1 Summary

The primary aim of the London-Wide PAH survey, which has been in operation since 1991, is to make an assessment of the exposure of the London population to PAHs. The data from this survey have been compared with guidelines for PAHs and with results of PAH surveys conducted in other urban areas in the UK, in order to increase the understanding of the scale of the pollution problem posed by PAHs in London.

There is evidence from epidemiological studies on coke-oven workers and coal-gas workers to implicate inhaled PAHs as a cause of lung cancer. It is estimated that exposure to Benzo (a) pyrene (BaP) results in a unit lifetime risk of about 10^{-4} per ng m^{-3}. This risk has been expressed in terms of BaP rather than total PAH because BaP is the best-known carcinogen in the PAH group, and 'total PAH' is not a well-defined substance.

There is currently no national guideline or standard for PAH. However, PAH's are included in the EU Ambient Air Quality Framework Directive as 'other pollutants to be taken into consideration' and it is expected that the Expert Panel on Air Quality Standards (EPAQS) will recommend a guideline for PAH's within the next year.

With respect to sources and chemical origin of PAH, estimates of atmospheric emissions of PAH by source type for Sweden and the UK indicate that the major sources in these countries are stationary and sensitive to the type of plant and fuel. In urban areas, however, mobile sources are likely to be the major contributors to PAH emissions and diesel emissions are thought to be the primary source of urban PAH.

The measurement programme for the London-Wide PAH survey was devised so as to reflect the fact that vehicle emissions are the primary source of PAH in urban areas (most of the locations chosen for sampling were therefore close to busy roads) and also that PAH levels tend to vary seasonally (measurements were therefore made in both summer and winter seasons). Fifteen PAH compounds were selected for measurement, based upon US EPA recommendations with respect to air monitoring programmes.

Nine measurement sites were chosen, one in each of the Boroughs participating in the 1996/97 survey. At each site, a sample of approximately two weeks duration was taken in the summer of 1996 and another in the winter of 1996/97. Sites were classified as roadside, intermediate and background. Roadside sites are generally within 20 m of a busy road, for example at the facade of buildings adjoining the road; intermediate sites are those either between 20 m and 40 m from a busy roadside and/or at a height greater than 10 m above the kerb; background sites are classed as those located at a distance greater than 40 m from any roadside. PAH measurements were also made at a site located on Southwark Street, London SE1 for two week periods in each month between March 1996 and March 1997.

It is possible to identify some general trends in the data set:

- As in previous London Wide PAH surveys wide variations in concentration were found, from compound to compound, site to site and season to season. This is a general feature of PAH concentrations surveyed in urban areas.

- Concentrations measured at roadside and intermediate sites were consistently higher than at the background sites, emphasising the importance of road traffic as a source of PAH.

- Use of BaP as an index of carcinogenicity indicates that concentrations of BaP in London monitored during the 1996/97 survey were considerably below European guidelines. However, annual means exceeded the US EPA guideline of 1 ng m^{-3} at six boroughs, these being Bexley, Brent, Harrow, Hammersmith and Fulham, Wandsworth and Westminster.

- Comparison of the results of the 1996/97 London Wide PAH survey with other surveys indicate that measured concentrations are broadly similar to those recorded in other parts of the country.

- In view of the limited quantitative information available on the health effects of the PAH species measured, it is considered that the health risks for individuals with the highest exposure to roadside PAH levels in London are finite but very small; for smokers the risks would appear trivial compared with those associated with exposure to PAH from cigarette smoke.

Policy measures to reduce emmisions from diesel cars and heavy goods vehicles include stringent emission standards and an improvement in the quality of diesel fuel. However, the effect that these reductions will have on ambient PAH concentrations in urban air is not yet clear as the legislation will be operating against an increase in the diesel fleet.

The London wide PAH survey provides a valuable database of information on hydrocarbon levels in London, particularly at roadside locations, allowing the impact of recent legislation on London's air quality to be monitored.

7 The Measurement Programme

7.1 General

Mobile sources are likely to be the major contributors to PAH emissions in urban areas and exhaust emissions from traffic have become one of the most important sources of PAHs in London and other towns. Most of the locations chosen for sampling were therefore close to busy roads, with the remainder located at a distance from any road, in order to provide some information on background pollution levels.

Air pollution levels tend to be higher during winter than summer because of less favourable conditions for atmospheric dispersion during the winter months. For PAHs, this effect is likely to be enhanced by the increased use of fossil fuels for the heating of homes and offices in winter. Measurements were therefore made in both seasons.

It is generally agreed that BaP by itself is not a satisfactory index of total PAH, but there is no universally agreed selection of PAHs which does perform such a role. About 500 PAH compounds have been detected in ambient air and it is clearly impracticable to measure all but a small fraction of this number.

The most authoritative recommendation with respect to the selection of a species for measurement is probably that of United States Environmental Protection Agency (US EPA), which has listed 15 PAHs as priority pollutants, due to their toxicity and common occurrence, for air monitoring programmes, and it is these that have been measured in this survey. The US EPA list contains a selection of compounds likely to occur at relatively high levels, and includes members across a wide range of molecular weights, from the volatile, 2-ring, napthalene to those of higher molecular weight, which are likely to be predominantly in the particle phase. The individual compounds are listed in Table 3.

Factors which influence the inclusion of a particular compound in a measurement programme include its carcinogenic potential, whether the compound is present in the atmosphere in sufficient concentration to permit reliable measurement with the analytical techniques and reference standards currently available, and also whether the relative concentrations of particular compounds give an indication of the main source of PAHs.

Human carcinogenicity data are available only for PAH mixtures, and our knowledge of the carcinogenicity of individual PAHs therefore comes from *in vitro* and animal studies. There is no definitive 'carcinogenicity classification' of PAH compounds, but two recent authoritative commentaries are in general accord (2 & 3). A rough classification based on these two commentaries is given in Table 3.

Table 3: The PAH Compounds Measured

Compound and Abbreviation		Cancer Rating [(a)]	Rings	Mol wt
Napthalene	Np	?	2	128
Acenapthene	ACE	-	3	166
Fluorine	FL	-	3	166
Phenanthrene	PHE	?	3	178
Anthracene	ANT	-	3	178
Fluoranthene	FLH	?	4	202
Pyrene	PYR	-	4	202
Benzo[a]anthracene	BaA	+	4	228
Chrysene	CHR	+	4	228
Benzo[b]fluoranthene	BbF	+ +	5	252
Benzo[k]fluoranthene	BkF	+ +	5	252
Benzo[a]pyrene	BaP	+ + +	5	252
Dibenz[ah]anthracene	DahA	+ + +	5	278
Benzo[ghi]perylene	BghiP	+	6	276
Coronene	COR	-	7	300

Note

(a) Carcinogenic classification: a dash (-) indicates that there is no evidence for carcinogencity, a question mark (?) that there is insufficient evidence, and one or more plus signs (+) that there is sufficient evidence.

