the possible exception of NO in the variety of car parking areas.

Acknowledgments

The authors are grateful to the British Airports Authority (BAA) and Warren Spring Laboratory (Department of Industry) for the financial support necessary to undertake this study.

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