7.2 Measurement Sites and Sampling Periods

Nine sites were chosen, one in each of the Boroughs participating in the survey. At each site, a sample of approximately two weeks duration was taken in the summer of 1996 and another in the winter of 1996/97. The sites, together with the dates of sampling, are listed in Table 4.

Sites were classified as "roadside", "intermediate" and "background". Generally, "roadside" sites are classed as being within 20 m of a busy road, for example at the facade of buildings adjoining the road; "intermediate sites" are those either between 20 and 40 m from a busy roadside and/or at a height greater than 10 m above the kerb; "background" sites are classed as those located at a distance greater than 40 m from the roadside. Full descriptions of all the sites are given in Appendix A.

Table 4: Sites and Sampling Periods

Site			Sampling Period	
No.	Borough	Type	Summer	Winter
1	Bexley	B	19/07/96 - 05/08/96	05/12/96 - 19/12/96
2	Brent	I	23/08/96 - 06/09/96	13/02/97 - 27/02/97
3	Greenwich	B	19/07/96 - 05/08/96	05/12/96 - 19/12/96
5	Hammersmith + Fulham	R	22/08/96 - 06/09/96	23/01/97 - 06/02/97
6	Harrow	I	06/09/96 - 20/09/96	13/02/97 - 27/02/97
8	Newham	R	05/08/96 - 21/08/96	05/12/96 - 19/12/96
9	Richmond	R	07/08/96 - 22/08/96	23/01/97 - 06/02/97
11	Wandsworth	I	07/08/96 - 22/08/96	23/01/97 - 06/02/97
12	Westminster	R	22/08/96 - 06/09/96	13/02/97 - 27/02/97

Note: B = Background
I = Intermediate
R = Roadside

PAH concentrations were measured for approximately two week periods at each location. The measurement periods were not, in general, coincident at all nine sites. As air pollution levels are dependant upon weather conditions, it is possible that site-to-site differences reported in previous surveys may have been due to changes in weather conditions from sampling period to sampling period. In an attempt to examine possible seasonal variations in PAH concentrations monitoring was conducted at a further site located on Southwark Street, London, SE1 for two weekly periods between March 1996 to March 1997.

7.3 Sampling Procedure

PAH samples were collected by drawing air through a filter.

Whatman GF/A glass microfibre filters (60 mm diameter), in conjunction with M-type samplers, were used throughout the survey. The filter holder was mounted with its open face horizontal and facing downwards. Prior to sampling, the filters were washed in dichloromethane, dried at 400°C, and wrapped in foil, and refrigerated until they were analysed. The M-type sampler operates at a flow rate of about 25 litres per minute and is fitted with a gas meter to record the total volume of air sampled. The sampling period was a nominal two weeks and each sample consisted of the particulate material in a volume of about 500 m^3 of air.

The method of sampling adopted does not collect that fraction of a PAH compound in the gas phase. The magnitude of this fraction depends principally on the molecular weight of the compound and the ambient temperature, being largest with low molecular weight compounds and high ambient temperatures. At temperatures to be expected in

London during the summer months, the gaseous fraction would be the dominant one for 2 and 3 ring compounds, while for compounds having 5 rings or more, the particle phase would be dominant. The distribution of a number of PAH compounds between gas and particle phases, as reported by Baek et al (6) for a set of measurements in London, is shown in Appendix C.

7.4 Analytical Procedure

The extraction of PAH from the filters were carried out by standard methods, and the final extracts analysed for the 15 PAH species listed in Table 3 by High Performance Liquid Chromatography (HPLC) with fluorescence detection.

A full description of the procedures is given in Appendix D.

7.5 Detection Limits

With the sampling and analytical procedures described above, the smallest measurable concentration of each PAH compound is as set out in Table 5. A result at, or below the detection limit has been recorded as equal to the detection limit.

Table 5: Detection Limits

Compound and Abbreviation		**Detection Limit (ng m^{-3})**
Naphthalene	Np	0.025
Acenaphthene	ACE	0.027
Fluorene	FL	0.048
Phenanthrene	PHE	0.027
Anthracene	ANT	0.011
Fluoranthene	FLH	0.080
Pyrene	PYR	0.034
Benzo [a] anthracene	BaA	0.007
Chrysene	CHR	0.006
Benzo [b] fluoranthene	BbF	0.020
Benzo [k] fluoranthene	BkF	0.004
Benzo [a] pyrene	BaP	0.008
Dibenz [ah] anthracene	DahA	0.009
Benzo [ghi] perylene	BghiP	0.011
Coronene	COR	0.020

8 Results

The concentrations of the PAH compounds measured at each site during the summer and winter sampling periods are given in Appendix B, Tables 1 and 2 respectively . These tables also give the total PAH concentrations (i.e. the sum of the concentrations of all 15 PAHs measured) for each site, the arithmetic and geometric means of each compound across all sites. The ratio of the winter to summer geometric mean concentration for each compound is shown in Appendix B, Table 2.

For each compound, at each site, the average of the summer and winter values was calculated to give an estimate of the overall mean concentration. These estimates are given in Appendix B, Table 3.

8.1 Concentrations - Overview

A general overview of the concentrations found is presented in Figure 1, which shows the total PAH concentrations for each site during the summer and winter sampling periods. It is evident that both the absolute concentrations and the winter/summer ratios vary considerably from site to site.

Typically it would be expected that winter PAH concentrations would be greater than those during the summer months, this however was not the case at the majority of sites. At all sites, with the exception of Harrow, Brent and Wandsworth, highest PAH concentrations were recorded in summer. The highest total PAH concentration was recorded at the Hammersmith and Fulham site during the summer monitoring period (59.18 ng m^{-3}), this site is located close to Fulham Broadway. The highest winter total PAH concentration (52.27 ng m^{-3}) was also recorded at this site. The lowest overall concentration (2.67 ng m^{-3}) was recorded at the Newham site, a roadside site located approximately 12 m from Newham High Street North.

The wide variations in measured concentrations, from compound to compound, site to site and season to season, are a general feature of the PAH concentrations typically found in urban areas.

8.2 Comparison of Roadside, Intermediate and Background Sites

It is of interest to make a general comparison of the PAH concentrations at roadside, intermediate and background sites. The mean concentration of each compound has been averaged across all three site categories and these are illustrated in Figure 2.

A classification of all sites is given in Section 7.3, Table 4.

It can be seen that the roadside and intermediate concentrations were consistently higher than the background ones, emphasising the importance of road traffic as a source of

PAHs. Concentrations were, for the majority of PAH species, slightly higher at the intermediate sites than at the roadside sites.

8.3 Winter/Summer Ratios

The winter and summer concentrations of each compound are shown in Figures 3 and 4 (absolute values) and Figure 5 (summer/winter ratios). In view of the volatility of the lower molecular weight compounds, and the relatively large fractions in the gas phase, these two figures are most informative for the compounds from benzo(f)fluoranthene (BbF) through to coronene (COR). The comments here are therefore largely confined to these compounds.

The major PAH species present in car exhaust emissions are reported to be fluoranthene (FLH) and pyrene (PYR). Benzo(ghi)perylene (BghiP) is also reported to be one of the PAHs most often associated with vehicle emissions. During the summer monitoring levels of BghiP and COR were higher than those of the other PAH species. Levels of PYR, CHR, BbF were present in the highest concentrations in the winter monitoring with levels of BghiP and COR also elevated above levels of the other PAH species. Such results suggest that emissions from motor vehicles were the largest contributing source to PAH levels measured in this study.

Figure 5 illustrates winter/summer ratios of PAH concentrations. Ratios were less than one for the majority of PAHs, as summer concentrations were higher than corresponding winter concentrations. This result differs from that which one would expect as as concentrations of many PAHs usually increase in winter due to a number of factors. For example, PAH emissions from heating sources are increased; the number of PAHs in the particulate phase increases in cooler weather; and seasonal climatic factors result in decreased dispersion and degradation of such pollutants. The exact reason for this variation is unclear but is most likely to be a reflection of climatic factors at the time of sampling.

The highest total PAH concentration was recorded during the summer period at the Hammersmith and Fulham site. Concentrations of CHR, BghiP and COR (indicative of vehicle emissions), were higher than concentrations of the other measured PAH species during this sampling period. This may be expected as the Hammersmith and Fulham site is located in close proximity to a heavily trafficked road junction on Fulham Broadway.

8.4 Comparison with Results of Previous LWEP PAH Survey

For a number of sites, sampling has been undertaken at the same location since the start of the LWEP PAH survey in 1991 and comparisons of levels from year to year are possible. Total PAH concentrations for each site monitored during the 1991/92, 1992,93, 1993/94, 1994/95, 1995/96 and 1996/97 surveys are illustrated in Figures 6 (for the summer period) and 7 (for the winter period). Note that the site at Richmond

was relocated during the 1992/93 survey; summer measurements were not made at Tower Hamlets in 1991/92; and the Kingston-upon-Thames site was relocated for the winter sampling period in 1995, therefore any comparisons must be made with caution at these sites.

Figure 6 illustrates that summer PAH concentrations at all sites, with the exception of Wandsworth, were higher in 1996 than in the previous years. Total PAH concentrations monitored in the winter 1996/97 period showed no clear pattern in relation to previous years with lower concentrations than in the 1995/96 survey recorded at Bexley, Brent and Newham. Concentrations at the remaining sites were higher than in previous year. Both the summer and winter concentrations measured at the Hammersmith and Fulham site were elevated above those recorded in all previous years. Such temporal and spatial variation is likely to reflect differences in meteorological conditions from one winter to the next.

8.5 The PAH Profile

The use of the relative proportions of the individual PAHs in a given sample or series of samples - the 'PAH profile' - has often been tried as a method of determining the relative contribution of different sources. For example, BghiP and Coronene have been suggested as markers for vehicle emissions. Benzo (a) pyrene (BaP) is readily produced by coal and coke-burning as well as being present in vehicle emissions. There is no general consensus as to the use of PAH profiles for source apportionment, and one reason for this must be that the effect of atmospheric transport, degradation and deposition processes tend to blur any initial sharp differences in the emitted PAH concentrations. However, in order to investigate the use of profiles in this study, the graph shown in Figure 8 was constructed. The PAHs chosen were the six most carcinogenic of molecular weight 228 or greater, and the average of the summer and winter concentrations was used.

Figure 8 indicates that similar PAH profiles were obtained for each of the sites. At the majority of sites concentrations of BaA, CHR, BbF and BghiP were the highest and the concentration of DahA was consistently the lowest. Such similar profiles suggest that no sites were affected significantly by a specific source, e.g. a localised industrial process, and can be attributed to a much wider source e.g. vehicle emissions.

8.6 PAH Concentration at Southwark Street, London, SE1

The short sampling periods used in the LWEP PAH survey limit data analysis to some extent as they only provide a snapshot of PAH concentrations. In order to assist our understanding of the individual results for each site more extensive measurements of PAH were made at one site over the 1996/97 period. This site is located on Southwark

Street, London, SE1 and is a rooftop site some 30 m above ground level in an area of heavy traffic. Air at this location could be considered well mixed and away from local sources. PAH concentrations at this site were monitored between March 1996 and March 1997.

The total PAH concentration (ng m^{-3}) for each sample period since the site was commissioned in 1993, is illustrated in Figure 9. The total PAH concentration varied considerably from month to month. As with the other sample sites PAH concentrations were generally higher in the summer months than winter months of 1996/97. The arithmetic mean of the total PAH concentration over the sample period was 12.16 ng m^{-3} which compares with 15.26 ng m^{-3} at the background sites (Bexley and Greenwich), 26.79 ng m^{-3} at the intermediate sites and the mean value of 28.60 ng m^{-3} from the roadside sites. The PAH profile of the mean concentration of the carcinogenic compounds for each sampling period at the Southwark Street site is shown in Figure 10. Throughout the survey CHR, BbF and BghiP the PAH species with the consistently highest concentrations, again demonstrating the importance of vehicle emissions at this urban background site.

As Figures 9 and 10 illustrate, total PAH concentration and the concentrations of individual PAH species varied from month to month, as might be expected.

8.7 BaP Concentration as a Percentage of all Major Carcinogenic PAHs

Benzo (a) pyrene (BaP) is the only PAH for which there are any authoritative recommendations as to an appropriate guideline or standard. It is often stated that the BaP concentration on its own is not a satisfactory index of the total carcinogenic potential of a mixture of PAHs, so it is of interest to find the BaP concentration expressed as a percentage of all the major carcinogenic PAHs. In the context of the present measurements, this is:

BaP conc. x 100 ÷ sum of conc. (BaA/CHR + BbF + BkF + BaP + DahA + BghiP).

This percentage has been calculated for the estimated annual average concentrations and the values are given in Table 6.

Table 6: BaP concentrations as a percentage of the sum of the concentrations of (BaA/CHR + BbF + BkF + BaP + DahA + BghiP)

Site	Borough	Percent BaP
1	Bexley	12.35
2	Brent	12.55
3	Greenwich	10.14
4	Hammersmith and Fulham	12.79
5	Harrow	7.86
6	Newham	7.63
7	Richmond	10.23
8	Wandsworth	11.41
9	Westminster	11.42
Arithmetic Mean		10.71

Percentages for background sites ranged between 10.14 % and 12.35 %; intermediate sites ranged between 7.86 % and 12.55 %; values at roadside sites ranged from 7.63 % to 12.79 %.

8.8 Comparison of Results with Guidelines for BaP

If BaP is used as an index of PAH carcinogenicity, then some comparison of the LWEP PAH survey results with the Dutch and German guidelines for BaP (5 and 10 ng m^{-3} respectively) is possible. However it must be noted that these guidelines relate to annual mean concentrations, and the short sampling periods used in this survey mean that any comparison can only be approximate.

The overall mean concentration of BaP ranged between 0.38 ng m^{-3} at Newham to 3.78 ng m^{-3} at Hammersmith and Fulham. The overall mean BaP concentration for the nine sites was 1.70 ng m^{-3} (Table 3, Appendix B).

The mean BaP concentration was lower in winter (1.65 ng m^{-3}) than in summer (1.75 ng m^{-3}). The highest BaP concentration of 4.13 ng m^{-3} was recorded during the summer sampling period at Hammersmith and Fulham.

The survey results indicate that mean BaP concentrations in all of the participating London Boroughs were below European guidelines over the sampling periods. The mean BaP concentration recorded during the 1996/97 survey did however exceed the guideline value of 1 ng m^{-3}, derived in Section 5.0 from US EPA estimates of 'acceptable risk'. This result is similar to those from the surveys prior to 1993 in which overall mean BaP concentrations were 1.5 ng m^{-3} (1991/92) and 1.91 ng m^{-3} (1992/93). Annual average BaP concentrations in 1996/97 exceeded the US EPA guideline at six of the nine sites, these being Bexley, Brent, Hammersmith and Fulham, Harrow,

Wandsworth and Westminster. Concentrations of 1.44 ng m^{-3}, 2.71 ng m^{-3}, 3.78 ng m^{-3}, 1.54 ng m^{-3}, 1.37 ng m^{-3} and 2.51 ng m^{-3} were recorded at these locations respectively.

8.9 Comparisons with the Results of Other Surveys

Owing to the limited sampling periods used in the Stanger Science and Environment LWEP PAH survey, and variation in sampling technique, regime and so forth, it is not appropriate to make detailed comparisons between the results obtained from this survey with other surveys. Despite the limitations of the measurements, some tentative comparisons may be made between PAH values for our survey and those presented in Table 2 of this report.

The results from the other urban surveys (i.e. those undertaken in South Kensington, Birmingham and Manchester) are compared with results from the 1996/97 LWEP survey (Table 10). It would appear that the concentrations of the PAH species recorded at the three urban sites are largely comparable with those recorded in the 1996/97 LWEP survey.

Table 7: Comparison of the Results of the 1996/97 LWEP PAH Survey with the Results of Other Surveys in Urban Areas of the UK

Compound and Abbreviation		Average Particulate PAH Concentration (ng m^{-3})			
		LWEP Survey	South Kensington	Birmingham	Manchester
Phenanthrene	PHE	1.04	0.11	1.10	0.40
Anthracene	ANT	0.19	0.18	0.40	0.05
Fluoranthene	FLH	0.13	0.81	1.20	0.63
Pyrene	PYR	2.68	0.79	2.40	0.80
Benzo [k] fluoranthene	BkF	1.45	0.68	1.10	2.40
Benzo [a] pyrene	BaP	1.70	1.44	0.73	1.60
Benzo [ghi] perylene	BghiP	4.47	3.30	1.90	3.10
Coronene	COR	3.28	1.67	1.00	1.40

10 Discussion

This survey was designed to give a snapshot of the PAH concentrations at roadside and background sites across London, and the short sampling periods used do not, therefore permit a detailed analysis of the intersite differences. The PAH survey conducted at Southwark Street, London, SE1 aimed to provide an insight into the variation in concentration at one site over time.

Despite the limitations of the LWEP PAH survey it is possible to identify some general trends in the data set, some of which are supported by findings from the Southwark Street, London, SE1 survey:

- As in previous LWEP PAH surveys wide variations in concentration were found, from compound to compound, site to site and season to season. This is a general feature of PAH concentrations surveyed in urban areas.

- "Roadside" and "intermediate" concentrations were consistently higher than the "background" sites, emphasising the importance of road traffic as a source of PAH.

- The PAH profiles for the six most carcinogenic compounds monitored were consistent across all sites, with concentrations of BghiP, BbF and BaA/CHR being consistently highest and those of DahA being consistently lowest.

- Use of BaP as an index of carcinogenicity indicates that concentrations of BaP in London monitored during the 1995/96 survey were considerably below European guidelines.

- Comparison of the results of the 1995/96 LWEP PAH survey with other surveys in South Kensington, Birmingham and Manchester indicates that the results are broadly similar across all four surveys.

- The mean concentration of BaP monitored during the LWEP 1995/96 PAH survey was well below European guidelines and did not exceed the recommended US EPA guideline value of 1 ng m^{-3}. However, annual average BaP concentrations measured at exceeded the US EPA guideline at Brent, Ealing, Harrow, Hammersmith and Fulham and Kingston.

- The average BaP concentrations recorded at background and roadside sites were 0.22 and 0.77 ng m^{-3} respectively, which for an individual exposed to these concentrations over a lifetime would represent a 22 x 10^{-6} and 77 x 10^{-6} risk of respiratory cancer.

- In view of the limited quantitative information available on the health effects of the PAH species measured, it is considered that the health risks for individuals with the highest exposure to roadside PAH levels in London are finite but very small; for smokers the risks would appear trivial compared with those associated with exposure to PAH from cigarette smoke.

The fixed site monitoring conducted at Southwark St., London SE1 provided some valuable information concerning the ambient PAH concentration at one site over time. The survey indicated the importance of vehicle emissions as the major PAH source in this area and the influence that seasonal factors exert on ambient PAH concentrations.

Diesel emissions from vehicles are thought to be the primary source of PAH in urban areas. Some PAH species are emitted in higher concentrations from diesel engines including known carcinogen benzo (a) pyrene (BaP).

With respect to diesel emissions from cars, an amending European Community (EC) Directive (91/441/EEC) published in August 1991 consolidates European legislation on vehicle emissions and sets more stringent emission standards which are mandatory and have applied to all new cars registered from 1 January 1993, and to new models from 31 July 1992. To meet the standards diesel engine vehicles require "state-of-the-art" technology.

With respect to heavy goods vehicles (HGVs), EC Directive 91/542/EEC published in October 1991 tightened standards for gaseous emissions in two stages. The first stage reductions were planned for 1 July 1992 (new models) and 1 October 1993 (all new vehicles). The second stage controls were planned for 1 October 1995 (new models) and 1 October 1996 (all new vehicles), these match the very stringent 'US 1994' diesel standards. The new limits will require an improvement in the quality of diesel fuel.

This European legislation will bring about a reduction on unit emissions of controlled pollutants, these being nitrogen oxides, carbon monoxide and hydrocarbons, from both cars and goods vehicles. A guideline for PAHs is due to be published by EPAQS in 1997.

However, the effect these reductions will have on ambient PAH concentrations in urban air is not yet clear as the legislation will be operating against an increase in the diesel fleet. Currently, only 6% of the cars on the road are diesel but, if current sales are maintained it is predicted that within 10 years the diesel car population could rise to 20% (4).

The London wide PAH survey provides a valuable database of information on hydrocarbon levels in London, particularly at roadside locations, allowing the impact of recent legislation on London's air quality to be monitored.

Figure 1: Total PAH Concentration (ng m-3) During Summer and Winter Sampling

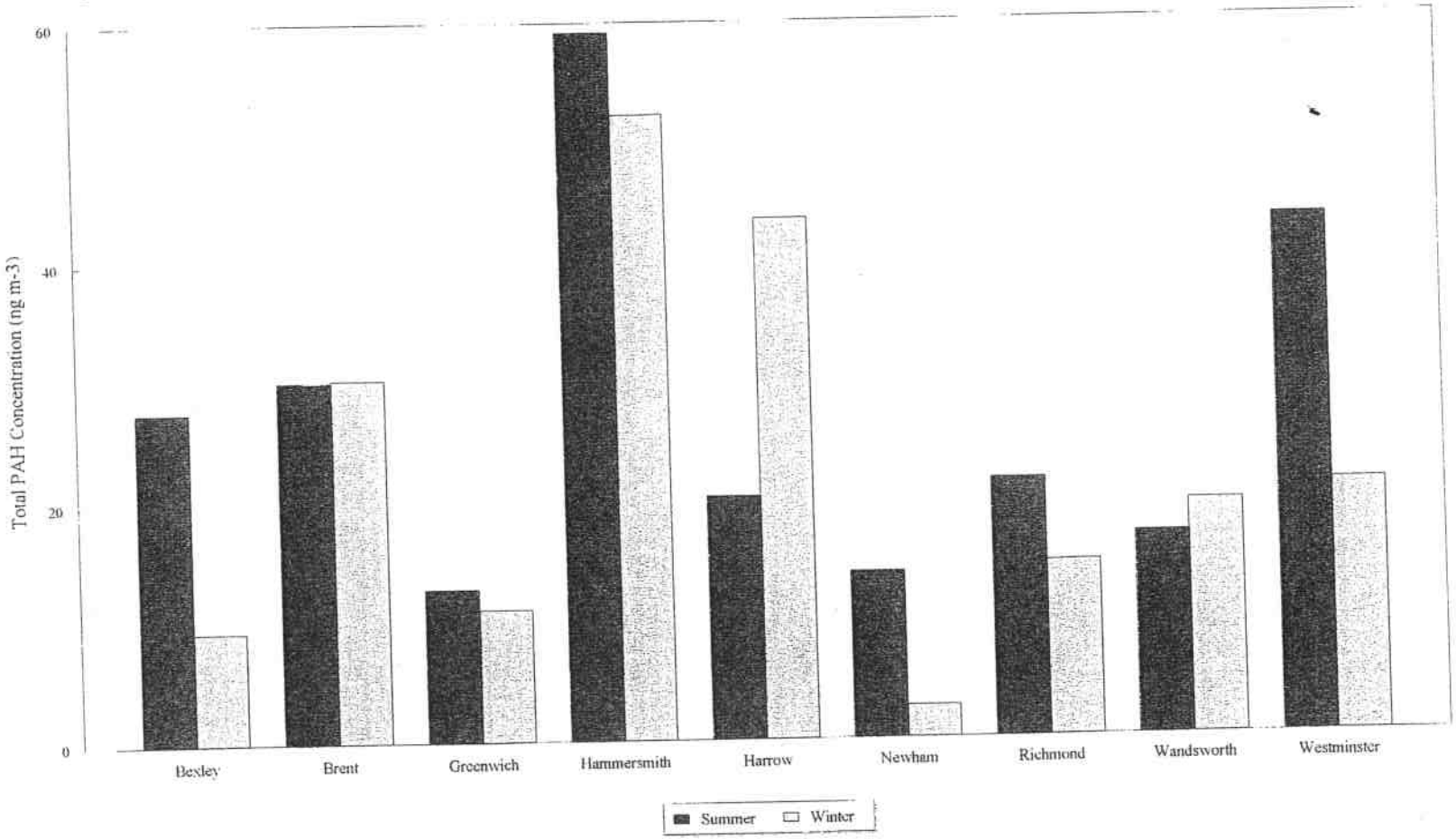


Figure 6: Total PAH Concentration (ng m-3) at Sites Sampled Each Year From 91/92 to 96/97 (Summer Sampling)

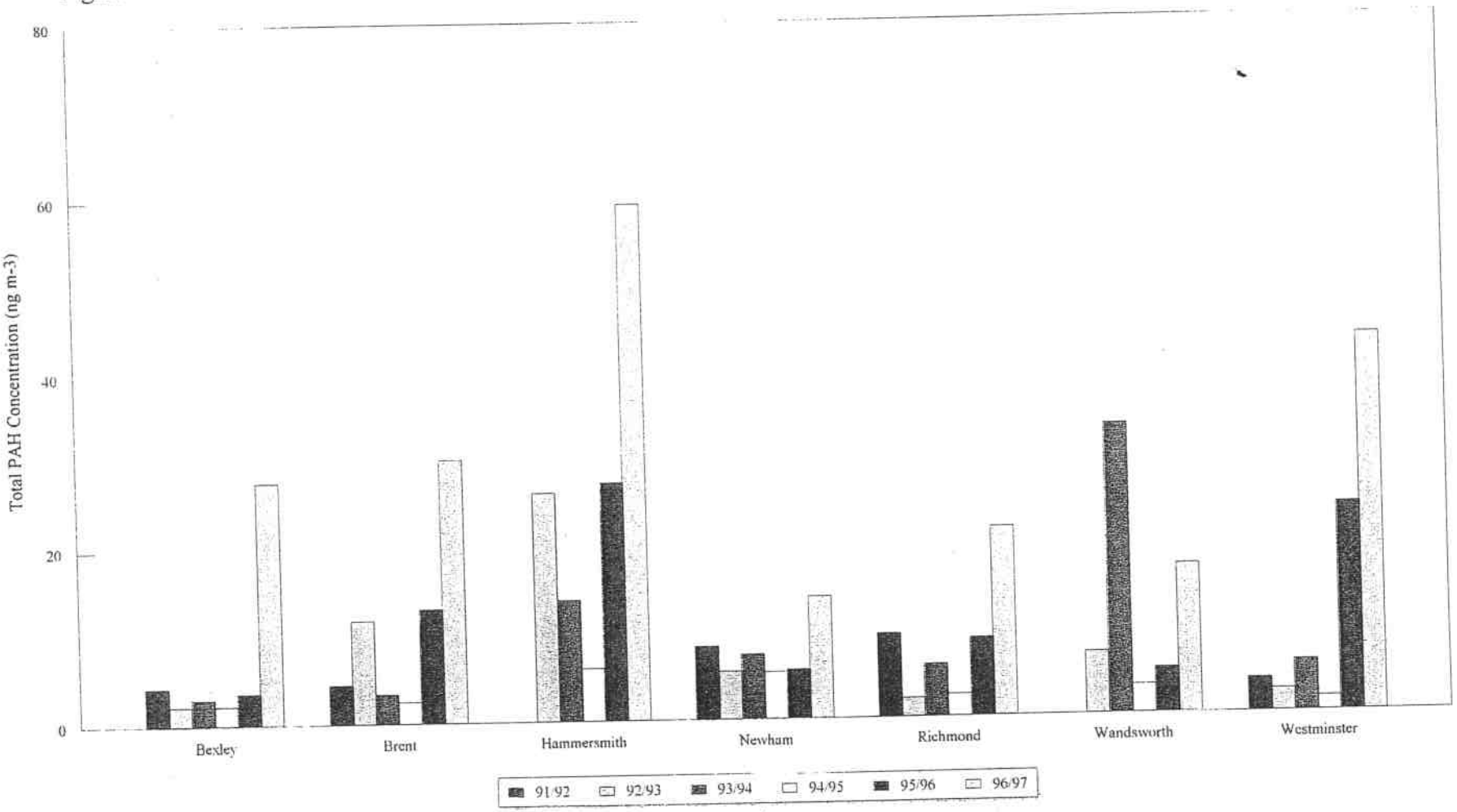


Figure 7: Total PAH Concentration (ng m-3) at Sites Sampled Each Year From 91/92 to 96/97 (Winter Sampling)

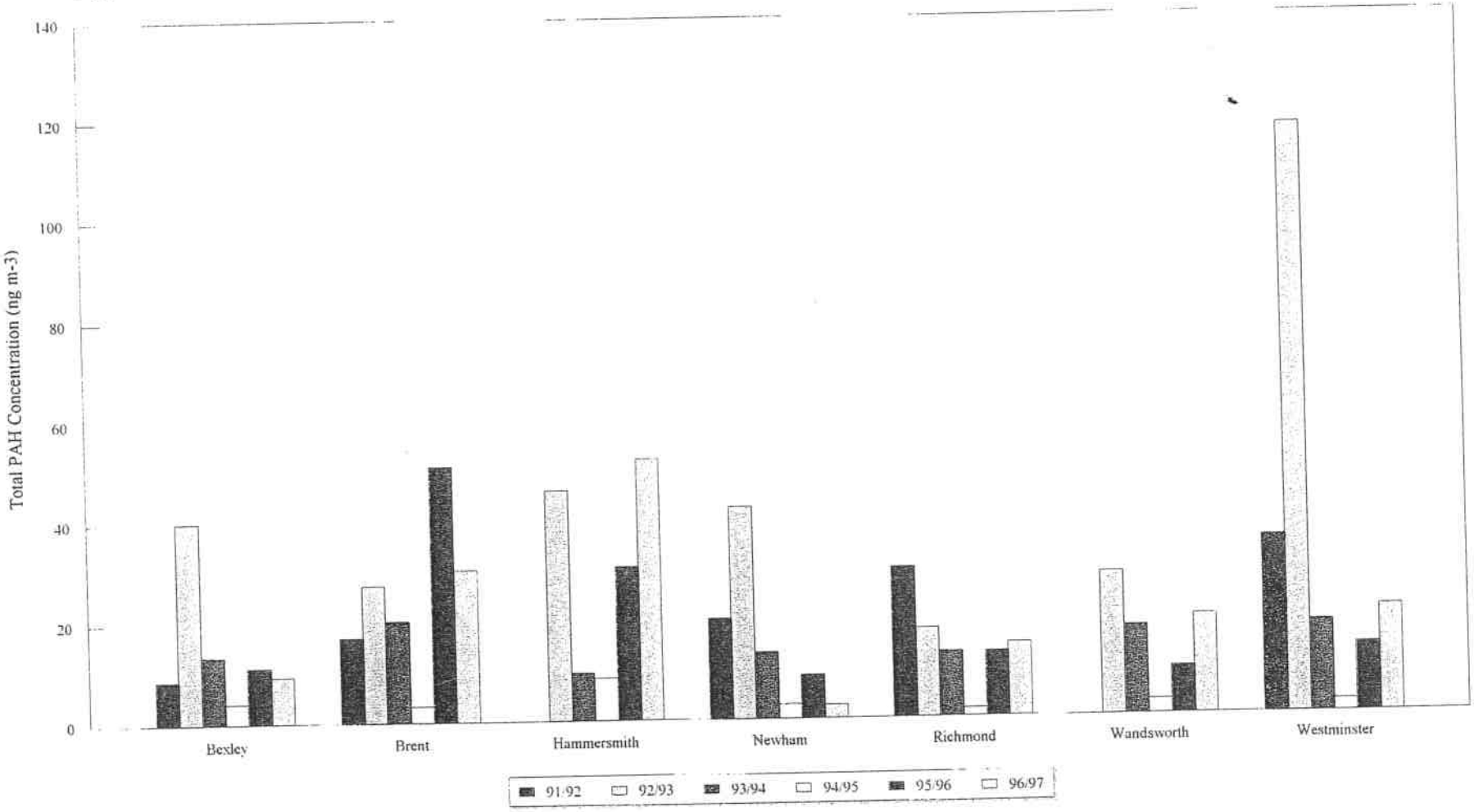
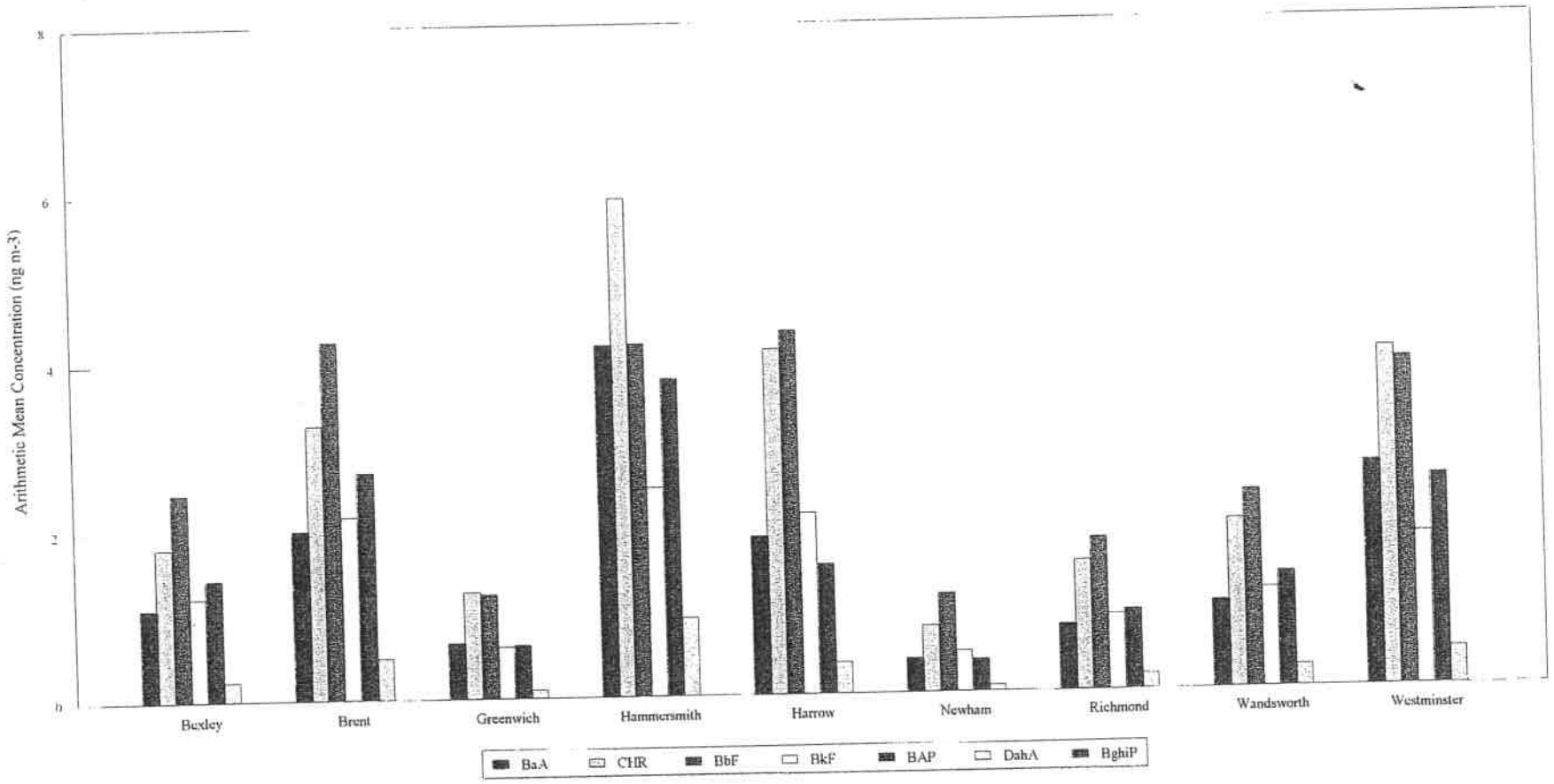


Figure 8: PAH Profile - Mean Concentration (ng m-3) of the Most Carcinogenic Compounds at Each Site



Appendix B

Table 1 - Results of Summer 1996 Sampling. PAH Concentrations at Each Site (ng m^{-3})

	Bexley	Brent	Greenwich	H+F	Harrow	Newham	Richmond	Wandsworth	Westminster	Arithmetic Mean	Geometric Mean
NP	0.32	0.15	0.17	0.11	0.03	0.12	0.26	0.09	0.11	0.15	0.13
ACE	0.16	0.12	0.09	0.03	0.03	0.07	0.15	0.03	0.05	0.08	0.07
FL	0.23	0.14	0.12	0.02	0.09	0.10	0.19	0.06	0.11	0.12	0.10
PHE	0.03	1.28	0.92	0.92	0.56	0.71	1.05	0.72	1.32	0.83	0.62
ANT	0.24	0.23	0.08	0.17	0.06	0.07	0.21	0.15	0.43	0.18	0.15
FLH	3.09	2.01	1.63	3.91	1.52	1.33	2.30	1.38	3.34	2.28	2.12
PYR	3.07	1.60	1.28	4.90	1.34	1.09	3.46	1.22	3.80	2.42	2.08
BaA	1.70	1.63	0.57	4.96	0.87	0.65	0.85	0.64	3.43	1.70	1.26
CHR	2.57	2.07	0.96	7.40	1.84	1.25	1.60	1.29	5.02	2.67	2.13
BbF	3.85	3.57	1.39	6.55	2.31	1.97	2.17	2.17	5.05	3.23	2.88
BkF	1.75	1.44	0.58	2.59	0.90	0.75	0.97	0.86	1.96	1.31	1.17
BAP	2.34	2.00	0.76	4.13	0.81	0.63	1.30	1.01	2.73	1.75	1.44
DahA	0.33	0.28	0.12	0.31	0.13	0.10	0.18	0.14	0.43	0.22	0.20
BghiP	5.57	8.35	2.40	13.64	5.29	2.99	4.37	4.54	10.10	6.36	5.53
COR	2.44	5.27	1.76	9.58	4.69	2.10	2.55	2.74	5.39	4.06	3.51
Total	**27.69**	**30.16**	**12.84**	**59.18**	**20.43**	**13.94**	**21.61**	**17.00**	**43.27**	**27.35**	**24.22**

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Table 2 - Results of Winter 1997 Sampling. PAH Concentrations at Each Site (ng m^{-3})

	Bexley	Brent	Greenwich	H+F	Harrow	Newham	Richmond	Wandsworth	Westminster	Arithmetic Mean	Geometric Mean
NP	0.71	0.12	0.22	0.03	2.07	0.11	0.96	0.03	0.28	0.50	0.22
ACE	0.03	0.03	0.11	0.03	0.13	0.05	0.20	0.43	0.03	0.12	0.07
FL	0.03	0.03	0.08	0.03	0.44	0.04	0.33	0.28	0.07	0.15	0.09
PHE	0.62	0.54	1.04	2.94	3.15	0.44	0.86	0.82	0.86	1.25	0.98
ANT	0.08	0.01	0.09	0.76	0.38	0.04	0.11	0.17	0.08	0.19	0.10
FLH	0.74	0.80	1.02	9.32	2.66	0.01	1.28	0.99	0.90	1.97	0.82
PYR	1.05	2.12	1.98	11.40	4.33	0.10	2.23	1.61	1.74	2.95	1.73
BaA	0.49	2.40	0.76	3.40	2.91	0.14	0.70	1.43	1.80	1.56	1.09
CHR	1.06	4.47	1.57	4.45	6.39	0.32	1.48	2.72	3.05	2.83	2.11
BbF	1.08	4.94	1.09	1.85	6.34	0.37	1.44	2.53	2.77	2.49	1.85
BkF	0.68	2.92	0.63	2.39	3.42	0.20	0.82	1.49	1.68	1.58	1.17
BAP	0.53	3.42	0.50	3.42	2.27	0.13	0.60	1.73	2.28	1.65	1.09
DahA	0.12	0.70	0.08	1.54	0.60	0.03	0.15	0.35	0.45	0.45	0.25
BghiP	1.19	4.99	0.97	2.43	5.07	0.38	1.91	3.08	3.16	2.58	2.00
COR	1.00	2.91	0.94	8.38	3.36	0.31	1.56	2.06	1.95	2.50	1.74
Total	**9.36**	**30.34**	**11.08**	**52.27**	**43.52**	**2.67**	**14.65**	**19.62**	**21.11**	**22.74**	**16.96**

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Table 3 - Average PAH Concentrations at Each Site - Arithmetic Mean (ng m^{-3})

	Bexley	Brent	Greenwich	H+F	Harrow	Newham	Richmond	Wandsworth	Westminster	Arithmetic Mean	Geometric Mean
NP	0.52	0.14	0.20	0.07	1.05	0.12	0.61	0.06	0.20	0.33	0.21
ACE	0.09	0.07	0.10	0.03	0.08	0.06	0.18	0.23	0.04	0.10	0.08
FL	0.13	0.08	0.10	0.02	0.27	0.07	0.26	0.17	0.09	0.13	0.11
PHE	0.33	0.91	0.98	1.93	1.86	0.58	0.96	0.77	1.09	1.04	0.92
ANT	0.16	0.12	0.09	0.47	0.22	0.06	0.16	0.16	0.26	0.19	0.16
FLH	1.92	1.41	1.33	6.62	2.09	0.67	1.79	1.19	2.12	2.12	1.74
PYR	2.06	1.86	1.63	8.15	2.84	0.60	2.85	1.42	2.77	2.68	2.14
BaA	1.10	2.02	0.67	4.18	1.89	0.40	0.78	1.04	2.62	1.63	1.29
CHR	1.82	3.27	1.27	5.93	4.12	0.79	1.54	2.01	4.04	2.75	2.30
BbF	2.47	4.26	1.24	4.20	4.33	1.17	1.81	2.35	3.91	2.86	2.55
BkF	1.22	2.18	0.61	2.49	2.16	0.48	0.90	1.18	1.82	1.45	1.26
BAP	1.44	2.71	0.63	3.78	1.54	0.38	0.95	1.37	2.51	1.70	1.38
DahA	0.23	0.49	0.10	0.93	0.37	0.07	0.17	0.25	0.44	0.34	0.25
BghiP	3.38	6.67	1.69	8.04	5.18	1.69	3.14	3.81	6.63	4.47	3.91
COR	1.72	4.09	1.35	8.98	4.03	1.21	2.06	2.40	3.67	3.28	2.69
Total	**18.55**	**30.27**	**11.96**	**55.79**	**31.99**	**8.30**	**18.12**	**18.38**	**32.19**	**25.06**	**21.70**

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Table 4 - PAH Concentrations at the Southwark Street Site (ng m^{-3}).

	March	May	June	August	September	January	February	March	Arithmetic Mean	Geometric Mean
NP	0.07	0.09	0.24	0.22	0.20	0.00	0.48	0.50	0.23	0.12
ACE	0.00	0.02	0.02	0.03	0.04	0.00	0.13	0.03	0.03	0.00
FL	0.04	0.12	0.09	0.06	0.10	0.02	0.15	0.09	0.08	0.07
PHE	0.40	1.84	0.66	0.64	0.85	0.08	0.10	0.80	0.67	0.44
ANT	0.04	0.24	0.17	0.14	0.16	0.02	0.05	0.10	0.12	0.09
FLH	0.84	3.49	1.44	1.28	1.83	0.05	0.29	0.74	1.24	0.76
PYR	0.69	2.56	1.15	1.01	1.59	0.07	0.42	1.45	1.12	0.78
BaA	0.32	1.08	0.64	0.61	1.15	0.03	0.26	1.59	0.71	0.45
CHR	0.72	2.44	1.08	1.09	1.84	0.10	0.58	2.54	1.30	0.93
BbF	0.93	3.41	1.67	1.29	2.28	0.12	0.76	2.47	1.62	1.17
BkF	0.35	1.26	0.67	0.52	1.02	0.06	0.40	1.39	0.71	0.52
BAP	0.33	1.39	0.81	0.67	1.35	0.02	0.25	1.50	0.79	0.48
DahA	0.04	0.28	0.14	0.10	0.15	0.01	0.06	0.33	0.14	0.09
BghiP	1.06	3.52	2.79	1.65	3.90	0.10	0.72	2.73	2.06	1.38
COR	0.66	2.59	1.81	1.05	2.26	0.09	0.54	1.80	1.35	0.94
Total	**6.48**	**24.32**	**13.38**	**10.37**	**18.71**	**0.77**	**5.19**	**18.06**	**12.16**	**8.59**